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Accelerating the Development of a Global Innovation and Technology Hub in the Guangdong-Hong Kong-Macau Bay Area: the Roles of Public Research Universities

加快建設粵港澳大灣區國際科技創新中心:
如何發揮香港公立研究型大學的作用

Strategic Public Policy Research Funding Scheme
S2018.A7.006.18S

Final report

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Executive summary

Abstract of the Research:

Public research universities in Hong Kong have the potential to play a vital role in accelerating the development of I&T in Hong Kong. They are the major actors in technology transfer, university-industry collaboration, and entrepreneurship education. Nevertheless, the extent to which these activities have originated from universities and how they can be fully exploited for improving the capacity of I&T are not yet well understood. Understanding these mechanisms are necessary to formulating appropriate public policies to effectively cultivate innovation-led growth in Hong Kong.

In this study, we focus on the roles of public research universities in fostering Hong Kong's I&T development and policies to take advantage of the existing strengths and resources of public research universities in Hong Kong and to convert them into catalysts for innovation, while paying close attention to the shortcomings and constraints that may undermine such efforts. Both quantitative and qualitative analysis were employed in this study to capture the patterns and pathways that might be relevant to Hong Kong. Comparative analyses of innovative universities as well as of leading innovation and technology hubs were conducted to identify regional and global good practices that are of relevance to Hong Kong. Surveys and in-depth interviews were conducted with diverse stakeholders, including university researchers and administrators, business practitioners, industry representatives, and government policymakers.

作為技術轉讓、大學與產業合作和創業教育的主要參與者，香港的公立研究型大學在加速香港創科發展方面具有極高潛力。然而，大學如何充分發揮優勢、利用資源並通過多種形式拓展自身能力的从而提高本地科創水平的程度和機制尚不清楚。了解這些機制對於製定適當的公共政策以有效培育香港以創新為主導的增長是必要的。

本研究旨在探究公立研究型大學在促進香港創科發展中的作用和政策，以利用香港公立研究型大學的現有優勢和資源，並將其轉化為創新的催化劑，同時密切關注可能會破壞這些努力的缺點和限制。本研究採用定量和定性分析來探索可能與香港有關的模式和途徑。我們對創新大學以及領先的創新科技中心進行了比較分析，以確定與香港相關的區域和全球良好實踐。我們對不同的利益相關者進行了調查和深入訪談，包括大學研究人員和管理人員、商業從業者、行業代表和政府決策者。

Layman summary on policy implications and recommendations

This research aims to contribute to the policy development mentioned above by focusing on the roles of public research universities in Hong Kong in accelerating the development of a global innovation and technology hub in the context of the GBA (Guangdong-Hong Kong-Macao Greater Bay Area) Initiative. Six broad policy recommendations were generated based on the findings, as listed below:

Theme 1: Government and universities in Hong Kong should review how to further strengthen collaboration in building a vibrant innovation ecosystem

Recommendation 1a: Hong Kong universities and governments should continue to seek opportunities to develop blue sky technologies by establishing strategic R&D centers and laboratories.

Recommendation 1b: Hong Kong government and universities need to build stronger connection with overseas Hong Kong and Chinese diaspora, and in particular those with science, technology, and engineering-related expertise who are currently based in major innovation hubs overseas (e.g. Silicon Valley).

Recommendation 1c: Hong Kong government may further expand their bilateral collaboration with more countries globally – in particular countries that are leading innovation hubs – in terms of STI-related collaboration, with a structure akin to US-Israel Bi-national Industrial Research and Development (BIRD) model.

Theme 2: Hong Kong government and universities should consider formulating new schemes to attract various sources to facilitate university knowledge transfer.

Recommendation 2a: The Hong Kong government – in close consultation with academia, industries, and other relevant stakeholders – may also consider formulating new schemes and/or incentives to encourage a wide variety of enterprises, whether local Hong Kong firms, mainland Chinese-based companies, or foreign MNCs (multinational corporation) to establish either joint R&D (Research and development) centers, or joint postgraduate programs, with the city's leading research universities.

Recommendation 2b: Universities may be encouraged to establish their own VC (venture capital) funds to support the booming spin-offs. Government should also set up different funding programs to encourage more private sector, venture capital funds and angel investors to invest in university education and knowledge transfer.

Theme 3: Hong Kong government and universities should further promote the engagement of various innovation actors in knowledge transfer - universities' success in promoting innovation and entrepreneurship with holistic inclusion of stakeholders.

Recommendation 3a: Universities should revisit the faculty evaluation and tenure policies and increase flexibility in existing academic scheme.

Recommendation 3b: Beyond the traditional roles such as teaching and education, Hong Kong should consider introducing institutional experiments in terms of the appointment policies of faculties.

Recommendation 3c: Existing KTOs (Knowledge Transfer Office)/TTOs (Technology Transfer Office) in Hong Kong's universities need to recruit more professionals with business-relevant backgrounds, particularly those with experiences as serial entrepreneurs, venture capitalists, and/or academic entrepreneurs.

Recommendation 3d: Hong Kong universities should venture beyond patenting and licensing for avenues of commercialization.

Theme 4: Hong Kong government should continue to develop innovation funding programmes, particularly in deep tech areas with high potentials.

Recommendation 4a: Hong Kong government should develop more funds and mechanisms for early-stage funding and attract greater private investment in developing early-stage funding. Specifically, Hong Kong government need to expedite its mechanism to de-risk given the embryonic nature of university-generated basic research. Government may consider set up a Proof-of-concept centre providing overall technical feasibility and commercialisation support specifically targeting the strategic industries.

Theme 5: Hong Kong government should invest more efforts in talent attraction and retainment

Recommendation 5a: Governments could develop schemes that offer prospective returnees a substantial amount of monetary support, ranging from start-up incubation fund to free housing, all-expense-paid packages for returnees' family members. Potential housing provision could be situated in Lok Ma Chau Loop, coupled with other supporting infrastructure.

Recommendation 5b: Hong Kong may consider developing a university-centered research park in Loop to attract and retain science and technology companies and talent.

Recommendation 5c: Governments could provide more postdoc positions targeting interdisciplinary programs and enhance industry career prospects of PhD candidates. Governments and universities need to develop entrepreneurial postdoctoral programs which allow the postdocs to collaborate with local business leaders to foster the cross-disciplinary knowledge exchange.

Theme 6: Transforming Hong Kong's innovation ecosystem cannot be solely implemented through policy changes alone; a shift in mindset hindering richer linkages among local innovation actors are also needed. Many local people could be risk-averse, and they constantly

pursue higher education with the expectation of gaining stable employment in large corporations in the long run.

Recommendation 6a: Universities need to provide interdisciplinary education and training that will prepare future scientists and engineers.

Recommendation 6b: Universities might also consider the inclusion of societal contribution and sustainable development goals aligned with their overall development strategy.

政策影響和建議的摘要

本研究旨在通過關注香港公立研究型大學在大灣區倡議背景下加速發展全球創科中心的作用，為上述政策制定作出貢獻。根據結果提出了六項廣泛的政策建議，如下所列：

主題 一：香港政府與大學應檢討如何進一步加強合作以建立充滿活力的創新生態系統。

建議 1a：香港的大學和政府應繼續尋找深科技發展的機會，並考慮與多主體建立戰略研發中心和實驗室的機會。

建議 1b：香港政府和大學需要與海外香港和中國僑民建立更緊密的聯繫，特別是那些目前在海外主要創新中心（例如矽谷）擁有科學、技術和工程相關專業知識的人才。

建議 1c：香港政府可進一步擴大與全球更多國家的雙邊合作，尤其是在科技創新相關合作方面，特別是領先創新中心的國家，其結構類似於美國-以色列雙邊工業研發（鳥）模型。

主題二：香港政府和大學應考慮制定新計劃，吸引各種資源，促進大學知識轉移。

建議 2a：香港政府在與學術界、工業界和其他相關利益相關者密切協商後，也可以考慮制定新的計劃和/或激勵措施，以鼓勵各類企業，無論是香港本地公司還是中國內地公司，或外國跨國公司與該地領先的研究型大學建立聯合研發中心或聯合研究生項目。

建議 2b：鼓勵大學建立自己的風險投資基金並不斷拓寬融資渠道，以支持蓬勃發展的衍生項目。政府也應設立不同的資助項目鼓勵更多私營機構、風險投資基金和天使投資者投資。

主題三：香港政府和大學應進一步促進各種創新參與者參與知識轉移——大學在促進創新和創業方面取得成功。

建議 3a：大學應重新審視教師評價與晉升政策並增加現有學術計劃的靈活性。

建議 3b：除了傳統的教學和教育角色外，香港應考慮在教職員工聘用政策方面引入製度性實驗。

建議 3c：香港的大學所現有的知識轉移辦公室需要招聘更多具有商業和技術相關

複合背景的專業人士。

建議 3d：香港的研究型大學應不僅僅關注專利和許可，尋求更多的能夠產生社會影響力的技術轉移途徑。

主題四：香港政府應繼續發展創新資助計劃，特別是在具有高潛力的深科技領域。

建議 4a：香港政府應發展更多的早期融資基金和機制，並吸引更多私人投資發展早期融資。具體而言，鑑於大學產生的基礎研究處於萌芽狀態，香港政府需要完善其風險分享機制。政府可考慮設立概念驗證中心，提供專門針對戰略產業的整體技術可行性和商業化支持。

主題五：香港政府應加大人才吸引政策和留住力度。

建議 5a：政府可以製定計劃，為潛在的歸國科學家提供大量支持，例如從創業孵化基金到提供免費住房。

建議 5b：香港政府可考慮在河套地區發展以大學為中心的研究園，以吸引和留住科技公司和人才。

建議 5c：政府可以提供更多針對跨學科項目的博士後職位，並提高博士生的行業職業前景。政府和大學需要發展創業博士後項目，使博士後能夠與當地商業領袖合作，促進跨學科知識交流。

主題六：改變香港的創新生態系統不能僅通過政策變化來實現；還需要轉變思維方式，阻礙當地創新行為者之間建立更豐富的聯繫。

建議 6a：大學可以不斷更新並提供跨學科教育和培訓項目，為未來的科學家和工程師做好準備。

建議 6b：大學還可以考慮將社會貢獻和可持續發展目標納入與其總體發展戰略相一致的內容。

1 Overview

1.1 Objectives of this project

The Hong Kong Government began to pay serious attention to innovation and technology as drivers of social and economic developments as early as 1998. Some of the major initiatives that were launched in the subsequent decade include the setting-up of the Innovation and Technology Fund (ITF) in 1999, the establishment of the Hong Kong Science and Technology Parks Corporation in 2001 and the Cyberport in 2003, and the development of five research and development centres in 2006. Despite such efforts, however, innovation and technology remain a weak area in Hong Kong's economy. The innovation and technology sector in Hong Kong accounted for only 0.7% of the GDP and 0.9% of the total employment in 2015. The laissez-faire approach adopted by the government, a lack of high-tech manufacturing basis, and a shortage of innovation talents are often considered as the leading causes of limited progress in the development of innovation and technology in Hong Kong (Dowejko and Au 2015; Lee et al. 2017; Tsui, Lun, and Cheung 2015).

Recent years have witnessed greater emphasis on innovation and technology in the policy agenda at local, regional and national levels. The Innovation and Technology Bureau has been established since 2015 to steer the policy development in this area. The Chief Executive Carrie Lam pledged to double the R&D expenditure in the coming five years in her 2017 Policy Address, followed by an increase of HK$50 billion in the 2018-2019 budget to support the development of innovation and technology. The aspiration to transform Hong Kong into an innovation and technology hub is also in perfect alignment with regional and national development priorities. The Guangdong-Hong Kong-Macau Greater Bay Area (GBA) Initiative, an ambitious development plan for integrative economic growth and social development of the 11 cities, will provide Hong Kong with ready access to world-class high-tech manufacturing, an innovation talent pool, and markets, all of which are critical factors for accelerating the development of innovation and technology.

Public research universities in Hong Kong have the potential to play a vital role in accelerating the development of innovation and technology in Hong Kong. They are the major actors in technology transfer, university-industry collaboration, and entrepreneurship education. The research capacity of public research universities in Hong Kong is well recognised in global university rankings such as QS and Times Higher Education. For example, five out of the eight universities funded by the University Grants Council (UGC) are ranked among the top 100 in the 2021 QS Ranking. Despite their stellar academic reputation and high research capacity, the contribution of Hong Kong's public research universities to the development of innovation and technology is low. The entrepreneurship engagement and university-industry collaboration are weak compared to those of some of the renowned universities in the US and elsewhere. For instance, the revenue from intellectual property rights (IPR) earned by Hong Kong's academics remain low compared to their overseas counterparts. Take for example the Chinese University of Hong Kong (CUHK), which generated the most income from IPR among Hong Kong's research universities. The university generated only HK$50 million (~US$6.4 million) from IPR in 2017, whereas Stanford University made US$45.4 million from royalty in the same year.

Hong Kong academics have also established relatively few spinoffs, startups, and consultancies. The weakness of public universities can constrain the development of innovation and technology in Hong Kong as universities account for over 50% of the R&D expenditure in Hong Kong.

This project focuses on the roles of public research universities in Hong Kong as a crucial actor in the development of a global innovation and technology hub in the Guangdong-Hong Kong-Macau Bay Area. To harness the full potential of public research universities in Hong Kong, four main objectives are listed in the original proposal:

1. To assess the extent to which public universities in Hong Kong are contributing to innovation-led development in Hong Kong and the Greater Bay Area.

2. To identify regional and global good practices on mechanisms, patterns, policies, and measures to enhance the roles of public universities in the development of global innovation and technology hubs.

3. To develop a policy framework and a roadmap for strengthening the roles of public universities in Hong Kong in fostering the development of a global innovation and technology hub in the Greater Bay Area.

4. To provide policy recommendations to the Hong Kong Government and university administration, as well as central, provincial and local governments in mainland China.

Specifically, four interrelated tasks are performed to develop a policy framework and a roadmap with the aim of enhancing the roles of public research universities in Hong Kong in accelerating the development of innovation and technology hub, as shown in Figure 1-1. Task 1 aims to assess the extent to which public research universities in Hong Kong are contributing to innovation-led development in Hong Kong and the GBA (Objective 1). Task 2 sets out to systematically collect information from world-leading innovative universities with the aim of identifying regional and global good practices for universities in Hong Kong, such as good practices on U-I collaboration (Objective 2). Task 3 focuses on the structure and functions of the innovation systems in global innovation and technology hubs to identify regional and global good practices, mechanisms, patterns, policies and measures to enhance the roles of public universities in the development of such hubs (Objective 2). Task 4 aims at identifying determinants of universities' contribution to the development of innovation and technology hubs for generating effective policy proposals for our Hong Kong context (Objectives 3 and 4).

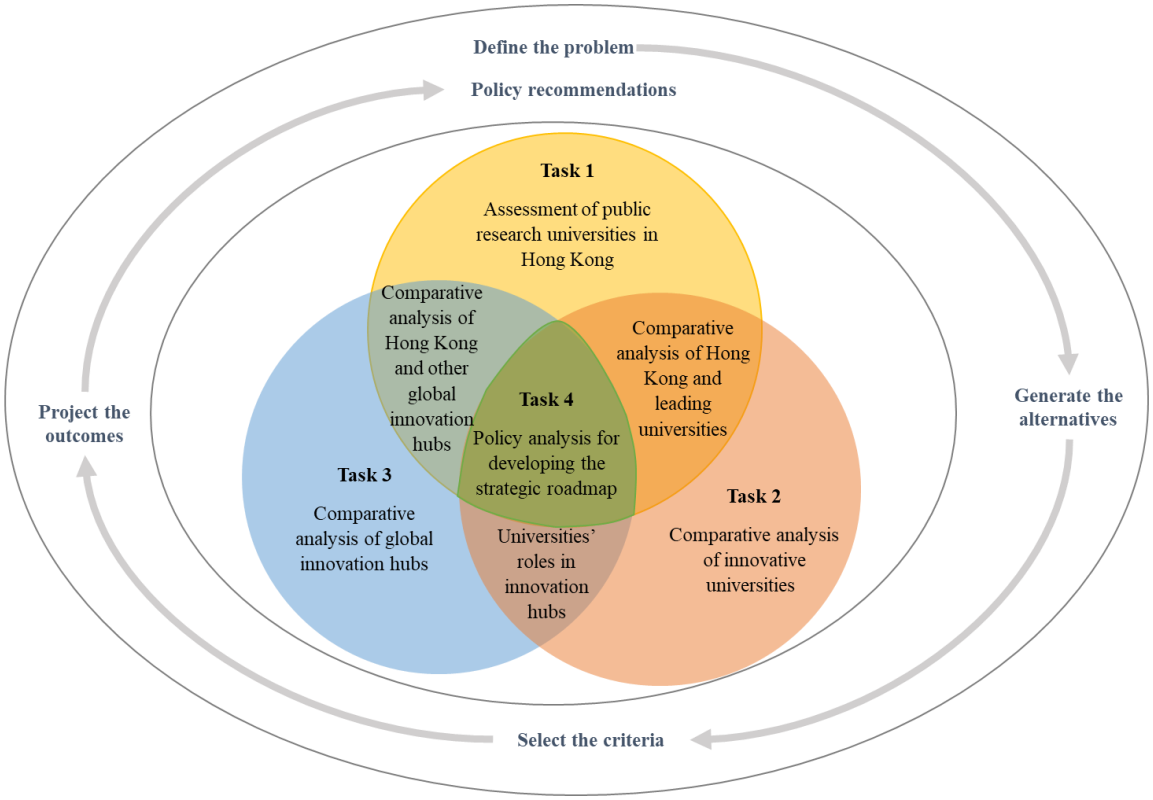


Figure 1-1. Framework of research tasks

1.2 Roles of Universities in the Development of Global Innovation and Technology Hubs

The rise of global innovation and technology hubs and Hong Kong as a hub

Given the significance of innovation in economic development, indexes have been devised by the media and international organisations to rank global science, technology, and innovation hubs. While the exact terms adopted to refer to innovation hubs may vary (2thinknow 2017; Hillner 2000), the key features that distinguish an innovation hub have been summarised in a recent research report (Sambuli and Nanjira 2017). An innovation and technology hub will typically lower the barriers to collaboration, encouraging the sharing of physical and digital space; this feature is often embedded in the local context of the hub (Toivonen and Friederici 2015). Hubs thus provide participants with opportunities in the innovation process to develop technological skills and apply them to problem-solving. Importantly, an innovation and technology hub frequently encourages creativity through a focus on social innovations that promote human-centred development, empowers communities, and provides benefits beyond purely market-based measures like profitability.

The above features of a conceptualized hub often lead to the physical result that an innovation and technology hub attracts and concentrates a large number of innovation activities in a given locality. With this in mind, we conceptualize the innovation hub—Hong Kong—as a distinctly 'physical' city-space located at the mouth of the Pearl River Delta, adjacent to the Guangdong province of the PRC. Furthermore, we consider Hong Kong as being capable of performing the functions of an innovation hub by leveraging its facilitator capabilities in the domain of

innovation. The functions served by an innovation hub entail not only spending increased indigenous resources on innovative activities borne of a greater commitment to R&D but also, and just as importantly, effectively applying new knowledge produced elsewhere to enhance value-added inputs to the production chain. We envisage an innovation hub to transcend the confines of a local cluster—as in a science park—and contribute with an extensive network of linkages and value-added activities to the generation and flow of knowledge from universities to industries.

In the emergent innovation hubs, core drivers of growth and expansion include stronger collaboration between enterprises, research institutes, universities, government departments, and capital venture organisations. The combination of the three organisational drivers, namely governments, universities, and enterprises, have been regarded as of critical relevance to the functions of the hubs. Nevertheless, different hubs may be promoted by different sets of stimuli. Universities facilitate the knowledge transfer to industries by engaging in activities such as searching, matching, learning, adaptation and integration. Accordingly, for our purposes, the question of critical importance here is to what extent and how universities can contribute to the creation and operation of innovation hubs. This could be particularly relevant in the context of Hong Kong and the GBA, where modes of governmental operations vary significantly. In the next section, we will narrow down our focus to look at what roles universities can play in fostering innovation hubs, especially in fostering linkage with industries to complete the knowledge transfer process.

Roles of universities in developing technology hubs

We conceptualized the role of universities in the development of innovation hubs into four types: knowledge production role, technology transfer role, social development role, and platform/network development role. While these roles of universities in knowledge transfer are different from each other in terms of pathways and effects, they are not mutually exclusive. Rather, universities may be shifting back and forth from one role to another or simultaneously performing several role-types according to institutional factors such as the availability of resources, individual universities' strategies and goals, and characteristics of the ecosystem where universities are situated.

The knowledge production role of universities is characterized by an emphasis on conventional teaching and research functions of universities. In carrying out its primary function of teaching, universities create a resource base of people, skills, and knowledge for institutional building at the local and regional levels. Chatterton and Goddard (2000) point out that learning and teaching activities have become more diversified, going beyond simply classroom teaching to more interactive and experiential approaches such as project work or work-based learning, much of which is location-specific. Moreover, while academics and scientists in universities tend to locate their research work within the research agenda of an international scholarship, there have been calls for increasing locally and regionally based teaching and research. Some large comprehensive universities have the capacity to develop a teaching research capacity with

a strong global perspective and maintain a resource base to engage and respond to local and regional development needs.

The enactment of laws of the Bayh-Dole Act 1980 in the US legitimized the technology transfer activities that some universities had already been actively engaged in and facilitated and encouraged knowledge transfer collaboration with industry in many other universities (Kenney and Goe, 2004). Prior to Bayh-Dole Act, the government retained ownership of inventions that resulted from federally funded research, which accounted for a large majority of research funding in universities. The policy was based on the principle that no single institution should enjoy exclusively the benefits derived from publicly-funded research, and therefore only nonexclusive licenses to patents were granted. However, this made academic inventions unattractive to companies because of the high risks involved, resulting in difficulty finding willing licensees to their patents. For instance, in 1978, of the 28,000 patents it had acquired, only less than 4% of these were licensed to companies (Loise and Stevens, 2010). Moreover, the government did not have connections with inventors whose tacit knowledge was necessary to continue developing the nascent invention and get it out in the marketplace. The lobbying of research universities already engaged in entrepreneurialism was crucial in the passage of the Bayh-Dole Act. Many argued that the Act was "as much a cause as an effect" (Mowery and Sampat, 2005: 119) of the growth of entrepreneurial activities in several universities, including UCB, beginning the 1960s. Bayh-Dole Act gave universities in the US the latitude to exploit the intellectual property rights (IPR) of their research, a significant proportion by which was funded by the federal government (Grimaldi et al., 2011). The passage of the law was followed by a wave of universities establishing their own local knowledge transfer offices. Technology transfer, and more specifically, the commercialization of university research in the form of licensing, patents and spin-offs, becomes a core mission of most universities along with traditional functions of teaching and research. The intended goal of the entrepreneurial function is to contribute to the economic growth of regions through the creation of new firms, the renewal of existing firms, the evolution of clusters, job creation, and the attraction of new talent and capital (Power and Malmberg, 2008; Trippl et al., 2015). While there is a growing trend among universities to foster economic development and innovation within their local community, the traditional research and teaching are not only not diminished, but universities seek more funding to support efforts to upgrade the quality of these conventional functions (Youtie and Shapira, 2008). Indeed, it is argued that the research universities' ability to make a significant economic and societal impact is predicated on high-quality research (D'Este, et al., 2018).

Nevertheless, the weaknesses inherent in the narrow entrepreneurial roles, which all too often have focused on income-generating categories and promotion of economic benefits, have raised calls for universities to consider broader developmental roles with economic as well as social impacts (Abreu and Grinevich, 2013; Arbo and Benneworth, 2007). Less formal activities that generate social innovation which in turn bring about the advantage of social welfare, are common in disciplines such as social science, the creative arts, and the humanities. Nevertheless, informal channels of knowledge transfer are often overlooked by technology transfer offices and scholars in innovation studies and policymakers, which tend to promote commercialization in fields that can maximize financial gains for institutions and protect

inventions through formal methods such as patents. Universities have increasingly encouraged the involvement of all faculty, regardless of academic discipline, in knowledge transfer, recognizing that innovation in less formal activities can also have both economic and social value for academics as well as external stakeholders. In addition, universities adapt their teaching and research to meet the industrial as well as the societal needs of their localities, setting the agenda for community development and working with other stakeholders or networks of actors to solve community challenges (Chatterton and Goddard, 2000; Gunasekara, 2006). As Abreu and Grinevich (2013: 410) put it

> " just as with social entrepreneurship, academic entrepreneurship can encompass activities that result in an increase in social welfare, and lead to positive organisational or societal changes, in addition to achieving financial rewards for the entrepreneur."

The decision on the part of the university to undertake a social development role may depend on several factors such as the age and type of university, the regionalization of the higher education system, the nature of the region, regional identity, and networks (Benneworth, 2013; Boucher, Conray and Van Der Meer, 2003; Trippl et al., 2015)

The fourth type of university's role in advancing innovation hubs is the platform/network development which involves the scaling up of technology and innovation hubs. This requires a high level of integration and coordination of key players in innovation ecosystems, including those outside the hubs. Under the platform/network development type, through their programs, organizational units, and institutions that promote entrepreneurship and innovation, universities provide platforms and networks for interactions among key players in government and industry in innovation activities (Etzkowitz and Leydesdorff 1997; Etzkowitz et al. 2000; Mars and Hoskinson, 2010). Thus, the platform/network development function of universities emphasizes, among others, the boundary spanning roles of organizations that help connect universities with elements in the environment in which both operate and interact. Boundary spanning roles are carried out by technically competent individuals who develop a wide range of networks inside and beyond the organization, such as the university. They facilitate links between researchers and scientists with innovation actors beyond the university such as VCs, entrepreneurs, and industry companies. Moreover, global platforms for knowledge transfers tap into innovation resources, such as talents (Wong et al., 2011) and patents for IP-bundling to enhance the value of patents (Siegel et al., 2003), outside the hubs they are located.

1.3 Research methodology

In Task 1, we engaged in in-depth studies of five selected Hong Kong universities (City University of Hong Kong / CityU, The Chinese University of Hong Kong / CUHK, The University of Hong Kong / HKU, The Hong Kong University of Science and Technology / HKUST, and Hong Kong Polytechnic University / PolyU). We collected the universities' knowledge transfer annual reports submitted to the University Grants Council (UGC) throughout the 2009-2018 period, as well as figures and statistics regarding their knowledge transfer-related indicators from UGC. Content analysis was employed, together with interviews

with faculty members, university administrators, as well as technology transfer office (TTO) officials.

In Task 2, we expand our scope of analysis beyond Hong Kong-based universities. Regarding this task, we conducted our benchmarking study with 18 universities around the world. The list comprises 9 universities in Mainland China and Macau (with 6 located in the Greater Bay Area region, 2 in Shanghai, and 1 in Beijing), as well as the remaining 9 universities in East Asia (in Japan, South Korea, and Singapore), Europe (in the United Kingdom and Belgium), Israel, and the United States (see Table 1-1). We relied on a combination of quantitative and qualitative methods in studying these 18 universities, ranging from desktop research (in which we gathered policy documents and relevant annual reports and summarized their content) to faculty survey and in-depth interviews with university leaders. While restrictions within mainland Chinese universities' internal regulations have hindered us in carrying out the survey, we were able to compensate the limitation by launching faculty surveys on universities in Hong Kong and the rest of the world. In total, we sent our questionnaires to over 18,000 identified faculty members in 6 universities in Hong Kong (with Lingnan University being the recent addition), 1 in Macau, and 9 other universities worldwide, generating a total of approximately 1,200 responses (or 6.7% response rate).

Table 1-1. List of universities studied for Task 2 of the SPPR project

University name	Location	Country	Region
Shenzhen University	Shenzhen	China	East Asia
SUSTech	Shenzhen	China	East Asia
Jinan University	Guangzhou	China	East Asia
SCUT	Guangzhou	China	East Asia
Sun Yat-sen University	Guangzhou	China	East Asia
University of Macau	Macau	Macau SAR, China	East Asia
Fudan University	Shanghai	China	East Asia
SJTU	Shanghai	China	East Asia
Tsinghua University	Beijing	China	East Asia
University of Tokyo	Tokyo	Japan	East Asia
Seoul National University	Seoul	South Korea	East Asia
KAIST	Daejeon	South Korea	East Asia
NUS	Singapore	Singapore	Southeast Asia
Imperial College London	London	United Kingdom	Europe
KU Leuven	Leuven	Belgium	Europe
Tel Aviv University	Tel Aviv	Israel	Middle East
University of Washington	Seattle	United States	North America
UC Berkeley	Berkeley	United States	North America

For task 3, we seek to broaden the scope of analysis beyond universities, and examines the localities where these universities are located from a historical and evolutionary point of view (see Table 1-2 for the selected hubs). Data were retrieved from various sources, namely USPTO PatentsView (patent data), Lens.org (an open-source repository for publication data), and Crunchbase (a database of technology companies across the world), which enabled us to perform an in-depth investigation of the city's innovation system. Moreover, for each of these

hubs, we standardized our analysis along three major dimensions: 1) inter-organizational linkages (which we proxy with patent data); 2) university-industry (U-I) collaboration in scientific research (proxied with U-I co-publications), and; 3) the degree of investments by VCs in co-located technology firms (based on their investment data). Survey questionnaires with entrepreneurs and plan visits to several incubators were designed to obtain in-depth information, focusing on the factors that influence entrepreneurs' activities in the hubs. Semi-structured interviews with relevant stakeholders were also conducted, e.g., university faculty and administrators, firms, and government officials.

Table 1-2. List of hubs studied for Task 3 of the SPPR project

Region	Hub	Pairing university selected in Task 2
Greater Bay Area	Hong Kong	The Hong Kong University of Science and Technology
		The Chinese University of Hong Kong
		The University of Hong Kong
		The Hong Kong Polytechnic University
		City University of Hong Kong
	Shenzhen	Southern University of Science and Technology (SUSTech)
		Shenzhen University (SZU)
Yangtze River Delta	Shanghai	Fudan University
		Shanghai Jiatong University (SJTU)
Beijing-Tianjin-Hebei	Beijing	Tsinghua University
East Asia outside China	Tokyo	University of Tokyo (Todai)
	Seoul	Seoul National University (SNU)
	Singapore	National University of Singapore (NUS)
Middle East	Tel Aviv	Tel Aviv University (TAU)
Europe	London	Imperial College London (ICL)
North America	Seattle	University of Washington (UW)
	Silicon Valley	University of California Berkeley (UC Berkeley)

2 Task 1 – Assessment of Public Research Universities in Hong Kong

2.1 Introduction

Throughout its history, Hong Kong has been largely known as a trading entrepôt, and more recently, a financial hub. Trading firms and consumer-goods manufacturers dominated the city's economic landscape for decades in the postwar era, many of which were run as family-owned businesses. As such, the emphasis was primarily on producing consumer goods (i.e., toys and garments). There was limited interest among the enterprises to embark on research and development (R&D) activities (**Sharif, 2006**). Furthermore, with China's economic reform enabling the relocation of these factories *en masse*, economic dynamics in Hong Kong paved the way for the arrival of service industries, particularly financial services-related sectors. Prior to 1997, there was limited attention on innovation and technology (I&T) sectors in Hong Kong (**Leung and Wu, 1995; Sharif and Baark, 2005; Sharif, 2006; Sharif and Baark, 2008; Fuller, 2010; Sharif, 2010; Tsui et al., 2015**). In addition, there was a relative absence of an official framework for innovation policies in the city prior.[1]

In 1998, the Hong Kong government began to pay serious attention to innovation and technology as drivers for social and economic developments (**Sharif, 2006**). The then-Chief Executive Tung Chee-hwa announced policy initiatives to grow high-technology industries in the city. Some of the major initiatives that were launched in the subsequent decade include the setting-up of the Innovation and Technology Fund (ITF) in 1999, the establishment of the Hong Kong Science and Technology Parks Corporation in 2001 and the Cyberport in 2003, and the development of five research and development centres in 2006. Moreover, Hong Kong boasts of being a world class city and one of the places with the highest concentration of top universities. Despite such efforts, however, innovation and technology remain a weak area in Hong Kong's economy. As mentioned, laissez-faire approach adopted by the government, a lack of high-tech manufacturing basis, and a shortage of innovation talents are often considered as the leading causes of limited progress in the development of innovation and technology in Hong Kong (**Dowejko and Au 2015; Lee et al. 2017; Tsui, Lun, and Cheung 2015**).

A fundamental indicator to measure the degree to which a country / region / city is involved in innovation and technology (I&T) is R&D-to-GDP ratio (the percentage of GDP devoted to R&D activities). Overall, with regard to Hong Kong, the city's ratio, while gradually increasing, has remained consistently low, especially when compared to the proportion spent on research activities by other similar high-income economies. As shown by **Figure 2-1**, in 1995, the territory spent 0.36% of its GDP on R&D; as of 2017, the ratio has more than doubled to 0.80%, but still comparatively lower than the similar ratio for 40 other economies, as **Table 2-1** demonstrates (World Bank Data Indicator).

Recent years have also witnessed greater emphasis on innovation and technology in the policy agenda at local, regional and national levels. The Innovation and Technology Bureau has been established since 2015 to steer the policy development in this area. The Chief Executive Carrie Lam pledged to double the R&D expenditure in the coming five years in her 2017 Policy Address, followed by an increase of HK$50 billion in the 2018-2019 budget to support the

development of innovation and technology. At the Smart City Summit 2018 on 27th June, Carrie Lam also asserted that I&T development is a top policy priority for her government. In addition, she stated that Hong Kong has clear advantages in developing I&T, and that she is confident that with the support of the Central Government, Hong Kong will be developed into a world-class technology hub.

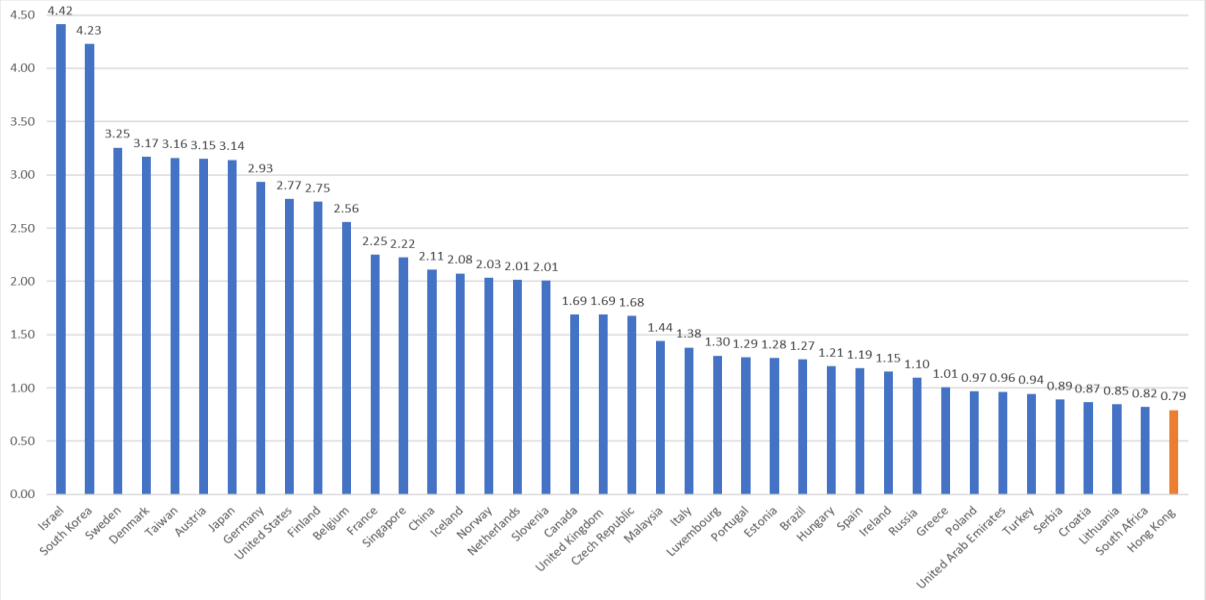


Figure 2-1 Comparison of R&D spending (as % of GDP) among 40-plus economies

Source: World Bank Data Indicator

Regarding the contribution of universities in innovation and regional development, one interesting pattern that could be identified by looking at the above-mentioned World Bank Data Indicator is the substantial contribution by higher-education institutions (HEIs), i.e., universities, to the overall R&D expenditure in Hong Kong. With the exception of 2004-2006 period (shown in **Table 2-1**), higher-education R&D (HERD) accounted for the highest proportion of R&D performed, compared to those by businesses (BERD) and government agencies (GOVERD). In other words, judging from this indicator alone, universities have been consistently among the most important actors in the Hong Kong innovation system.

Table 2-1 Descriptive Statistics on R&D spending (as % of GDP) in Hong Kong (1995-2017)

Year / Sector	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
GERD	0.36	0.39	0.38	0.43	0.46	0.47	0.55	0.59	0.69	0.74	0.80	0.82
BERD	0.11	0.13	0.10	0.12	0.11	0.08	0.16	0.19	0.29	0.36	0.41	0.43
HERD	**0.24**	**0.25**	**0.27**	**0.30**	**0.34**	**0.38**	**0.37**	**0.38**	**0.39**	**0.36**	**0.37**	**0.37**
GOVERD	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.02

Year / Sector	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
GERD	0.77	0.72	0.77	0.75	0.72	0.73	0.73	0.74	0.76	0.79	0.80
BERD	0.37	0.31	0.33	0.32	0.32	0.33	0.33	0.33	0.33	0.34	0.35
HERD	**0.38**	**0.39**	**0.41**	**0.39**	**0.37**	**0.37**	**0.38**	**0.38**	**0.40**	**0.41**	**0.41**
GOVERD	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04

Note: GERD = general expenditure on R&D (GERD = BERD + HERD + GOVERD), BERD = business expenditure on R&D, HERD = higher-education expenditure on R&D, GOVERD = government expenditure on R&D. The expenditure is calculated based on the amount of R&D performed by respective parties.

Nevertheless, while HEIs are an influential driving force, these dynamics are not balanced with the contribution by businesses to the overall R&D landscape in the city. Therefore, given this discrepancy, it is important for us to comprehensively understand and assess the extent to which universities contribute to the innovation development in Hong Kong. Public research universities in Hong Kong have the potential to play a vital role in accelerating the development of innovation and technology in Hong Kong. They are the major actors in technology transfer, university-industry collaboration, and entrepreneurship education. Nevertheless, the extent to which these activities have originated from universities and how they can be fully exploited for improving the capacity of innovation and technology are not yet well understood. Understanding these mechanisms are necessary to formulating appropriate public policies to effectively cultivate innovation-led growth in Hong Kong. Thus, one of the aims of the study is to assess the extent to which public universities in Hong Kong are contributing to innovation-led development in Hong Kong and the Greater Bay Area.

In this task, five local public research universities are selected as listed in Table 2-2. A simple logic model, consisting of inputs, processes, and outputs/outcomes, is used as the analytical framework to assist in identifying and understanding how key indicators of knowledge transfer interact and contribute to promote I&T development.

Table 2-2 Public research universities in Hong Kong chosen for analysis

Region	City	University
Greater Bay Area	Hong Kong	The Hong Kong University of Science and Technology
		Chinese University of Hong Kong
		The University of Hong Kong
		The Hong Kong Polytechnic University
		City University of Hong Kong

2.2 Benchmarking Hong Kong's education performance

In this sub-section, we refer to the Organization for Economic Cooperation and Development (OECD) as our benchmark with regard to the overall education performance. One interesting thing to note is that relative to the average figure of OECD member states, Hong Kong's public expenditure on education (as % of GDP) remains low. The most recent average figure for the former was 4.5%, as of 2016 (**OECD Statistics, 2016**); for the latter (as of 2017), the total amount was 3.3% of the city's GDP (**Hong Kong Annual Digest of Statistics, 2018**).[2]

Nevertheless, with respect to tertiary education spending, Hong Kong's performance was on par with that of OECD. For the 2017/2018 fiscal year, tertiary education accounted for approximately 28% of the city's total public spending on education (or nearly 0.83% of Hong Kong's GDP). This figure was slightly higher than the average 25% figure for OECD countries. In other words, we can argue that the Hong Kong government pays serious attention on developing the city's higher-education system. In addition to public spending on tertiary education, Hong Kong universities also devote their resources considerably in R&D activities. As illustrated in Table 2-3, its HERD-to-GDP ratio (for the year 2017) was comparable to that of OECD members. Indeed, the city's ratio is slightly higher than the figures for South Korea (0.39% of GDP), Taiwan (0.29%), and Mainland China (0.15%). Hong Kong's major drawback, however, lies on its fairly low GERD-to-GDP ratio; within this table, Hong Kong was ranked the lowest (only 0.80% of GDP) among the other economies in this category.

Table 2-3 A comparison of HERD-to-GDP and GERD-to-GDP ratio among the selected economies (as of 2017)

COUNTRY/REGION	HERD/GDP (%)	GERD/GDP (%)
Finland	0.70	2.76
Netherlands	0.59	1.99
Japan	0.39	3.21
OECD average	0.41	2.37
Korea	0.39	4.55
Hong Kong	0.41	0.80
Ireland	0.27	1.16
Taiwan	0.29	3.30
China	0.15	2.15

Source: OECD Statistics

Hong Kong also ranks very highly in terms of its local universities' presence among outstanding universities. As an illustration, based on the most recent QS World University Ranking (2019), Hong Kong has the highest number of top-100 universities (5, namely HKU, HKUST, CUHK, CityU, and PolyU) compared to other major cities across the globe. In a comparative lens, the city performs better than major cities like London (with 4 top-100

universities), Boston-Cambridge area (3), and Seoul (3). Nevertheless, the contrast was evident when the consideration of innovative universities' performance is also taken into account. Based on the most recent Reuters World Innovative Universities ranking, none of the top QS-ranked universities in Hong Kong managed to enter into the top 100 of the list. Most other cities on the table, with the exception of Sydney and Melbourne, have at least 1 university listed in the 2019 ranking. Such surprising finding further laid the basis for our analysis on the innovative capacities of local universities in Hong Kong.

Despite their stellar academic reputation and high research capacity, the contribution of Hong Kong's public research universities to the development of innovation and technology is low. The entrepreneurship engagement and university-industry collaboration are weak compared to those of some of the renowned universities in the US and elsewhere. For instance, the revenue from intellectual property rights (IPR) earned by Hong Kong's academics remain low compared to their overseas counterparts. Take for example the Chinese University of Hong Kong (CUHK), which generated the most income from IPR among Hong Kong's research universities. The university generated only HK$50 million (~US$6.4 million) from IPR in 2017, whereas Stanford University made US$45.4 million from royalty in the same year. Further elaboration will be provided in more details when we discuss about each of the five selected universities. Overall, the weakness of public universities can constrain the development of innovation and technology in Hong Kong as universities account for over 50% of the R&D expenditure in Hong Kong. The study is partly motivated by the need to search for solutions to improve the current situation, so that public research universities in Hong Kong can be more instrumental, as they should, in shaping the future of the development of innovation and technology.

One possible reason that may explain the low degree of engagement among Hong Kong universities in the innovation and technology development in the city. In a report by RAND Corporation, **Parks et al. (2017)** argued that the current higher education system – for which its performance is regularly assessed by the University Grants Council under the Research Assessment Exercise (RAE) – continues to prioritize the virtues of academic merit and originality over the benefits of knowledge production to the society. **Tsui et al. (2017)** further elaborated the findings by **Park et al. (2017)**, highlighting that the current RAE system in Hong Kong still drives faculty members to maximize their career focus on producing publications; moreover, RAE itself has been criticized for its tendency to overlook locally focused research and collaboration. Existing discourse on the need to promote knowledge/technology transfer within Hong Kong universities has also been noticeably lacking in UGC's policy documents (**University Grants Council, 2010**). While the Council gradually began to incorporate the elements of knowledge/technology transfer, **Newby (2015)** cautioned that areas relevant to these indicators (e.g. overseas activities, university subsidiaries, IPR management, and spin-off development) may require closer monitoring given the significant reputational risks they may present to the universities. Further discourses will be provided upon synthesizing our findings from the analysis of selected individual universities.

Table 2-4 Benchmarking Hong Kong to other global cities regarding university performance

City name	Country name	Number of QS World Top 100 universities (2019)	Number of Top 100 World Innovative Universities (Reuters, 2019)
Hong Kong	China	5	0
London	United Kingdom	4	3
Boston-Cambridge	United States	3	4
Seoul	South Korea	3	4
San Francisco Bay Area	United States	2	2
Los Angeles	United States	2	3
Chicago	United States	2	2
New York City	United States	2	2
Paris	France	2	2
Zurich	Switzerland	2	2
Munich	Germany	2	2
Beijing	China	2	2
Shanghai	China	2	1
Tokyo	Japan	2	3
Singapore	Singapore	2	2
Melbourne	Australia	2	0
Sydney	Australia	2	0

Selection of Hong Kong universities for the study

We selected 5 UGC-funded universities that emphasize research-based teaching as well as basic and applied research. In this regard, HKU, HKUST, and CUHK suitably fit in the former characteristic. The latter describes institutions with a strong focus on application-oriented teaching and research, giving them a polytechnic-like orientation. PolyU and CityU would fit well within this description (Table 2-5).

Table 2-5 UGC-funded research universities in Hong Kong and their areas of emphasis

University	*Established*	*Faculties*	*Area of emphasis*
HKU	1912	Architecture, Arts, Business & Economics, Dentistry, Education, Engineering, Law, Medicine, Science, Social Science, Graduate, SPACE	Research-based teaching, basic & applied research
CUHK	1963	Arts, Business administration, Education, Engineering, Medicine, Science, Social Science, Law	Research-based teaching, basic & applied research
HKUST	1991	Science, Engineering, Business and Management, Humanities & Social Science	Research-based teaching, basic & applied research
PolyU	1994	Communication, Construction and Land Use, Engineering, Health and Social Science, Design, Hotel and Tourism Management	Advanced teaching, applied research
CityU	1994	Business, Humanities & Social Sciences, Science & Engineering, Creative Media, Law, Graduate Studies, Building Science & Technology, Continuing & Professional Education	Advanced teaching, applied research

2.3 Approaches to Knowledge Transfer by Selected Local Public Research Universities

The narratives below are presented based on the analysis of major policy documents such as the annual reports on knowledge transfer (KT) (2009/10 – 2020/21), IP policies, promotion and tenure policies, University Accountability Agreement (UAA), and Research Assessment Exercise (RAE) of selected universities. In the following accounts of the KT operations/activities in these universities, particular features are identified for highlighting and some other features are clearly pointed out as strikingly unique to an institution.

2.3.1. City University of Hong Kong

City University of Hong Kong was established in 1984 and achieved university status in 1994. In 2023, it ranks 54 in QS Rankings. It is also placed Among its 10 colleges and schools are business, engineering, liberal arts and social sciences, science, veterinary medicine and life sciences, creative media, data science, energy and the environment, and law. There are four

subjects at CityU that rank in the top 50 in the world: Linguistics, Social Policy and Administration, Communication and Media Studies, and Material Sciences.

It is important to mention that like other universities, CityU has signed the institution-specific University Accountability Agreement (UAA) with the UGC, committing itself to a set of KPIs on KT. Curiously, however, despite the priority to student initiative in spin-off formation as opposed to faculty, as will be seen shortly, CityU has not included student participation in entrepreneurship among the KPIs under UAA. The KPIs that CityU and UGC agreed on include four groups of metrics: first group, staff participation in KT activities, including contract research, consultancy, and patents; second, number of companies, NGOs, and government organizations involved in partnership agreements with the university; third group, number of high quality inventions for which patent filing are pursued; and, the fourth group refers to the quality of patents in terms of the number issued by the US Patent Office. Having said this, however, the observation we got, upon examination of the entire document on the KPI under UAA, is that publication is given the most attention among the five domains discussed, the other four being teaching and learning, KT, internationalization, and financial sustainability.

Licensing: CityU's main vehicle for technology transfer

CityU has stated clearly that licensing is the main vehicle of KT and commercialization of CityU's technology, instead of setting up limited companies under CityU Enterprises Limited (CityUE). In its annual report for 2011/12, the KTO outlines its FEEDS (stands for firm institutional commitment, education programmes) licensing strategy, which aims to forge collaboration with industry, education improvement and expansion to mainland China. Resulting from this policy strategy, CityU has diligently complied with the five-year exit policy set out by the Finance Committee of CityU. According to its 2013/14 annual report on knowledge transfer (KT) submitted to the University Grants Committee (UGC), in the past years CityU has not formed any new companies, specifically those initiated by faculty.

CityU has prescribed the main role of faculty members which is to provide technology consultancy in business ventures, so that they avoid getting involved in the day-to-day operations of the company. Instead, CityU has stated clearly that students (and alumni) are more suitable to establish spin-offs, since they are not university employees and thus have less restrictions and less concerns over conflict-of-interest issues compared to faculty members. Conflict of interest is one of the commonly-cited obstacles to university spin-offs (for example, Neves et al., 2018), requiring clear and specific policies and regulations to overcome (Hossinger et al., 2019). A study of UK universities conducted by Franklin et al. (2001) show that universities which are more successful than others in terms of spin-off process are those who allow the hiring of surrogate entrepreneurs who are outside the university with commercial experience. These surrogate entrepreneurs work with and complement the technical competence of academics, and help to overcome difficulties in the spin-off process, including conflicts of interest.

In line with the thrust of encouraging faculty to consider consultancy as their main channel of KT, the revised version of the Policy and Regulations on Outside Practice and Outside Work, released in 2010/11, promotes high-level consultancy services, emphasising quality over quantity. The direct responsibility over the promotion of high-level consultancy was placed under the Outside Practice Administration Unit, formed in 2011, which has taken over the job of managing consultancy services from the CityU Professional Services Limited, a wholly-owned subsidiary of the university.

To date, CityU maintains more than ten spin-offs, of which it does not have institutional ownership, except for Vitargent, a biotech start-up, although these companies use CityU IPs. It is interesting to note that CityU is quite generous in that it does not take any share of income or profit of the spin-offs created using CityU's IPs. Wright et al. (2006) point out that IP ownership can be more attractive than licensing in embryonic companies. As regards royalty rates, CityU's share varies according to whether or not the university covers the patenting cost of the technology. The royalty rates received by interested parties is based on two basic criteria – (1) whether the patented technology is funded by CityU or the inventor; (2) whether or not the technology is patented. If the patented technology is funded by CityU, the net income is distributed as follows – 35% host department, 30% faculty (student) inventor, and 35% CityU. If the inventor funded the patented technology, 25% of the net income goes to the host department, 50% to faculty (student) inventor, and 25% to CityU. In the case of non-patented technology, the net income is shared according to the following proportion – 25% host department, 50% faculty (student) inventor, and 25% CityU.

CityU has consistently kept the percentage of exclusive licenses to less than fifty percent of its total licenses it maintains every year. This seems to be consistent with the observation of Siegel et al. (2003) that universities are committed to the role of being the guardians of university IPs, so that they can to a certain degree be inflexible and conservative in structuring deals. At the same time, CityU grants a limited number of exclusive licenses which are incentives to firms that are more aggressive and eager to maximize profits by commercializing university-based technologies.

Strategies for marketing CityU IPs – emphasis on the outsourcing model

The heavy reliance on the outsourcing model to market its IPs to potential licensees, particularly outside Hong Kong, is perhaps a unique characteristic of CityU. It outsources its licensing management to international IP management firms or IP agents in the Mainland. CityU has signed licensing agency agreements with well-known IP management companies and technology trading exchange service providers in places where it would like to have their technologies marketed to local companies. CityU has found it more efficient to hire the services of a local company or to collaborate with an academic institution to act as an IP agency, instead of directly liaising with enterprise in places such as the Mainland provinces of Shanghai and Jiangsu. CityU's adoption of the outsourcing model is line with the observation pointed out by Siegel et al. (2003) that the functions of marketing inventions, seeking potential licensees, and searching existing IPs with which to bundle university's own IPs to enhance their value are

usually outsourced by the TTO. Presumably, the rationale for adopting the outsourcing model is the understanding that IP management firms have a network of industry firms in their own localities and are more knowledgeable of the specific needs of companies, which can increase the rate of transfer of research innovation to the private sector (Parker and Zilberman, 1993).

In 2012/13, CityU began to implement a new licensing strategy called IDEA, which stood for Intellectual Property and New Technology Scouting, Deepening Licensing Network, Empowerment of Technology Transfer and Advancement for Novelties, aimed at improving licensing performance. It was implemented for three academic years. Apart from signing licensing agency agreements with IP management firms and partnership agreements with the TTO of top universities, CityU used a wide range of marketing strategies ranging from tapping into KTO's own personal network to the listing of university patents in web listing systems maintained by international universities or TTOs of these universities. CityU also asked IP management firms to provide assistance in bundling IPs to increase the value of its own technologies. Jointly established research institutes on the Mainland, i.e., between CityU and the local government (e.g., CityU Shenzhen Research Institute and CityU Chengdu Research Institute) have been an important channel for CityU to tap into Mainland funding sources, as well as to identify higher education institutions and industry firms with whom to undertake collaborative research or as potential licensees of CityU technologies.

One of challenges identified by CityU, as mentioned in its 2009/10 KT report, is the existence of a technology gap in the local industry, that is, the industry is not ready to adopt the results of research. This was perhaps the reason why CityU began to be more proactive in tapping into regional and international markets as well. Its current UAA includes an action plan to expand capacity for KT, which it specifically plans to do by seeking partnerships with institutions beyond Hong Kong, such as those listed in the Global 500 companies, as well as leading mainland companies and emerging high-tech companies. To widen its overall reach and impact of its research and inventions and to improve its licensing performance, CityU has started to explore and seek potential licensees across the border since 2013/14.

Also unique to CityU is the appointment of a KT representative in every College or School to discuss the challenges and opportunities on KT. CityU's knowledge transfer office (KTO) also proactively and regularly approaches academic and research staff members to learn about their latest research topics and deliverables, which CityU considers as a good practice. While the annual reports do not provide reasons why this is considered as a good practice, perhaps presumably this has helped the TTO to reduce information asymmetry related to invention disclosure and expected quality of the research.

TTO capacity - expertise and staff size

One of the major themes that emerged in the interviews with CityU's TTO officials is the capacity of the office in terms of personnel, which is one of the areas where the university encountered major challenges. Currently, CityU's KTO has personnel knowledgeable in IP, patent-related matters, and commerce. Their staff with academic background in science possess relevant professional licenses. Some of them are members of relevant professional institutes.

TTO staffing is one of the organizational factors that can crucially contribute to the university's performance in TT (Siegel et al., 2003). Therefore, given that the demands of the job of a staff in the KTO are high, it is also important that the university pays attention to the recruitment process and the continuous specialized training of staff, so as to maintain their high capacity to promote entrepreneurship in the university. As will also mentioned later, Cyberport and Science Park organize training workshops that university TTO personnel can avail of to upgrade their knowledge and skills in matters related to licensing and IP marketing, as well as to update themselves of the latest developments in IP laws and in industrial structures around the world.

In addition to possessing relevant knowledge and academic background, TTO staff also need to have the communication skills and an entrepreneurial sense and business acumen to deal with various innovation actors. For example, one of TTO's important 'clients' is the university's academic researchers. TTO personnel are expected to have the communication knowledge and skills to be able to hold a conversation with faculty scientists about technology, science, and so on. (Anonymous. 2020. Interview with a knowledge transfer official. March 20.) In addition, while faculty can be capable of producing creative innovations, they are not necessarily skilful in marketing their inventions or in establishing good relations with industry people. So, one of the areas where KTO plays a crucial role is to assist faculty in marketing and commercializing their inventions (**Powers and McDougall, 2005: 299)**. As the KTO official interviewed remarks,

> "In the case of our university…I think technical capabilities is very limited in my office right now. And I hope to expand that [the office], because I cannot rely on people to do everything for everyone, and at the same time also have to educate their colleagues in the office. They can't do so many things…. They have to conduct external liaising. They have to deal with stakeholders like…industry people. You're looking for licensees. My technology licensing managers have to focus on finding licensees. They will not be spending time educating their colleagues in the office or helping their colleagues do whatever that needs to get done. They just don't have that bandwidth. So, you can see right now why I have a huge dilemma. Because I find that in Hong Kong, the people who have a technical background, I don't know where they go, what do they do. (Anonymous. 2020. Interview with a knowledge transfer official. March 20.)

Infrastructural and funding support for entrepreneurship in CityU

Through the Hong Kong Science and Technology Park (HKSTP), the government provides CityU start-ups access to value-added services and facilities. Under the joint HKSTP-CityU Incubator Scheme, start-ups incubating in CityU which meet certain standards set by HKSTP, can also receive various kinds of supports from the Science Park in terms business development, fund raising, and financial subsidies. Apart from its Shatin location, the Science Park also

provides the facilities at Innocentre, situated near CityU, to operate pre-incubation and incubation programs. The proximity of Innocentre is an additional advantage for CityU. Cyberport is another infrastructural support from the government and which CityU also has relied on not only for funding and incubation programs, but also for training workshops for its technology transfer (TT) staff such as patent drafting. CityU students have tapped into two funding schemes under Cyberport, namely, Cyberport Creative Micro Fund and Cyberport University Partnership Program. The former provides seed fund for promising start-up projects and business concepts in ICT-related areas. The latter has provided CityU's young tech and entrepreneurial talents not only seed funding but also the opportunity to join in company visits to Silicon Valley.

As for internal support, CityU encourages students to play a more active role in spin-off formation and faculty to take the role of a technology consultant in business ventures. Boh and De-Haan (2012) show in their study of eight U.S. universities that student involvement plays a significant role in the spin-off formation process. As mentioned earlier, because of university regulations and issues related to conflicts of interest, CityU considers students as more suitable for spin-off formation and faculty are encouraged to focus in providing technical consultancy in their TT efforts. To facilitate students establishing technology start-ups, CityU provides funding support at various developmental stages of spin-offs.

In 2015, CityU launched a funding system, which the university characterized as constituting a complete innovation and entrepreneurial ecosystem, because it supports the early, mid-, and late stages of the process of spinoff formation. The funding system consists of three funding schemes, namely, Student Early Entrepreneurship Development Scheme (SEED), Technology Start-up Support Scheme for Universities (TSSSU), CityU Investment Fund. Funded by CityU's alumni and friends, SEED supports the early stage idea validation, feasibility and marketing studies. In other universities, such as HKUST, the stage is referred to as the proof-of-concept stage. The Innovation and Technology Commission (ITC) launched TSSSU in 2014 to help entrepreneurs in commercializing their business ideas. The funding is administered by the respective local universities where successful student or faculty applicants study or work. To further develop promising start-ups, CityUE Investment Fund, a venture-capital-style investment mechanism, provides financing support in exchange for stock ownership. There were other incentives, such as the Student Consultancy Scheme, introduced in the early 1990s. Moreover, since 2012, CityU has allowed students, except research students, to have 100% ownership of the IP created during their course of studies, unless they received significant support from the university in terms of funding, use of facilities, and supervision from staff.

Apart from the financial incentives mentioned above, CityU also provided both physical and nonphysical infrastructures to promote the culture of innovation within the university community and to foster the active student participation in KT. In 2011/12, CityU launched the Discovery-enriched Curriculum (DEC) to promote the culture of innovation and entrepreneurship among the students and to help students better participate in KT. The core component of DEC is the unique set of Gateway Education (GE) courses that provide critical core skills and perspectives that are necessary to prepare students to participate in innovation and the creation of new knowledge. Among these GE courses, perhaps the most noteworthy

one is the project-based Discover&Innovate GE courses wherein students can take on a wide variety of projects, ranging from product design and marketing to evidence-based policy innovation projects that address social or environmental issues. In 2014/15, CityU launched the Idea Incubator Scheme to provide further support to DEC and incentivise students and staff from all disciplines to create innovative ideas. CityU's KTO has also offered professional mentoring support to students. Under the Inno-preneurship Mentoring Scheme, students are given access to seasoned professionals from whom they can gain insights about various aspects of KT, from business plan writing to prototype development to IP protection to commercialization. As for outreach with business and industrial sector, the CityU Business and Industrial Club (CUBIC) under KTO regularly organizes events and forums (e.g. Emerging Technologies Forums, Technology Transfer Forums, Special Interest Group Gatherings, etc.) for its members to expand their relationships and enhance their expertise. In recent years, CityU has expanded its focus on the GBA cities to build strategic partnerships with local industry and government. While CUBIC's membership has steadily grown and its influence has extended as well, its operation has been adversely affected by the current pandemic, based on the latest KT annual report. A greater emphasis is now placed on local KT and innovation exhibitions under the premise of virtual meetings.

"HK Tech 300" is one of CityU's most recent large-scale innovation and entrepreneurship program. Annouced in March 2021, this program aims to create 300 start-ups in three years for CityU students, alumni, research staff, and those who use University IP or technology. Resources and networks are provided, and eligible participants are offered with an eight-week sponsored training program that trains them in entrepreneurship skills, business plans, and presentation skills. Each successful team will be provided with ongoing funding to help them develop innovative ideas and incubate their start-ups at different stages of the program.

The program has expanded its scope outside Hong Kong and seeks to promote startup entrepreneurship in both mainland China and Hong Kong. In 2022, a nationwide "HK Tech 300 Start-up Competition" was initiated, focusing on five main areas: biotech and health, deep tech, fintech, information technology and artificial intelligence (AI), and energy and green technology.

Table 2-6 Some highlighted entrepreneurial support based in CityU

Academic year	Infrastructure	Funding / Program	Expansion to and collaboration with Mainland cities
2009/2010	KTO was set up		Operation of CityU Shenzhen Research Institute (CityUSRI)
2011/2012		• New Business Adventure 2012 Competition • Discovery-enriched Curriculum	
2012/2013			Formation of Shenzhen Marine Research and Technology Consortium
2013/2014	Set up of Innovation Commons (IC)		
2014/2015		Idea Incubator Scheme	Establishment of CityU Chengdu Research Institute (CityUCRI)
2015/2016	Implementation of INTEUM IP management system	A funding system consists of SEED, TSSSU, and CityU Investment Fund was launched	
2016/2017	Opening of InnoCentre with HKSTP	A number of seminars and entrepreneurial schemes, including, AUTM Asia 2017 Conference, CityU-HKSTP Pre-Incubation Programme, and Inno-preurship Mentoring Scheme is established	
2018/2019			Set up of Research and Professional Education Establishment
2019/2020			Set up of CityU-Shenzhen Futian Research Institute
2020/2021		Launch of HK Tech 300™ programme	

Source: University Grants Committee

2.3.2. The Chinese University of Hong Kong

Founded in 1963, the Chinese University of Hong Kong (CUHK) is a comprehensive university specializing in research. In 2022, CUHK ranks 38 among the universities worldwide and 2nd in Hong Kong. With 20 subjects ranked among the top 50 in the world, including Languages, Nursing, Geography, Computer Science, Computer Information, and Communication and

Media Studies, CUHK performs well in multidisciplinary development.

One of CUHK's mission statements is "to assist in the preservation, creation, application and dissemination of knowledge by teaching, research and public service in a comprehensive range of disciplines."[3] The above statement expresses CUHK's intention of giving importance to knowledge transfer (KT) and its subset technology transfer (TT). In addition, the annual report on KT (2009-10: 20) states, "no Faculty or individual should have the excuse that there is not a role for them to play in KT," which sends a clear message that CUHK wants that all the faculties be involved in this mission. As part of its Strategic Plan 2016-2020, CUHK focused on innovative biomedicine and information and automation technologies. In light of the ample amount of resources invested in related fields, CUHK 2025 emphasizes UI collaboration, with the objective of making CUHK an even more trusted go-to partner for Public-Private-Partnerships (PPP) and establishing 2 to 3 partnerships in the near future. The newly signed UAA has added PPP undertaken into KPI. Additionally, it includes the participation in KT activities by academic staff members whereas students' participation is not mentioned in the newest version.[4]

Requirements for spin-off creation by faculty

While there is no explicit prohibition for academics to create spin-off companies, CUHK imposes stringent requirements on spin-off creation by faculty. According to the latest Governance Framework for Subsidiaries and Spin-off Companies,

> "In deciding whether to establish a subsidiary or spin-off company, the University must consider, and the applicant must provide justifications, on whether there is a genuine need to do so, and whether other available platforms and channels (e.g., licensing) have been explored and found to be of a lesser advantage than the subsidiary/spin-off option."

It is important to note though that the Governance Framework document only refers to spin-off companies with which the university has shares (e.g., Hong Kong Internet Exchange and Hong Kong Institute of Biotechnology). By contrast, the arrangements are different for faculty members who establish 'start-up' companies, which according to CUHK refers to companies funded by ITC scheme, particularly Technology Start-up Support Scheme for Universities (TSSSU), and with which the university has no shares.

CUHK encourages its faculty to start their own companies, provided these are based on their research work at the university. As pointed out by a TTO official, without these companies it is difficult to license out inventions and the university prefers to license out technologies to their own inventors (Anonymous. 2021. Interview with a TTO official. January 11.). If faculty academics decide to found their own venture companies, they may rely on non-professoriate staff for support to overcome time constraints due to heavy teaching load and/or research work. More discussion on this is provided shortly.

Regarding the sharing of licensing income, CUHK incentivizes faculty researchers by according inventor/s the first priority in recovering their costs and benefiting from licensing income. By completing an Invention Disclosure Form, creators will decide whether to apply for Patent Application Fund (PAF) from the University or apply independently, thereby determining the percentage of gross royalty income they may receive. Inventors will receive 25% of revenue if PAF is applied. Patent applicants may receive 75% of revenue if they pay all patent application costs.[5] For the rest of the revenue which goes to the University, 60% of the remaining value will go to the University Central Fund and 40% to the host faculty of the inventor. The faculty dean has the discretion to make the appropriate distribution to departments or units.[6] However, although the sharing arrangement on royalty adopted by CUHK seems generous, given that normally financial returns from licensing income can be slow, inventors may find equity ownership more attractive as they may give more importance to having access to venture capital (Wright et al., 2006). It is interesting to explore the preferred commercialization option by faculty and how they think the university could facilitate their using it.

Non-professoriate staff to support start-ups initiated by their professors

A striking feature of CUHK is that the Outside Practice policy has been extended to non-professoriate staff, such as research assistants, post-doctoral fellows, and technical assistants, since 2015/16 allowing them to support spin-offs founded by their professors. This is in line with the policy of avoiding that academics get directly involved in spin-off formation and management. Nevertheless, 60%, or majority, of TSSSU and Sustainable Knowledge Transfer Project Fund start-ups are founded by professors (see Figure A.11). In order to avoid professors detracting from their primary roles of teaching and research, to overcome the time constraints of professors, and to enhance the rate of success of spin-off companies, the ORKTS (Office of Research and Knowledge Transfer Services, CUHK) has worked out with the Personnel Office some policy adjustments permitting non-professoriate staff to support start-ups founded by their professors in a proportional and financially accountable manner.

> "A lot of times, we ask the university for resources, and we have to fight hard to get them. When we do research, especially on matters we would like to commercialize, often it's not only about the technologies. It is almost impossible for the professors to do all these works by themselves. That's why we need those colleagues [non-professoriate staff] to contribute. If faculty members develop patents, this is not only the role of professors, but also their research members. If professors want to commercialize, and research team members can further build on them, why should we set up barriers? I don't see any worries from the university about the management, because the PI can, by themselves, optimize how to manage responsibilities and task-sharing." (Anonymous. 2021. Interview with a senior faculty member. January 11).

The functions of these non-professoriate staff involved in the management of spin-offs on behalf of their originators seem somewhat similar to those of 'surrogate entrepreneurs,' first conceptualized by Radosevich (1995) who saw their role in adding business knowledge and professional network. A surrogate entrepreneur is typically someone who has a business background, capable of market analysis and of refining and tailor-making a technological innovation according to the needs/wants of the customers to enhance the chances of successful commercialization (Kassicieh, 2011). As the name implies, a surrogate entrepreneur, is someone other than the original founders (Lundqvist, 2014). While they can be someone brought in from outside the university with commercial experience (Franklin et al., 2001), students can also be appointed as surrogate entrepreneurs (Lundqvist, 2017).

Support for entrepreneurship and knowledge transfer in CUHK

CUHK provides funding support for both conventional (technology-based) and non-conventional (nontechnology-based) KT projects. Through the ORKTS, CUHK tries to promote the culture of innovation and entrepreneurship among CUHK staff and students. In 2014, CUHK established the Pi Centre (pre-incubation) to promote student entrepreneurship by cultivating an interest in start-ups through start-ups news and events, sharing from CUHK and well known entrepreneurs, job placements in start-ups, training and mentoring, POC funding, facilities and equipment for incubatees to start their enterprises. The Pi Centre has two structured programs where the Chief Mentor will meet with each team monthly to guide and assist in their progress. The objective is also to assist staff & students teams within the Centre to graduate from Pi Centre by obtaining investment support from angel investors or a venture capitalist or and join an external incubation program.

The Entrepreneurship and Innovation Hub (Inno-Hub), coordinated by ORKTS, is a scaled-up Pi Centre that has developed a start-up ecosystem with more support for entrepreneurship on campus established in 2016/17 academic year. To promote the co-creation environment and the development of entrepreneurship ventures, Inno-Hub provides comprehensive services in from business support to competitions to boot camps, like legal services, corporate services to access to investors, business partners, customers' verification trial partners. Events like industry and VC networking opportunities are part of the activities that the Pi Centre designed and planned for the start-ups in CUHK. Inno-Hub also provides well equipped Design-Make-Test facilities (cf. Annual Report, 2016/17). Lockett and Wright (2005) argue that since the university environment is non-commercial, the TTO plays a crucial role in business coaching and stimulating entrepreneurial activity.

Another incentive CUHK provides is to acknowledge KT projects by staff that received funding in the University Staff Profile Update System under the category 'Research & Scholarship: Other Contributions and Recognitions.' In addition, KT activities are included in the evaluation criteria. Despite this, however, KT activities performed by staff are classified under 'service' along other yardsticks, while 'education' and 'research' each having their own independent classifications. Thus, the impression one gets is that publication outputs – and

citation measures to some extent – are the most important indicators in the universities' faculty assessment policies.

CUHK recognizes the challenges of getting its academic staff to get on board the entrepreneurial project, and asserts that other kinds of support in addition to funding are needed to promote the environment and culture for KT. More success stories are needed, letting the word spread across the campus and create enthusiasm among staff and students.

> "The concept of what KT is about does more effectively circulate among people by the word of mouth. People do not easily take an interest in attending a KT seminar, no matter how it is promoted. But when there is the news that a colleague or team receives funding for conducting KT, people may wish to know about it by first asking the person who gets the fund. That is why the KTU [Knowledge Transfer Unit] actively visits holders of funded projects and encourages them to spread the message to their colleagues." (cf. Annual Report, 2009/10: 10)

A celebrated example of a success story which CUHK hopes can serve as an inspiration to other scientists is the technology invented by Professor Dennis Lo Yuk-ming, a professor of Medicine and of Chemical Pathology and the Director of the Li Ka Shing Institute of Health Sciences. Through his research, he discovered a way to conduct a prenatal diagnosis non-invasively through blood samples from a pregnant mother. His invention has also found other innovative uses such as cancer detection. The technology has been licensed to the start-up company Xcelom.

The marketing of CUHK's IP portfolio and advertising its corporate identity also fall under the responsibility of the ORKTS. To illustrate some of the major developments of CUHK, a TTO official remarks,

> "We already have nurtured two big unicorns coming from our university. You probably have heard it from the Science Park's reports. One is focusing on diagnostic and the other is on artificial intelligence. Recently, the university has also been awarded,… under the InnoHK Clusters,… to build up this international laboratories and research centers in collaborations with other top universities around the world. These research centers focus on health technology and also communication technology, 5G, all these hot technology topics nowadays. So, I would say our university will continue to stay in the frontline of developing innovation and IP commercialization." (Anonymous. 2020. Interview with knowledge transfer official. March 24.)

As mentioned above, CUHK encourages all academics, i.e., not only those from the science and engineering fields, but also social sciences and humanities, to be actively involved in innovation and KT activities. Based on the examination of annual reports, it is seen that nontechnology-based innovation, such as social innovation, is clearly given importance by CUHK. A good example is the above-mentioned Sustainable Knowledge Transfer Project Fund

(cf. footnote 2), which is provided within CUHK to faculty members to transform their social projects into sustainable social enterprises. An interesting observation we made is that CUHK clearly stated in its 2009/10 annual report on KT that it would strive for a change of mind-set to expand the horizon of KT beyond its conventional scope. Commenting on the currently on-going Research Assessment Exercise (RAE), a CUHK KTO official remarked,

> "For example, some faculty are doing social science. It's a big issue in fact when we talk about the impact of research. I think you probably have heard about the RAE exercise. The UGC has introduced the measurement of impact of each university research to the society instead of just counting the publication numbers." (Anonymous. 2020. Interview with a KTO official. March 24.)

The above insights provided by the KTO officials are quite interesting, particularly when seen in the context of the latest RAE exercise (**UGC, 2020**). Possibly in response to the advice by **Tsui et al. (2017)** and **University Grants Committee (2017)**, RGC has indicated in its latest RAE exercise that assessment on impact[7] will comprise 15% of the entire evaluation scores, while the proportion allocated to academic outputs has been reduced from 80% to 70%. Furthermore, in relation to impact, RGC also incorporates their assessment on academic environment by assigning the remaining 15% of assessment scores based on indicators specific to this theme.

Table 2-7 Some highlighted entrepreneurial support based in CUHK

Academic year	Infrastructure and Policies	Funding / Program	Expansion to and collaboration with GBA cities
2009/2010 and before	Establishment of a new Knowledge Transfer Unit (KTU)	Launch of Knowledge Transfer Project Fund (KTPF)	
2010/2011	Establishment of a new KTO	Launch a number of new funding schemes, including Patent Application Fund (PAF), Technology and Business Development Fund (TBF)	
2011/2012		Set up of Professional Enhancement Fund (PEF)	Operation of CUHK Shenzhen Research Institute (SZRI)
2012/2013	Revise of policy on research, IP and KT	Establishment of the Awards of Excellence in Social Engagement	
2013/2014	• Establishment of a new ORKTS • Establishment of Pre-Incubation		

	Centre (Pi Centre)		
2014/2015	Establishment of technology liaising team at ORKTS	Foundation of CUHK Alumni Torch Fund to help alumni expose to more entrepreneurial opportunities	
2015/2016	Extension of Outside Practice (OP) Policy to non-professoriate research staff	Launch of Sustainable Knowledge Transfer Project Fund (S-KPF)	
2016/2017		Launch of Entrepreneurship and Innovation (EPIN) minor programme	
2017/2018			Establishment of Entrepreneurship and Innovation Hub (InnoHub) in SZRI
2019/2020			Establishment of CUHK Hong Kong-Shenzhen Innovation and Technology Research Institute (Futian)
2020/2021		Launch of Fast-track Provisional Patent Fund	

Source: University Grants Committee

The merging of research and KT offices under a single organizational unit

In addition to financial incentives, CUHK also provides organizational support to promote innovation and entrepreneurship among staff and students. Having a clear mission to support TT in the university is one of the factors that contribute to a positive effect on TTO output (Friedman and Silberman, 2003). To reflect what the university's main thrust is and to send a clear message, CUHK also changed the names of relevant offices and documents. After several organizational restructuring, since 2014, the KT activities in CUHK has been overseen by the Office Research and Knowledge Transfer Services (ORKTS) formed by the merging of the KTO and Research Administration Office (RAO). The objectives of the merger were to promote high-quality research, improve KT capacity, and to have better coordination.

> "Everything is changing. Even the research component is changing. We stopped thinking about only relying on UGC/RGC funding, although they remain very vital… We hope the ORKTS structure can be an inspiration for other universities to better synergize their research and KT together. Now, IP

> and licensing are getting closer and closer to research, instead of only KT. There are now more meetings between the research teams and IP/licensing teams, so there is less bureaucracy. But, the main disadvantage is that the amount of work burden does also increase significantly." (Anonymous. 2021. Interview with a senior faculty member. January 11, 2021).

The organizational set-up of ORKTS allows it to provide specialized central services related to funding, IP management, licensing, spin-offs, social innovation, and so on. There are merits to CUHK's intended purpose for adopting such a directorial structure such as for organizational synergy towards improved governance. Macho-Stadler et al. (2007) also point out that a specialized TTO can reduce asymmetric information between university and industry regarding the value of inventions. The latest annual report on knowledge transfer, however, also mentions contributions from other offices. For instance, the Office of Innovation and Enterprise (OIE) established in 2019 aims to establish connections between CUHK professors and start-ups. In order to achieve the goal of commercializing research products, OIE provides funding assessment, enterprise communication, and consultation services. In some ways, OIE's services overlap those of ORKTS, whereas the former focuses more on entrepreneurship and start-up assistance than knowledge transfer services. The effectiveness of efforts to centralize knowledge transfer services to ORKTS remains to be seen. In terms of knowledge transfer, it would be worthwhile to examine the relationship and collaboration effectiveness between ORKTS and other important offices mentioned in annual reports, including the Office of Strategic Development (OSD), and the Office for Greater Bay Area Developments.

Particularly for ORKTS, one of its tasks, as expected by industries, is to assess and distinguish the IPs with high and low values. From the economic perspective, a specialized TTO can lower transaction costs and/or opportunity costs of time related to the search for potential buyers or licensees.

With the establishment of the ORKTS, CUHK also began taking steps to improve its capacity in developing and marketing its IP portfolio. For example, working with external market research and licensing agents to analyse market opportunities for CUHK's portfolio; hiring of IP team members with experience with specialized advisors and legal experts; and, establishing a technology liaison team with extensive industry knowledge. The KT annual reports clearly show that CUHK stresses the importance of hiring TTO personnel with the relevant qualifications required for the job. The current director of the ORKTS is a professor of biostatistics and public health, has an ample experience with the industry, and an expert in efficient data management using advanced computer technology. Specific to the IP and technology licensing team of the office (about 8 personnel), about 70% of the staff have a law degree on top of their first degree in Science, Medical Life Science, Engineering, or Chemistry. Some have a second degree in business or MBA.

The Knowledge Liaison Team, established under the ORKTS in 2014, concentrates on assisting university inventors in securing contracts and sponsorship. The work involves preparation of presentation materials, arranging one-to-one matching sessions between inventors and investors and, even representing inventors in international forums and meetings (Annual Report, 2015/16). TTO also tailors their services in accordance with the circumstances

of different clients, particularly when it comes to the assignment of intellectual property rights (IPR). CUHK takes meticulous care of their dealing with project clients. As a TTO official puts it,

> "If the [contract research] arrangement is simple, we will go by the standard rules, unless there is opposition or parties involved do not accept our general clauses. There are some cases (disputes) that happen due to different applications that have to be renegotiated. For instance, some NGOs may ask for intellectual property [of the university]. Sometimes this IP may not be patents, but still considered an IP… If they claim ownership of any piece of IP, we require them that for differences [in the proportion of revenues] they have to pay some portion, because that work is virtually done for their own purpose, for the organization. Sometimes the third party may not agree to that, due to various reasons. We often get stuck with different perspectives, different jurisdiction requirements, or because collaborators are from other parts of the world with their own laws. Ultimately, we have to resolve these differences on arriving at such acceptable risks before they agree to sign. At the moment, once the contracts are signed and with our involvement, we follow closely how the agreements are being implemented. But as the magnitude of the contracts becomes bigger, we do need to contemplate a system to make sure the outputs are still delivered, and we can still monitor the progress." (Anonymous. 2020. Interview with a knowledge transfer official. March 25)

2.3.3. The Hong Kong Polytechnic University

Reforming knowledge transfer (KT) policies for better governance

Around the period between 2000 and 2010, PolyU saw a rapid growth in the number of subsidiaries and joint ventures (JV). However, the mismanagement of dozens of these companies caused the loss of over HK$50 million.[8] The incident prompted the establishment of an independent review panel[9] to investigate. As reported by the independent panel, the relevant subsidiaries did not have a thorough business plan, budget strategy or exit strategy. This phenomenon seems to exemplify what **Clarysse et al. (2005)** called the 'low selectivity model' of managing the spin-out process whereby the objective of the parent organization is to maximize the number of entrepreneurial ventures, as well as the lack of clear exit strategy.

Following the above experience, the panel made a number of recommendations to improve the university's governance capacity. One of the major policy changes was that staff who wanted to establish a spin-off company would have to undergo a business plan review and to get approval from the university. The panel stressed that the business plan needs to have a clear exit strategy for subsidiaries and that it should be executed in a timely manner. The KT Committee, which was also established in 2010 to review the KT framework, policies, and

framework of PolyU, also recommended, upon consultation with university staff, the university to have a policy of requiring spin-off companies to have a "mandatory exit within fixed term to avoid perceived conflict of interest and undue commitment of university management resources for running business ventures," (cf. PolyU's annual report on KT, 2010/11: 2) which meant that the university should be prepared to exit not only from underperforming JVs but also profitable ones. The approach that PolyU adopted in response to the above recommendations seems to represent what **Clarysse et al. (2005)** described as the 'incubator model' of managing spin-offs, as far as these being exit-oriented. The spin-offs under the 'incubator model' are also characterized as involving cutting-edge technology, has the potential of generating significant revenues, and requires specialized venture capital funds as shareholders at the start. Following the adoption of the recommendation above, PolyU executed the exit strategy on existing spin-outs, particularly those which had a poor performance.[10] Given the stringent requirements on spin-off creation, PolyU has since then recommended licensing as the preferred channel of commercializing.

Aside from exit policies, PolyU also implemented reforms in other areas, as suggested by the KT Committee (cf. annual report 2009/10). PolyU changed the policy regarding directorship or shareholdings by faculty in his/her own spin-off. The panel recommended to the university staff to avoid having shareholdings or directorship position in the university's subsidiaries, associates, and jointly controlled entities as well. If a full-time faculty did take up directorship of subsidiaries, they should not receive any remuneration. In addition, the panel recommended to avoid cash investments by the university to promote technology transfer (TT).[11] Following the reforms, as a KTO official pointed out, the university began to emphasize the formation and management of start-ups by students or alumnus or academic staff or university researcher. Such start-ups involve either university invention licensed to these companies or university investment in exchange for equity share. In the latter case, university would never hold majority share. There are no university officials sitting in the board of such companies and these operate independently of the university allowing these to enjoy greater operational and financial flexibility. (Anonymous. 2021. Telephone interview with a KTO official. February 3.)

PolyU hires entrepreneurs-in-residence to support start-up formation. PolyU currently as has one entrepreneur-in-resident. Such entrepreneur-in-residence are recruited for their expertise such as in start-up fundraising, modelling, and/or investing.[12] While their task or function may be similar to a serial entrepreneur but the former provides entrepreneurial services not just to one company but to any staff or student in the university who might need advice on TT related issues. It is expected the capacity of this entrepreneur-in-residence to develop any one company can be quite limited. It is interesting further explore what function does the entrepreneur-in-residence have, and, how different it is from that of a surrogate entrepreneur; whether the university has considered having policy on allowing surrogate entrepreneurs; and, what factors would it consider for deciding whether to hire their services.

PolyU indicates its support for spin-off development through its funding policies as well as in its KPIs under the University Accountability Agreement (UAA) signed with the University Grants Committee (UGC). A significant portion of funding for KT received from government

and local and non-local private sources have been channelled into a comprehensive funding mechanism to support spin-offs (as well as social enterprises[13]), i.e., from proof-of-concept to growth acceleration.[14] In addition, PolyU allows its IP to be licensed to spin-offs in exchange for a small equity share, enabling the inventor to conduct fundraising so as to acquire sufficient IP capital. Another clear indication of the importance PolyU places on spin-offs can be found in the inclusion of the survival rate of start-up ventures, the ratio of external to university funding, as well as the number of jobs created and maintained by start-ups as KPIs in two versions of UAA. As was the case for HKUST discussed later, PolyU has revised the scope of its definition for university spin-offs. The revised definition since 2019/20 includes not only start-ups that license PolyU IP, but also those that receive funding from universities. The number of economically active spin-off companies increased by a significant amount during the same reporting period.

PolyU has what are called joint ventures (JV) which are more commercially-oriented than ordinary spin-offs in the sense that the former has industry firm involvement and the latter has no industry firm involvement and fully owned by the university. PolyU has also reported the number of JVs in their annual reports on KT submitted to UGC. PolyU Enterprise Limited enabled companies (e.g. Nanos Technologies Holdings Company Limited) to form JVs with the university. However, as mentioned earlier, since the reforms, PolyU has been emphasizing start-up formation rather than the establishment of JVs or spin-offs.

Innovative promotion of the culture of innovation but faces much of the same challenges

PolyU adopts a unique approach to promoting the culture of innovation within campus. Annually, PolyU organizes a thematic campaign to promote innovation in specific fields of study such as healthcare technologies and aviation. One of the important tasks of TTOs is to market the university's IPs, since inventors often do not have skills and time to do this (Powers and McDougall, 2005). TTOs need to have the appropriate professional staff among whom have the ability to launch a business and market inventions (Swamidass and Vulasa, 2009). The thematic approach has the potential of providing adequate attention and time for TTO to market and for VCs and/or firms to learn more deeply and develop interest in a set of inventions relevant to a specific industrial sector. A response we got from a transfer official at PolyU indicates that they have found clear advantages in adopting the thematic approach which has produced positive results in terms of promoting its IPs.

> "Targeted promotion can also better arouse audience's interests, and is more likely to foster engagement. For example, promoting healthcare technologies to health related industries would generate a higher response rate…Depending on the nature of each promotional activity, thematic campaigns can be used to create awareness, achieve brand building, attract potential business partners and collaborators, and generate commercial leads." (Anonymous. 2020. Email response from a KT official. December 19.)

In addition, the balanced workload concept aims at giving due recognition to KT achievement of faculty (cf. annual report 2015/16). This concept is fairly straightforward, as it expects PolyU's academic staff to divide their work into three tasks as follows: 40% for research, 40% devoted to teaching, and the remaining 20% on service. KT activities fall under the 'research' purview. In 2014/15, PolyU introduced further measures to enhance governance. As mentioned, PolyU invited individual departments and schools to come up with their own industry- or discipline-specific measures of KT performance, recognizing the fact that metrics for tech-related industries can be different according to specific sectoral industries. In this regard, PolyU adopts a bottom-up approach. Another measure is to provide more relevant guidelines, such as on conflicts of interests, and ensure proper mechanisms to facilitate staff and students to engage in ventures. Starting 2012/13, PolyU adopted the 'Do Well Do Good' ethos to guide innovation and entrepreneurship, emphasizing collaborative partnership with industries and businesses, balanced workload concept, and aligning research and entrepreneurship for maximum societal impact.

While PolyU adopted 'KT for social and economic impact' as one of its KPIs under the UAA, TTO continues to encounter the challenge posed by the dominant concern over university ranking and boosting its ranking in terms of research publications. The 'publish or perish' mentality is pervasive especially among academics at the associate professorship level and below, which means that research publications continue to take priority over KT. Under such institutional and cultural climate, faculty motivation to devote time in KT endeavors are affected (O'Shea et al., 2008).

> "…it is a general situation to find associate professors who have only one goal: 'I want to be promoted, to become a professor.' Because if I don't generate enough paper, or if I don't reach my KPI, I will get fired. So, the associate professors or academic staff at that level, they don't care about KT. Instead, they want to survive by generating papers. You don't have to talk about KT with them. It seems a waste of their time. So, this is a complicated situation. [On the other hand] the professor or chair professor who already reached that level don't worry about promotion or get fired. So, they will have more room for KT, apart from doing research paper they want to generate." (Anonymous. 2020. Interview with a knowledge transfer official. March 18.)

Currently, the criteria for promotion of faculty does not seem to align with the university's push on KT, because it does not attach significant weighting to KT. As mentioned, faculty are expected to devote 40% of their working time to research work. The extent to which KT-related assessment is incorporated into research portions is also decided not by the university's highest administration level, but rather devolved into individual departments and/or schools. In other words, the degree to which faculty members perform KT regarding their research is contingent on the level of KT embeddedness within their respective departments. As a university official elaborated,

> "It [the proportion of KT incorporated into research portions of faculty assessment policy] really depends on the colleagues' research agenda. We

> [university's highest administrators] don't fix [the proportion] at a percentage, so the figures can be like, say, 30%, 40%, or 60%." (Anonymous. 2021. Interview with a university official. January 14.).

Unlike 'teaching' which is a major criteria and has a category of its own, KT is only considered a part of research work. Parks et al. (2017) and Tsui et al. (2017) pointed out the tendency for faculty members in local universities to continue prioritizing publications given the universities' existing configuration for performance assessments, as set by UGC. It is important to explore how the university can effectively implement the balanced workload principle which has been considered in 2015/16, and if it were implemented how will the university adequately recognize the efforts and achievements of faculty who opt to take the entrepreneurship track?

Because of this crucial role of a TTO, PolyU emphasizes that transfer personnel need to have the proper knowledge and skills, as well as an entrepreneurial attitude in order to deal and develop good relationships with industry people. Regarding the leadership, the current director of the Institute for Entrepreneurship, majored in mechanical engineering, and has had an extensive work experience in innovation, IPR, and business management in the Mainland. As for the KTO personnel training and qualifications, the TTO official interviewed emphasized the need to find people who not only write reports, but also understand the industry because one needs to understand one's customers. A TTO official remarked that PolyU's faculty has had long-standing partnerships with many industrial firms, enabling the university to maintain an active collaborative research field. The TTO tries to complement the faculty's network of industrial contacts with its own extensive outreach, marketing, and partnership-building effort (Anonymous. 2020. Interview with a knowledge transfer official. March 18).

Stressing concern over high-level consultancies, and society impact over financial returns

Despite the amendments to policies, guidelines, and procedures related to licensing and spin-off-creation in 2011/12, a clear and steady improvement is yet to be seen in terms of number and income. Regarding spin-offs, the relatively recent adoption of an exit-oriented approach to the management of the spin-off process, as well as possibly the implementation of much-needed enhancement of organizational and institutional support for spin-off development probably means that any significant increase in the number of spin-off would take time to materialize. While PolyU recorded an increase in the number of licensing deals in 2012/13 academic year, which may have been partly due to the recommendations set forth by the KT Committee on improving licensing activities, but the impact on licensing income was more mixed as the increase was much more gradual and fluctuated (between 2012/13 and 2020/21).

At the same time, PolyU has also intended to emphasize the importance of social impact through the use of certain technologies and know-how over maximizing financial return. In fact, PolyU had considered in 2014/15 enabling the provision of free licensing of PolyU IP, if this was the best way to create positive impact for society.[15] In other words, the university can decide to grant a license at gratis basis if they licensee intends to use the technology for charitable or non-commercial purposes. Currently, the royalty rates are proportionately distributed between the university and inventor based on the percentage of share of each party

in the cost of patenting and maintaining patents. The host department gets a fixed proportion of the royalty.

Perhaps part of the strategy to improve performance in licensing, PolyU has been to encourage more collaborative partnerships with Mainland entities. In a 2008 survey of entrepreneurship education in European higher education institutions, the European Commission (2008) noted the multi-dimensional nature of entrepreneurship education, requiring parallel actions in various areas for the effectiveness of promoting in universities. Thus, perhaps efforts to improve performance in collaborative research are due to in part to collaborative research being seen as a potential source for licensing. In addition, based on inquiry with PolyU's TTO, the structure of the licensing agreements in terms of size is majority are with SMEs, less than 5% with large companies, and 10-20% with non-commercial. In terms of location, 70% are with Hong Kong-based companies and 30% in the Mainland. As for the sectoral industry, about 10-20% are medicine, 10-12% biomedical diagnostic instruments, 10-20% textile, and 40-70% engineering.

Proactive support for student-driven entrepreneurship

PolyU actively promotes and supports student-based innovation and KT, which perhaps partly explains the fairly high number of TSSSU-funded start-ups with UG/PG students as team members (see Appendix) or persons in-charge (see Appendix), as well as the high degree of participation by alumni as persons in-charge (see Appendix). Student entrepreneurship is embedded into PolyU's mission which emphasizes the nurturing of students to become critical thinkers and innovative problem solvers. Student involvement in KT plays a significant role in the entrepreneurial activity of universities (Boh and De-Haan, 2012).

In 2010/11, PolyU began to introduce a series of entrepreneurship programs aiming at fostering innovation and entrepreneurial culture and practices within PolyU community, with a particular interest on student-based innovations and entrepreneurial activities. Some of these initiatives were the PolyU Micro Fund Scheme which provided seek funding and pre-incubation support; Entrepreneurship Parade, a yearly event serving as a platform to exchange views on innovation and entrepreneurship; and, Pilot-Scale Entrepreneurship Center at Shenzhen. PolyU also provided support to its graduates through funding schemes that encourage seeking job opportunities in the Mainland. For example, the China Entrepreneurship Fund which was the first Hong Kong-Mainland China matching fund for PolyU graduates to start new businesses in Shenzhen and Shanghai. As mentioned in recent reports, the University has also highlighted the potential for GBA development and endeavors to integrate its supportive programs with enhanced collaboration with GBA cities. In 19/20, the GBA Startup Postdoc Programme was initiated in collaboration with and under the support of the Shenzhen government. As part of the program, graduates have been provided with multiple opportunities for training and to enable them to pursue a technopreneur career path.

Table 2-8 Some highlighted entrepreneurial support based in PolyU

Academic year	Infrastructure	Funding / Program	Expansion to and collaboration with GBA cities
2009/2010 and before		Launch of a number of seminars and programs, including the China-Europa Forum, Entrepreneurial Contest for Students	
2010/2011			Set up of Pilot-Scale Entrepreneurship Centre at Shenzhen
2011/2012		Launch of Micro Fund Scheme for Innovation and Entrepreneurship	
2013/2014		Establishment of STEFG-PolyU China Entrepreneurship Fund	
2014/2015		Launch of a number of funding schemes and programs, including Tech Incubation Fund (TIF) and the Tech Launchpad Fund (TLF), and Good Seed Programme	
2016/2017	Set up of Innovation Commons for Entrepreneurship (ICE)	Launch of Student Entrepreneurial Proof-of-Concept Fund (POC Fund)	
2017/2018		Launch of pilot cohort of Lean Launchpad Programme (LLP)	Development of GBA International Institute for Innovation with Shenzhen University
2019/2020		Launch of GBA Startup Postdoc Programme	
2020/2021		Establishment of Entrepreneurship Investment Fund (EIF)	

Source: University Grants Committee

2.3.4. The Hong Kong University of Science and Technology

Consistent support for entrepreneurship efforts

As one of the youngest universities in Hong Kong, the Hong Kong University of Science and Technology (HKUST) ranks 40th among all universities worldwide and third locally as of 2022.

In order to contribute to the development of a knowledge-based society, the University strives to play a key role in collaboration with governments, businesses and industries on a local level. Based on examination of HKUST's annual knowledge transfer (KT) reports, the university has consistently supported efforts on nurturing entrepreneurship within the campus.

Relative to other UGC-funded universities, HKUST has been an exemplar pioneer of university-based entrepreneurship culture, particularly since the 1990s (Sharif and Baark, 2008). Furthermore, the university's strong emphasis on promoting entrepreneurship is also evident from the latest University Accountability Agreement (UAA) between HKUST and UGC for 2022-2025 triennium: one of the three KPIs proposed for evaluation of performance in KT (the other two being technology transfer/commercialization outputs and community service projects) is entrepreneurship, indicated by the number of spin-off and start-up companies. Such orientation may explain the institution's strong emphasis on promoting creation of start-ups/spin-offs commercializing university-invented technologies since the first KT report in 2009/10 period. HKUST's spin-off policies have also been fairly generous: the senior management openly encouraged all relevant stakeholders – whether faculty members, staff, and/or students – to be actively involved in spin-off formation so long as the intended technologies are deemed promising. One relevant scheme they have been regularly offering since 2009/10 reporting year to incentivize these efforts is Proof-of-Concept (POC) Fund, which provides seed funding for inventors to demonstrate basic feasibility and potential of practical application of their inventions. Pre-seed funding, which enables the faculty scientists to conduct market research and product development (including prototyping and application validation, among others), is one of the important antecedents to the formation of spin-offs (Berbegal-Merabent et al., 2015).

Furthermore, another interesting aspect of the university's spin-off policies – which has been stipulated as early as the 2009/10 report concerned – is that HKUST allows faculty members to have 'substantial' ownership shares in the spin-offs/start-ups that they founded, but did not permit them to undertake corporate executive roles (e.g. the titles of CEO, CTO, etc.). As Wright et al. (2006) argue, equity ownership is more attractive than licensing. Thus, the substantial inventor ownership shares at HKUST may have been a strong incentive to spin-off formation, as shown in the high number of spin-off companies relative to the other selected universities. According to a TTO official, the percentage of ownership shares in spin-offs can in some cases be more than 50% and in others less than 50%, depending on the degree to which they use the university's technology. TTO does not regulate the ownership of share in spin-offs. (Anonymous. 2020. Interview with a KT official. November 24.)

Specific to HKUST's support for academic entrepreneurship activities by faculty members, one senior KT official made a remark about the impact of the university's support:

> "When faculty members want to set up their own companies, HKUST always more than welcomes [such efforts]. Our only caveat is that they have to abide by the university's one-day-per-week policy, as their main focus should continue to do research and teaching as their core services. But, we won't ask them too much about equity conditions. From our own record, we have at least 60 faculty members who are active in commercializing these

technologies, especially through company formation." (Anonymous. 2021. Interview with a KTO official. January 15, 2021)

Table 2-9 below provides a snapshot of some of the ongoing entrepreneurial development programs that are based in the university.

Table 2-9 Entrepreneurship programs based in HKUST

Academic year the program / initiative was introduced	Name of the program/initiative
2009/2010	The annual Proof of Concept (PoC) Fund was launched
2010/2011	HKUST One Million Dollar Entrepreneurship Competition
2010/2011	'Be Your Own Boss' (BYOB) series of entrepreneurship seminars were launched
2012/2013	The first start-up incubator was established in HKUST Shenzhen Research Institute (SRI)
2012/2013	HKUST Entrepreneurship Academy (E-Academy), which is directly run and led by students (with university guidance)
2014/2015	The BASE co-working space was established
2014/2015	A series of workshops, seminars, and competitions organized by Entrepreneurship Center (EC), e.g. E-Week, Friday Dreamer's Workshop, innovation and entrepreneurship training bootcamps
2014/2015	Launching of Technology Start-up Support Scheme for Universities (TSSU)
2014/2015	The inaugural student-led HackUST competition was launched
2014/2015	Second start-up incubator at HKUST SRI was launched
2016/2017	Third start-up incubator (Blue Bay Incubator) at HKUST SRI was established
2016/2017	A series of new start-up funding schemes, namely Dream Builder Funds, U*STAR, Yeung Wing Yee Entrepreneurs Fund
2017/2018	A series of new start-up funding schemes, namely Walter Kwok Start-Up Fund for TSSSU Awardees, HKUST Entrepreneurship Fund (with HK$50 million university capital)
2019/2020	The PoC Fund was repositioned as Bridge Gap Fund

In addition, HKUST plans to provide additional incentives to enhance the linkages between faculty research outputs and student-established start-ups. In other words, the university aspires to see more student-initiated businesses that commercialize scientific breakthroughs and technologies developed by professors and researchers in the university. This commitment

demonstrates HKUST's unique position as a platform for student-driven entrepreneurial ecosystem, which we will elaborate in the next section below. (Anonymous. 2021. Interview with a KTO official. January 15, 2021)

Promotion of student-led entrepreneurial ecosystem

In nurturing the development of the university's entrepreneurial ecosystem, HKUST has also been actively putting in place a quite substantial number of incentives (e.g., funding schemes and competitions). In addition to the POC Fund highlighted above, it is important to highlight the Dream Builder Program and Dream Builder Fund managed by the Entrepreneurship Center. This initiative provides entrepreneurship training, pre-incubation, incubation, and acceleration programs for start-ups by students. Perhaps due to HKUST's strong focus on students' and alumni's involvement in commercialization of science, it has been observed that the HKUST TSSSU-funded start-ups has a significantly high number of post-graduate students involved as persons in-charge (or founders) for these companies. It is important to note here a striking feature that is unique to HKUST regarding the IP ownership of inventions by students during the course of their study, i.e., HKUST allows students to retain 100% IP ownership, unless the project has received sponsorship from a company which has signed an agreement assigning back the IP ownership to the university. This finding demonstrates that the university has been active in promoting entrepreneurship education and practice, introducing various incentives, not only for faculty members, but also students, to fill in their lack of entrepreneurial backgrounds and limited expertise (Pirnay et al., 2003).

Beyond funding schemes, HKUST has also been promoting innovation among its students through entrepreneurship-themed competitions such as the One Million Dollar Entrepreneurship Competition (it debuted in 2010/11 reporting year) and Hack@UST , a series of 24-hour 'hackathons' comprising of student teams developing mobile app- and hardware-based solutions. Overall, the above findings appear to illustrate that university programs – such as courses, funding schemes, and competitions – can help improve entrepreneurial efforts for commercialization, especially for students (Boh et al., 2012).

Active engagement with mainland China

HKUST has had a highly active engagement with mainland China particularly since the start of annual KT reports. HKUST has been demonstrably assertive in this matter, establishing research institutes – that also dually function as KT platforms – in mainland China. For instance, as early as 2011/12 reporting year, the university has operated four such platforms, namely: 1) Shenzhen Research Institute (SRI); 2) Fok Ying Tung Research Institute (FYTRI) in Guangzhou; 3) HKUST LED-FPD R&D Center in Foshan, and; 4) Zhejiang Advanced Manufacturing Institute in Hangzhou. Subsequently, both SRI and FYTRI would serve as the most pivotal 'gateways' for HKUST to maximize their KT engagement in the mainland. FYTRI's new primary mission would be to implement and coordinate the university's technology transfer (TT) and commercialization activities in mainland China (as stated in the

2013/14 report), as demonstrated by the establishment of Technology Transfer and Incubation Office (TTIO) in 2013/14 – later renamed 'Technology Marketing and Incubation Office' (TMIO) in the following reporting year – to centralize coordination efforts on KT activities in all of HKUST's mainland Chinese platforms. Simultaneously, SRI's principal objective relates to incubation of HKUST start-ups that seek to commercialize the university's research outputs, shown by the establishment of three incubation and business development centers in the institute over the span of a decade. Each of these incubators was set up in 2012/13, 2014/15, and 2016/17 reporting years respectively.

Beyond SRI, FYTRI has also been another no less influential platform for incubating business entities seeking to commercialize the university's research. Furthermore, HKUST – through EC – has also helped to co-organize entrepreneurship competitions across mainland China's major cities as a strategy to build closer ties with Hong Kong's start-up business community. One effect of such approaches is the high proportion of spin-off and start-up companies incubated in Mainland China, through FYTRI and HKUST SRI, relative to the entire spin-off population for HKUST. In the 2017/18 KT report, slightly above one-third (62 out of 180) of such companies were based in SRI (with 45 such entities) and FYTRI (for a total of 17 firms). This finding shows that the university has been actively harnessing the benefits resulting from the phenomenon of increasing university-industry linkages across mainland Chinese universities, both in the form of spin-off formation and collaboration with private firms (Kroll and Liefner, 2008; Lei et al., 2012).

Adopting spin-off formation as its main commercialization route

HKUST's favorable polices on spin-off formation, dating back to the university's founding in the early 1990s, have seen massive growth of spin-off companies. Of 84 such companies in 1991-2004 period identified by Leung and Mathews (2011) in their study, more than 50 of them – over 60% – could trace their origins to the university. Throughout the 10-year reporting period from 2009/10 to 2017/18, HKUST has consistently 'outshone' their counterparts in terms of the number of economically active spin-offs that is generated. Indeed, the growth phenomenon was near-exponential, with the number rising from 28 in 2009/10 to 184 as of 2017/18. It is important to note, however, that the reported number of spin-offs in the KT reports is based on the way in which HKUST defines 'spin-off' ventures.

In addition, HKUST has adjusted their definition of 'economically active spin-offs' at least three times, given their expanding scope of programs and incentives to promote entrepreneurship (Another interesting aspect of HKUST's spin-off development approach is that their targeted graduation rate from the university's three-year incubation program has remained at 25%, more than double the figure expected from private-sector incubators of approximately 10% (as stated in their 2012/13 annual KT report). However, the extent to which these companies survive market competition in post-graduation settings – or eventually thrive (e.g., public listing, dominating market shares, etc) – remains largely unknown as no income figures were reported to UGC in their annual KT reports. The TTO conducts an annual survey of graduated spin-offs and start-ups to collect information relevant to their performance and

development. The survey is voluntary, and therefore a good to high participation rate cannot be ensured. In fact, the response rate has been quite low (Anonymous. 2020. Interview with a knowledge transfer official. November 24).

Another interesting aspect of HKUST's spin-off development approach is that their targeted graduation rate from the university's three-year incubation program has remained at 25%, more than double the figure expected from private-sector incubators of approximately 10% (as stated in their 2012/13 annual KT report). However, the extent to which these companies survive market competition in post-graduation settings – or eventually thrive (e.g. public listing, dominating market shares, etc) – remains largely unknown as no income figures were reported to UGC in their annual KT reports. The TTO conducts an annual survey of graduated spin-offs and start-ups to collect information relevant to their performance and development. The survey is voluntary, and therefore a good to high participation rate cannot be ensured. In fact, the response rate has been quite low (Anonymous. 2020. Interview with a knowledge transfer official. November 24).

Table 2-10 Revisions to the scope of inclusion for 'spin-off' category in HKUST

Reporting year	Revisions made
2014/15	Economically active spin-off companies include start-up companies that are funded by Technology Start-up Support Scheme for Universities (TSSSU) scheme
2015/16	Economically active spin-off companies include start-up companies under HKUST's entrepreneurship program in Clear Water Bay, Shenzhen Research Institute (SRI), and Fok Ying Tung Research Institute (FYTRI) in Guangzhou, in addition to TSSSU-funded ones
2017/18	Economically active spin-off companies further encompass start-up and spin-off companies being funded / incubated / coached under entrepreneurship programs in both Hong Kong and mainland Chinese campuses, namely TSSSU, U*STAR, Yeung Wing Yee Fund, Entrepreneurship Acceleration Fund, Alumni Endowment Fund, One Million Dollar Competition, Blue Bay Incubator at SRI, as well as all entrepreneurship programs under FYTRI
2019/20	Economically active spin-off companies further encompass start-up and spin-off companies being funded / incubated / coached under entrepreneurship programs in both Hong Kong and mainland Chinese campuses, namely TSSSU, U*STAR, Yeung Wing Yee Fund, Entrepreneurship Acceleration Fund, Alumni Endowment Fund, One Million Dollar Competition, Blue Bay Incubator at SRI, as well as all entrepreneurship programs under FYTRI and HKUST Foshan Research Institute of Smart Manufacturing
2020/21	Economically active spin-off companies further encompass start-up and spin-off companies being funded / incubated / coached under entrepreneurship programs in both Hong Kong and mainland Chinese campuses, namely TSSSU, U*STAR, Yeung Wing Yee Fund, Entrepreneurship Acceleration Fund, Alumni Endowment Fund, One Million Dollar Competition, E-Fund, companies under InnoHK, Blue Bay Incubator at SRI, as well as all entrepreneurship programs under FYTRI and HKUST Foshan Research Institute of Smart Manufacturing

Source: University Grants Committee

Promoting U-I collaboration through collaborative research and joint labs

Collaborative research is one area where HKUST has been very actively involved (further elaboration by which will be shown in the following comparative analysis chapter). This trend could be possibly attributed to the university's frequent partnerships with major industry players through the establishment joint research laboratories on-campus, by which the collaborating firms – in turn – may contribute a substantial amount of industry research income for HKUST. As a policy, HKUST pro-actively promotes U-I collaboration through the setting-up of joint labs. The Vice-President for Research and Development regulates U-I joint labs, for example, in matters related to the amount of money involved and the duration of the agreement. HKUST also distinguishes themselves from other universities through their frequent mention of establishment of joint laboratories with industry firms. As the annual reports have regularly provided brief cases about their recent joint university-industry labs, we would highlight, in Table 2-11 below, some of the examples of such facilities.

Table 2-11 Examples of joint U-I laboratories at HKUST

Reporting year	Joint university-industry collaborations and laboratories in HKUST
2011/12	• Xilinx-HKUST Joint Lab • GlaxoSmithKline R&D (China)-HKUST collaboration in research on neurodegenerative diseases • HKUST-Huawei Joint Innovation Lab
2013/14	• Ford-HKUST Conservation and Environmental Research • HKUST-Thales collaboration on smart cities research • HKUST-AVIC collaboration on aerospace engineering • HKUST-Qualcomm Joint Lab
2015/16	• WeChat-HKUST Joint Lab • Collaboration with top 3 IC firms on IC design • Google Solve for X @ HKUST
2016/17	• France-HKUST Innovation Hub
2017/18	• HKUST-Chiaphua Joint Lab • HKUST-BGI Joint Lab • Joint research with Didi Chuxing • HKUST-Magvii Joint Lab • HKUST-Naver/LINE Joint Lab
2018/19	• HKUST-Xunlei Joint Lab • HKUST-Xiao-I Joint Lab • HKUST-WeBank Joint Lab • HKUST-BDR Joint Research Institute
2019/20	• Guangdong-Hong Kong-Macau Joint Lab of Infectious Respiratory Guangdong-Hong Kong-Macau Joint Lab of Collaborative Innovation for Environmental Quality
2020/21	• National Engineering Lab for the System Safety and Operation Assurance of Urban Rail Transit

Mixed experience with open innovation model in the past

It is also interesting to note that HKUST has experimented with an open innovation-driven model of technology transfer (Baglieri et al., 2018). The open innovation initiative was introduced in 2009/10 but was short-lived. In 2009/10, HKUST launched the Open Innovation and Collaboration Platform (OICP) and KT Management System (KTMS) to promote and facilitate university-industry interaction. OICP was intended to be a platform to support innovation and creativity at HKUST, to facilitate inventor-consumer interactions, to market and accumulate technology know-how, as well as distribute knowledge across the ecosystem; meanwhile, KTMS was meant to enhance the existing KT process by managing the KT tasks and their inter-linking relationship. In 2011/12, OICP was revamped and its name changed to Open Research, Innovation and Collaboration Network (ORION). While the open innovation platform looked promising, the idea eventually failed. Universities' open innovation programs may fail due to power gaps between faculty and TTO, lack of trust, miscommunication or misunderstanding of policy, as well as substantial mismatch in the objectives and expectation of KT between the TTO staff and faculty members (Siegel et al., 2004; Franzoni and Lissoni, 2010). In HKUST's case, a possible major factor for the failure of past open-innovation programs may have been the lack of trust between industry and the university network which in turn may be attributed to Hong Kong's weak industrial landscape (Anonymous. 2021. Interview with a senior KTO official. January 15, 2021).

Other possible reasons suggested that firms are quite unlikely to disclose their challenges/issues straight to KTO; they would rather go straight to the professors. Second, professors oftentimes open source their inventions completely on their own, or that they set up spin-offs independently, based on their own inventions. (Anonymous. 2020. Interview with knowledge transfer official. March 11.) Another possible reason is that companies are perceived to be less willing to communicate with universities when they need to pay membership fees for discussing technical matters with no guaranteed outcomes (Anonymous. 2020. Interview with knowledge transfer official. November 24). Having said that, according to a transfer official, the principle of open innovation is to some degree still 'alive' in HKUST – without need of paying a membership fee – as companies continue to engage the university in other forms.

2.3.5. The University of Hong Kong

Strong emphasis on community engagement projects and two-way knowledge exchange

University of Hong Kong (HKU) ranks 21st among universities worldwide and first locally as of 2022. Aside from its advantage in omnipotent development across diverse disciplines, HKU has placed a strong emphasis on community engagement on the projects supported by the university. Much of the attention on these community service-oriented work is particularly on non-technology-based dimensions, as demonstrated by projects relating to suicide prevention, public health service in rural areas, seminars/workshops on awareness of social and/or health issues, etc. These activities continue to remain as major elements in HKU's KPI assessment in the latest University Accountability Agreement (UAA) with UGC for 2019 and 2022 triennium.

In this regard, the university emphasizes the two-way exchange between the university and the community, which also includes the industry, for mutual benefit. Thus, the expression 'knowledge exchange' tends to be used more than 'knowledge or technology transfer.'

In line with the missions of many advanced economies including Hong Kong, HKU has set knowledge exchange as one of its pillars of development. Knowledge exchange is an integral part of the work to be done by each faculty or department. Since 2010/11, each of the faculties in HKU has established its respective Faculty Knowledge Exchange Unit forming part of the formal structure within each Faculty. Each Faculty's Knowledge Exchange Unit is led by the Dean or Associate Dean serving on the Knowledge Exchange Working Group to ensure that KE objectives are spread to all faculties in the university. Each Faculty website has its respective webpage for KE. Furthermore, to ensure longer-term capacity-building measures on KE, HKU sent a clear message to Faculties that given KE should be a core element at the faculty level, Faculties are encouraged not only to rely on additional KE funding, but also provide matching funds and/or redeployment of existing resources. This finding appears to suggest a certain form of decentralization of knowledge transfer (KT) function. It is interesting to further explore the nature of the tasks of the faculty KE units.

The university offers several measures in order to incentivize the participation of university actors in HKU's KE-themed projects. One such scheme offered by the senior management is Faculty Knowledge Exchange (KE) Awards, which was implemented beginning from 2009/10 reporting year. This series of annual awards is intended to properly acknowledge faculty contribution in implementing the university's KE mission through community engagement projects. In addition, HKU senior management also made use of the KT-specific funding allocation provided by UGC to launch several schemes to promote KE. The two most notable schemes funded under UGC funding for KT are Impact Project Funding Scheme (introduced and launched in 2010/11 reporting year) and Student Knowledge Exchange Grant (similar to the former, but were targeted specifically for students, this scheme was launched in 2011/12 reporting year).

Beyond the annual incentives and schemes described above, HKU also set up a one-off funding scheme which was titled 'Interdisciplinary Knowledge Exchange Project Fund' in 2016/17 reporting year; this scheme was intended to promote cross-faculty collaboration in community engagement-oriented, KE-themed projects. Given the university's strong interest in emphasizing the realization of impact in their KE projects – as well as increased efforts to assess the extent of societal impacts already generated from the projects, they also offered a special funding round in 2017/18 reporting year to provide resource support for faculty members in the collection of evidence of impact from their past and/or existing KE works.

Combining impact with community engagement at the core of knowledge transfer

HKU's unique approaches to KT activities partly shape their distinctive understanding and conceptualization of 'good practices.' Two aspects that are worth mentioning in this regard are related to 'service to community' and 'emphasis on impact'; indeed, for the university's KT projects, there is an emphasis in ensuring that these two aspects go hand-in-hand. The 'service

to community' dimension has been consistently underscored since the first launching of KT report in 2009/10 reporting year; in this regard, the university accentuates the importance of applying knowledge generated from university research in relevance to the existing societal issues, whether in Hong Kong, Mainland China, or overseas. Moreover, inextricably linked to the dimension of community service is the essence of 'impact'; in addition to highlighting the relevance of university research and KT to existing societal problems, the university management also strongly encourages faculty members and other participating stakeholders to utilize these projects to create a noticeable impact on addressing the existing issues of concern. HKU has also been an early adopter of 'impact case studies' in their reports on knowledge transfer activities. The in-depth elaboration of such cases in its KT reports is intended to illustrate to readers the extent to which active research and engagement efforts by the project participants have resulted in positive changes in relation to the issues of concern. The embodiment of 'impact', in this matter', may vary, ranging from technology-based breakthroughs to progress in non-technology-based areas (e.g., policy changes or legal/regulatory reforms).

It appears, from our observation, that HKU's approach closely mirrors the observation by **Hughes and Kitson (2012)** on how UK universities strategically position themselves from creating pathways for real impact.[16] The scholars demonstrated, through faculty surveys, that universities' routes to KT through direct commercialization and TT only represent a small proportion of the actual scope of KT being applied in practice (e.g., community engagement, public lectures, sitting on advisory boards of organizations, etc.). HKU gives importance to the inclusion of non-technical experts, e.g. philosophers, ethicists, social scientists, in deliberating the social, cultural, economic, and political impacts of emerging technologies developed from university research (Anonymous. 2020. Interview with a KTO official, November 24, 2020). While HKU has yet to establish specialized research centres to study the impacts from these dimensions, the university acknowledges they are aware of these potential consequences.

The training of staff at the university's Knowledge Exchange Office / KEO (HKU's equivalent of KTO) also incorporates an 'impact' dimension through the so-called 'impact workshops' that began to be introduced into the KT reports from 2013/14 reporting year onward. In this regard, the university was fairly elaborate about their mission to inculcate the necessity of 'impact' in the KE projects that are funded, implemented, and supported by the KEO. In relation to the impact workshops, one consistent picture that emerged from their discourse was the extensive attention they pay on quantifying 'positive media impact' from the KE projects implemented by HKU community members, particularly from 2012/13 onward. Our review of HKU's annual KT reports thus far demonstrate that their conceptualization of impact remains primarily on a positive-connoting domain and less nuanced than what the authors have discussed (e.g., close emphasis on positive media coverage as one indicator of impact). Our follow-up interview so far demonstrates that the university has yet to consider the nuanced approach, given that the university has very clear and specific targets from their KT works (Anonymous. Interview with a knowledge transfer official. November 27).

Gradual alignment of HKU's innovation orientation with UGC's innovation thrust

As mentioned earlier, HKU's understanding of 'impact', as illustrated through the impact cases in KT annual reports, includes both technology and non-technology-based innovation. At first, however, the KE activities of HKU mainly consisted of organizing workshops, events, seminars, and community events to disseminate information or provide training related to dental hygiene, health awareness, etc. It was only from 2015/16 reporting year onward that HKU included making advances in translational research and giving more recognition to technology-based entrepreneurship in its current strategic plan (2016-2025). In this sense, HKU is relatively a latecomer in the promotion of technology-based innovation.

In addition, based on the analysis of KT annual reports, an apparent contrast in the information presented in the reports' main content and the figures listed in the tables in the appendix with regard to UGC's categories of KT has been observed. In this regard, the figures reported in the appendix tables (on KT categories such as patents, licensing deals, spin-offs, collaborative research, contract research, consultancy, CPD courses, etc.) are largely in sync with the direction provided by UGC. Nonetheless, the remaining sections of the reports principally focus on public engagement activities that are not directly related to the quantitative metrics as directed by the Commission, e.g., highlights on the university's series of projects on volunteering, health awareness workshops, building rehabilitation, policy advocacy efforts, awareness on certain legal/social issues, etc. Thus, HKU seems to be quite a 'newcomer' in terms of their endeavors on promoting the culture of innovation (particularly technology-based innovation) and entrepreneurship. Our follow-up interview demonstrates that the university did not see such discrepancies as a sign of tension between the need to adhering to UGC's direction and performing KT activities based on their own strategic direction. Rather, they view these contrasting features as being complementary, given that their community engagement and knowledge application projects are seen as a continuing process that may take a long time – 5-10 years or even more – to materialize; furthermore, due to the annual reporting requirement to UGC, HKU's KT officials often report these figures and projects as 'work in progress' (Anonymous. Interview with a knowledge transfer official. November 27).

Having said that, overall, while 'knowledge exchange' has remained at the core of HKU's KT mission, the concept – over time – has also been substantially broadened so as to include innovative and technology-based entrepreneurship. Such paradigm shift is also in sync with HKU's new vision statement in their 2016-2025 Strategic Plan of participating 'as a key player in innovation for Hong Kong's future'.

Gradual and piecemeal acknowledgement of faculty contribution to knowledge transfer

While the university has consistently incentivized relevant stakeholders (faculty members, students, and other staff) to be engaged in KE activities, the incorporation of KE/KT performance into the assessment criteria for faculty promotion can be characterized as gradual and piecemeal. For most of the reporting periods, KE was treated as an integral part of the 'service' component in faculty performance assessment, alongside 'research' and 'teaching' (Anonymous. Interview with a knowledge transfer official. November 27). In 2008/09, HKU

for the first time required faculty to report up to three examples of KE activities with positive impact. In 2009/10, HKU introduced Faculty Knowledge Exchange (KE) Award only as an added value to the faculty, but not as a criterion for promotion, let alone faculty tenure or substantiation. In the following academic year, HKU launched the Faculty Knowledge Exchange Award Scheme to recognize and reward each faculty's outstanding accomplishments which demonstrated clear economic, social, or cultural impacts on the community, industry, or partner organizations. In the same year, the Knowledge Exchange Working Group agreed to propose for Faculty consultation that a separate weighting for KE be introduced to the main portfolios of professoriate staff, alongside teaching, research, and service/administration.

In 2011/12, HKU recommended a separate weighting of up to 5% for KE be introduced to the main portfolios of professoriate staff, alongside teaching, research, and service. However, this effort would require several more years before it was eventually approved by the university leadership. As an illustration, in 2012-2015 triennium, the university allowed faculty contribution to be included in their 'Academic Portfolio of Achievements' system, which included Knowledge Exchange Activities System (KEAS); this system allowed faculty members to input their KE projects that may contribute to HKU's mission. Nevertheless, KEAS was not taken into consideration apropos faculty tenure and/or promotion; in other words, KEAS was treated as no more than 'bonus points' for participating faculty members. Moreover, bulk of faculty contribution that was properly acknowledged was primarily non-technology-based.

It was only from 2016/17 reporting year onward that HKU included TT and commercialization as an assessment element in the revised Performance Review and Development process of professoriate and academic-related staff, along with teaching, research, and service/administration. The inclusion into faculty assessment was formalized starting from 2017/18 reporting year. As observed above, the incremental changes over a span of about ten years showed that more, and perhaps faster, reforms are needed. For example, a HKU TTO official asserts that the KE achievements of faculty should be duly recognized and taken into account in career promotion.

"Let's say, for example, you have 2 professors – one professor is publishing a paper in Nature; another professor, his paper is not up to that level, but he has tons of patents and a 1-billion industry investment and is creating 20 companies. Which of them would you want to promote as a tenured professor?"

> "So, if university believes that innovation is one of the goals, then they have to change this part, especially for the professors, [regarding] promotions and tenure track, appraisal. These are very important. If a professor wants to become a part of the game, the university has to recognize these activities. Let these people be tenured professors. Then, a lot of young professors are willing to do it. I have encountered cases of professors saying in the assessment that they don't have the time, because they have to publish papers. They count the number of PhD students, but they don't count the number of patents. They don't count the number of licenses and of industry investment.

So, that is the overall effect [of the policy]. Our university changed the assessment criteria in 2017. They recognized knowledge exchange. So, it helps their career development. So that's why the university has to say their priority clearly." (Anonymous. 2020. Interview with a KTO official. March 12.)

Table 2-12 Some highlighted entrepreneurial support based in HKU

Academic year	Infrastructure	Funding / Program	Expansion to and collaboration with GBA cities
2009/2010 and before	• New KEO has been set up • HKU Scholars Hub • Approval of IPR policy		
2010/2011		Launch of a number of funding schemes and programs, including Competitive Impact Project Funding Scheme, Faculty Knowledge Exchange (KE) Award Scheme, and Three Minute Thesis (3MT^{TM}) Competition	
2011/2012	Launch of KE Newsletter	Launch of KE Award for non-faculty unit	
2013/2014	Launch of Knowledge Exchange Activities System (KEAS) to measure individual's KE contribution		
2014/2015		Launch of a number of funding schemes and programs, including DreamCatchers, and TSSSU@HKU	
2015/2016			
2016/2017	KE has been added as an assessment element in the revised Performance Review and Development (PRD) system	Launch of Interdisciplinary Knowledge Exchange Project Fund	
2017/2018	● Set up of IP management team in TTO ● Establishment of iDendron		Launched of GDPU-HKU Innovation Platform in Zhongshan
2018/2019	Set up of industry liaison team in TTO	Launch of Interdisciplinary Quick (IQ) Talks	

2019/2020	Launch of iDendron Incubation Programme (iIP)
2020/2021	Launch of HKKUTTO Techshow

Source: University Grants Committee

Shifts in approaches on technology commercialization

At first, the university's stance on entrepreneurship – particularly in commercializing scientific and technological inventions based on university research – was to encourage staff to prioritize licensing, rather than spin-off, as the commercialization route. One closely linked aspect to the concept of KT, in addition to technological innovation, is entrepreneurship, as this relates to the transformation of ideas (whether technology-based or non-technology-based, as well as originating from university research) into products and/or services that can contribute to addressing societal needs. Given such recognition, UGC has openly included categories relating to entrepreneurship (e.g., 'the number of economically active spin-off companies' and 'income generated from economically active spin-offs') as required components in the annual reporting exercise by the funded universities. However, until 2015/16 reporting year, HKU's position has been that 'licensing is a preferred route to commercialization'; the idea of spin-off formation would only be considered when inventors have demonstrated sufficient evidence of feasibility of these university-based inventions. While HKU gradually started to endorse the idea of 'start-ups' as early as 2013/14 reporting year, their support was largely limited to 'student-driven, non-profit' start-ups (which most likely refer to social enterprises); as regards commercialization of university-based technologies, the university leadership continued to prioritize licensing as the preferred mode.

While weak support for spin-off formation may contribute to HKU's current entrepreneurial culture (Degroof and Roberts, 2004), this practice may have incentivized faculty members to engage in other 'safer' forms of KT, such as contract research, collaborative research, as well as consultancy practices. The figures – the elaboration by which will be shown in the comparative analysis chapter – indeed show HKU's high performance in contract research deals and income, as well as the steady growth in licensing agreements over the 10-year period from 2009/10-2017/18. Perhaps one of the reasons to explain what seems to be a positive direct relationship between licensing and contract research performance is that the university considers contract research as a good channel for eventual licensing to firms who collaborate with the university.

Indeed, contract research is shown to be among HKU's biggest sources of income from knowledge transfer (KT) activities – the details by which are elaborated in the next chapter. HKU TTO adopts an approach to managing contract research which perhaps can be characterized as laissez-faire. The KTO facilitates contract research deals between the relevant faculty members and their prospective clients, but does not get involved in the details, as well as potential issues, arising from works on contract implementation.

> "We have separate offices dealing with the financial and legal matters related to these [contract research] agreements. I sign all the agreements. I sign about 1,000 agreements per year. However, we [the KTO] don't manage them. The projects themselves are run by the PIs (project investigators). The final reports are assessed by their people. We don't review their final project reports, and also the legal and finance-related issues. Whether they actually deliver the things or whether there are meaningful and impactful things [from these projects], we actually have no idea." (Anonymous. 2020. Interview with a KTO official. March 12).

In other words, HKU TTO's sole responsibility is to facilitate and formalize the contract research agreements between the faculty members and their clients. With regard to monitoring of progress and resolution of issues that possibly arise in the course of project implementation, the TTO essentially outsources such responsibilities to the project investigators and relevant parties. Overall, the TTO is primarily responsible for the inception of these projects. The fact that HKU performs very well in the area of contract research demonstrates the university's extensive academic engagement with industry and other external stakeholders that seek to utilize the former's scientific expertise (Perkmann et al., 2015). This finding also reflects the university's ongoing, strong support for active engagement with external stakeholders, as indicated by the inclusion of public-private partnership and relevant projects – e.g., consultancy, contract research, collaborative research, community service and relevant public engagement projects, etc. – as one of their major KPIs for 2019-2022 and 2022-2025 triennial exercises.

The substantial change in HKU's stance on entrepreneurship began with the introduction of TSSSU scheme in 2014/15 reporting year by ITF. HKU began to more actively promote spin-off/start-up formation, which is beyond solely organizing seminars, workshops, and public lectures. TSSSU funding scheme explicitly supports start-ups/spin-offs that solely concentrate on commercializing university research. Such paradigm shift could also be partly attributed to HKU's 2016-2025 strategic plan, in which the university aspires to be a major player in building Hong Kong's innovation and technology ecosystem. To illustrate such paradigm shift, starting from 2015/16, the university leadership revised their position from 'licensing as the preferred route' to taking a dual approach in considering [both] licensing and spin-offs'. In the 2015/16 and subsequent reports, HKU also promoted more success stories about spin-offs/start-ups utilizing research based from the university, as well as established related programs and competitions. Another illustration that exemplifies the positive impact of HKU's shift in commercialization route is evident from the number of economically active spin-offs, which has risen to 11 in 2015/16 after staying constant at 2 for 5 consecutive reporting periods (up to 2014/15 period). At the recent 2019/20 KT report, the number of spin-offs was reported to be 34.

While HKU has provided more support to entrepreneurial activities in the university in the forms of spin-off/start-up creation, the senior management does not appear to consider either the number of university-based companies – or their subsequent generated income – into their major KPI. Our argument stems from analyzing the most recent University Accountability Agreement (UAA) with UGC. While one of their four KPIs is related to innovation and

entrepreneurial activities, the relevant sub-indicators are more related to events, projects, number of participants in these activities, as well as impact cases.

2.4 Comparative analysis

In this section, we synthesize our findings and insights from individual analysis of the five universities in Hong Kong for comparative analysis. Below summarizes our findings with respect to these institutions in the previous chapter. Observations that we found to be highly distinctive specific to the university of interest are highlighted in bold letters and blue-colored cells in the table below. We also seek to build linkages – in reference to literature germane to KT and entrepreneurship – between our findings and insights from the existing literature. Our discussions in this chapter are centred on five themes: 1) KT-versus-academic-excellence debate; 2) commercialization routes oriented towards patenting and licensing; 3) U-I collaboration in scientific and technical activities; 4) spin-offs, and; 5) student entrepreneurship.

Theme 1: universities prioritizes over KT and research

Our in-depth analysis of policy documents shows that universities in Hong Kong have been making tremendous efforts to promote knowledge and/or technology transfer, but differences remain over promoting KT (which KTOs largely favor) and prioritizing research (which are the most important component in faculty members' performance evaluation and tenure reviews). Such dynamics, indeed, are not unique to Hong Kong universities; existing literature has provided quite comprehensive discussions about this contention in a multitude of countries and regions (whether in North America, Europe, East Asia, etc.).

This is reflected in their policies on faculty tenure (refer to the fourth row of Table 2-13). In majority of the universities that we studied, KT has not been included in the evaluation for faculty promotion; instead, senior leaders in these universities provide other forms of recognition for faculty contribution in KT activities, such as special award schemes for academics that are active in KT (as CityU and PolyU demonstrate) or allowing faculty staff to update their accomplishment records (illustrated by CUHK). Only HKUST and HKU have explicitly adopted KT as components of their faculty promotion and substantiation system, with HKU formally introducing this measure very recently in 2017/18 academic year.

In general, universities are described to be oftentimes reluctant to further enhance their KT activities, due to friction between professionalization (codification of knowledge transfer, e.g., patenting / licensing / spin-offs) and academics' focus on tacit-based knowledge exchange, e.g. informal interaction between faculty members and non-university actors (**Benneworth and Charles, 2005**). With regard to the university's senior management level, these strains are manifest in the dilemma on whether to prioritize bureaucratic or entrepreneurial management model (**Kwiek, 2008**).[17]

Table 2-13 Summaries of some major KT elements based on individual university analysis

	CityU	**CUHK**	**PolyU**	**HKUST**	**HKU**
Infrastructure innovation building/space	Innovation Commons (co-working space)	Pi Centre (incubation-accelerator; working space)	House of Innovation	BASE (co-working space, managed by the Entrepreneurship Center) Innovation Building under construction	iDendron (working space, managed by TTO)
Government-built infrastructure In the vicinity of the university	(Innocentre - managed by Hong Kong Science and Technology Park, provides working space and incubation programs)	The Hong Kong Science and Technology Park	None	none	(Cyberport - provide working space and incubation programs)
Proof-of-Concept (POC) funding scheme	provides Proof-of-Concept (POC) funding scheme	PiCentre provides pre-incubation and incubation support to staff and student start-ups (includes POC)	provides POC funding scheme	provides POC now known as Bridge Gap Fund (starting 2020)	does not provide POC
Faculty tenure inclusion of KT in evaluation for	not included (recognition through awards)	not included (recognition by entering KT performance into staff records, i.e., University Staff	not included (recognition to KT performance through awards)	Since 2000, KT has been incorporated into the assessment criteria for faculty promotion and substantiation.	In 2016, KT and commercialization included as an assessment element in the Performance Review and

faculty promotion/tenure		Profile Update System, as well as considering KT as an important component of academic research of staff)		In 2016/17, HKUST introduced a new appraisal system 50% of which consists of teaching-based metrics and the other 50% uses research and KT metrics. **N.B. KT is included in the evaluation criteria for faculty promotion**	Development Process. In 2017, this was formalized. KT given a weighting of 5%. (see main text for the process/changes over the years to the present status)
Technology Transfer Office organizational structure	Knowledge Transfer Office KT representative in each College/School CityU Enterprises Limited CityU Research Ltd. (CityUR) (licensing or	**Office of Research and Knowledge Transfer Services (ORKTS) - in 2014 CUHK's KTO and Research Administration Office (RAO) were merged under ORKTS; ORKTS houses all TT-related offices**	Institute for Entrepreneurship (PolyU's KT Office) PolyU Technology and Consultancy Company Limited (business and strategic professional consultancy arm)	Technology Transfer Center HKUST R and D Corporation Limited (commercialization arm) Entrepreneurship Center (manages entrepreneurship activities and promotes	HKU's TTO/Versitech Limited and Knowledge Exchange Office are all under a committee comprising the Chief Innovation Officer, Senior Advisor to the President, Director of KEO, and Director of TTO/Versitech Under the KEO (KE Executive Group; KE

	commercialization arm of CityU)	**N.B. Houses all research- and TT-related offices under a single entity**		entrepreneurship culture)	Working Group; Faculty KE units)
Technology Transfer Office size (est.)	23 at KTO: 3 (Management); 5 (Technology Transfer); 2 (Licensing Administration); 2 (Marketing and Communications); 9 (HK Tech 300) 1 (Innovation); 1 (Office Administration) (manual count on website, as of 14/10/2022)	61 at ORKTS: 17 (Grants Team); 4 (Administration Team); 7 (IP and Technology Licensing Team); 4 (InnoPort Team); 3 (Venture Acceleration Team); 6 (Social Innovation Team); 6 (Innovation and Impact Development Team);	3 (Technology Transfer and Commercialization Division); 8 Entrepreneurship Division; 8 Technology Marketing and Industrial Networking Division); 11 (PTeC)	42 in OKT including: 4 (Intellectual Property Team); 8 (Business Development Team); 3 (Translational Project Team); 9 (Joint Research Institute and collaboration centre); (manual count on website, as of 14/10/2022)	31 (TTO/Versitech) 3 (KE executive Group) 11 (KE Working Group) (manual count on website, as of 14/10/2022)

		9 (Legal Team) 2 (Information Management Team)			
Commercialization route licensing vs. spin-off	**N.B. Explicitly promotes licensing and discourages spin-off formation by faculty; encourages start-up formation among students**	Stringent requirements for spin-off formation by faculty Promotes start-up formation by students **N.B. Since 2015/16, CUHK allows non-professoriate staff (e.g. post-docs and research assistants) to support spin-offs initiated by faculty**	Licensing preferred commercialization route; stringent requirement for spin-off formation by faculty Promotes company formation by students **N.B. Currently hires at least one entrepreneur-in-residence**	Favorable policies on spin-off formation since 1990s; promotes licensing	Since 2015/16, HKU has taken a dual approach, i.e. licensing and spin-off
Marketing outsourcing/in-house	**N.B. Uses outsourcing model heavily**	Mainly in-house management and marketing of IP	Mainly in-house management and marketing of IP	Mainly in-house management and marketing of IP	Mainly in-house management and marketing of IP

IP policy IP ownership	100% university for inventions by faculty 100% students for inventions by students, unless (a) they receive financial support from the university in the form of wages, studentship, etc. to undertake research work, (b) project involved the use of more than HK$100K of university-administered fund or use of specialized equipment or significant faculty supervision	100% university for inventions by faculty and/or by student	100% university for inventions by faculty and/or students	100% university for inventions by employees/faculty 100% students (except research postgraduate students supervised by faculty) for inventions solely by students **N.B. no other conditions for IP ownership by students except when the project received money from a company which has signed an agreement assigning the IP back to the university**	100% university for inventions created by faculty/staff 100% university for inventions created by a student in the course of study and developed with more than incidental use of University resources and/or developed under a project funded by or through the University

Licensing royalty share distribution	Net income from patented technology funded by CityU: 35% host department 30% faculty (student) inventor 35% CityU Net income from patented technology funded by inventor: 25% host department 50% faculty (student) inventor 25% CityU Net income from non-patented technology: 25% host department 50% faculty (student) inventor 25% CityU	(Introduced in 2017) Inventor/s: will receive a percentage of the gross royalty income received by the University at a proportion allocated in accordance with the funding source stated, at the option of the inventor(s) University: 60% of remaining value after deducting the share of income for inventors Faculty: 40% (the Faculty Dean will have the discretion to make appropriate distribution to the Department/Unit concerned) **N.B. 1 Priority accorded to investor/s who receive a percentage**	Net revenue from patented technology (if the University pays for the cost of obtaining and maintaining a patent or any form of registration for the Intellectual Property concerned): 35% inventor(s) 10% host department 55% University Net revenue (if the Inventor(s) pays for the cost of obtaining and maintaining a patent or any other form of registration for the Intellectual Property concerned): 70% inventor(s) 10% host department 20% University **N.B. grants licenses at gratis basis to**	Commercialization Revenues (net) received shall be distributed in the following proportions until the Commercialization Expenses have been fully recovered: 10% creators 80% towards recovery of the Commercialization Expenses 10% HKUST business case processing unit Then, for the subsequent HK$ 2 million of Commercialization Revenue, the distribution will be as follows: 50% creators 20% Performing Unit 15% University Development Fund 15% HKUST business	Net income (after deducting patenting costs, among others): 1/3 University 1/3 Faculty/department 1/3 Inventor/s **N.B. Emphasizes equal sharing**

		of the 'gross' rather than the net; then, remaining value distributed to other stakeholders (see above) **N.B. 2 the Faculty Dean has a say on how is licensing income shared between Faculty and relevant Department under it**	**benefit and create positive societal impact**	case processing unit Thereafter, Commercialization Revenues will be distributed as follows: 35% creators 30% Performing Unit 20% University Development Fund 15% HKUST business case processing unit	

Spin-off/start-up internal definition	Spin-off: Involves CityU technology; new venture founded by at least a staff or former staff or student or alumnus from CityU to champion CityU IP(s); no institutional ownership but using IP licensed only Start-up: (1) New venture with at least 1 founding member from the CityU community (i.e., staff or former staff or students or alumni; does not champion CityU IP; (2) New venture with no CityU members as founder/s, and champions CityU IP primarily as a licensee	Spin-off: Companies which the university has shares of Start-up: Funded by ITC, TSSSU companies	Spin-off: Fully owned by University; no industry firm involvement **N.B. for spinoffs that are "more commercialized" in nature are referred to as joint venture; such JVs has industry firm involvement** **Start-up: involves either university technology licensed to the company or university investment in exchange for equity share which is never majority share; management and operations are independent of the university; no**	Spin-off: (a) Companies with or without university share; (b) affiliated with HKUST; (c) incubated and coached by entrepreneurship programs based in Clear Water Bay campus and Mainland campus (current definition adopted in 2017/2018) Start-up: Mainly run by students; affiliated with HKUST; incubated and coached by entrepreneurship programs based in Clear Water Bay campus and Mainland campus (above both types of companies are reported in annual KT reports to UGC)	Spin-off: Company set up using university technology; mainly those set up by faculty (reported in annual KT reports to UGC) Start-up: Involves HKU technology; funded by TSSSU; majority are student startups

			university official sitting on its board		

Our findings also align with the observations by **Mok (2013)** on universities in East Asia, by which changes in both faculty pay and tenure structure 'direct' them to increasingly emphasize high-quality publications.[18] In addition, our reviews of the universities' strategic plans over the past decade also demonstrate that all five universities aspire to be world-class universities, but simultaneously have ambitions to be major players in innovation and technology. Previous studies have shown that both these ambitions hardly reconcile with one another (**Murray, 2010; Siegel and Wright, 2015; D'Este et al., 2018**). One major reason such discrepancy exists relates to universities' inherent tensions on generating outstanding research (which is useful for faculty evaluation and university rankings) versus generating useful research (that has strong applicability for industry players and other non-university actors), as well as challenges in balancing them (**Siegel and Wright, 2015**). Furthermore, these schisms will continue to linger as long as academic reward systems remain fundamentally science-based (**D'Este et al., 2018**).

Specific to Hong Kong, the dilemma between prioritizing KT vis-à-vis research is also attributed to the existing incentive structure in the higher education system, which from our follow-up interviews, has been described as inflexible and inadequate. While faculty members can diversify their research funding sources beyond the UGC schemes (notably General Research Fund / GRF), such as

applying for funding support from ITC and other government agencies, the current system appears to place more credits for academic staff that primarily rely on UGC funding sources for their research activities. One of our interviewees, a high-level senior university official, provided further elaboration on this issue:

"My view is that RGC [UGC] wants to fund mainly basic research. Of course the government has other initiatives, like ITF schemes [by ITC], and these funding schemes are good. But I see that the bottlenecks come from the universities themselves. Colleagues often see their counterparts having their research published in Nature or Science, and will try to apply for UGC's schemes worth HK$1 million instead of other schemes, say from ITF, that can provide them HK$10 million. A lot of this has to do with the existing incentive and evaluation structure at UGC, especially RAE [that mainly looks at basic research performance]… These funding [schemes] are not always related to innovation and knowledge transfer." (Anonymous. 2021. Interview with a university official. January 14, 2021).

Efforts to address the existing contention are highly contingent on both institutional and organizational dynamics of the higher-education institutions (**D'Este et al., 2018**). In accordance with these scholars, we suggest three sets of factors that are of strategic importance in managing such differences, namely: 1) individual antecedents (understanding faculty members' motivation to engage in KT); 2) organizational conditions (in this regard, to inquire how universities facilitate research that is not only academically outstanding, but also useful in addressing industrial and/or societal needs, and; 3) process-context factors (which relate to how universities' institutional settings facilitate productive interaction and exchange of knowledge among academics and other stakeholders).

As suggested in some of our interviews, there is a need to promote flexibility in the current academic system, such as increasing additional positions on research-only tenure-track academic position (e.g. research professor position), as well as revising the existing faculty evaluation policies that reflect academic staff's contribution to research that is funded by sources beyond UGC's existing schemes.

> "We need more resources. Funding by RGC [UGC] is not substantial. I think the government has given more resources, but they are still not enough. For RGC, the success rate [of grant application] is only around 30%. While in principle we should fund the best, many other fundable proposals are not funded at all because of the lack of money. That's the first hurdle. We should also emphasize the need to promote more research professors, or people who will only focus on research. Our colleagues are very stressed out because they have to do both teaching and research. We should consider this. In the US, there is a 'buy-out' concept; say, with more funding, colleagues can buy more time to do less teaching, and more research. In Hong Kong, we may want to give more thoughts about this." (Anonymous. 2021. Interview with a university official. January 14, 2021)

Nonetheless, echoing what we discussed in the case of HKU (p. 63), there are concerns among university administrators that too drastic a change on the existing faculty assessment policy can be detrimental to the universities' interests in the long run. This view was shared by a senior faculty member we interviewed:

"When we put KT into evaluation, the system [UGC] does not know where to put it. Often they include it on 'service' component. I think universities are gradually making changes on this. See, if you change the policy too drastically, it will disincentivize people and result in fewer KT initiatives instead. For leaders, it is a very difficult decision to do so. I don't blame the leaders for facing such difficulties, because it is very tough to quantify KT metrics for faculty assessment… Too drastic changes will be very dangerous for any university." (Anonymous. 2021. Interview with a faculty member. January 11, 2021).

Theme 2: commercialization through patenting and licensing

Despite the challenges, Hong Kong universities have made significant inroads regarding their efforts on commercializing academic science. One example is shown by a steady increase in the number of new licensing deals for accessing university IP, e.g. patents. Our analysis of individual universities demonstrates – over time – a steady growth in the number of patent filings, grants, and licensing deals across all five of them (see Figure 2-2 - Figure 2-4; Table 2-14).

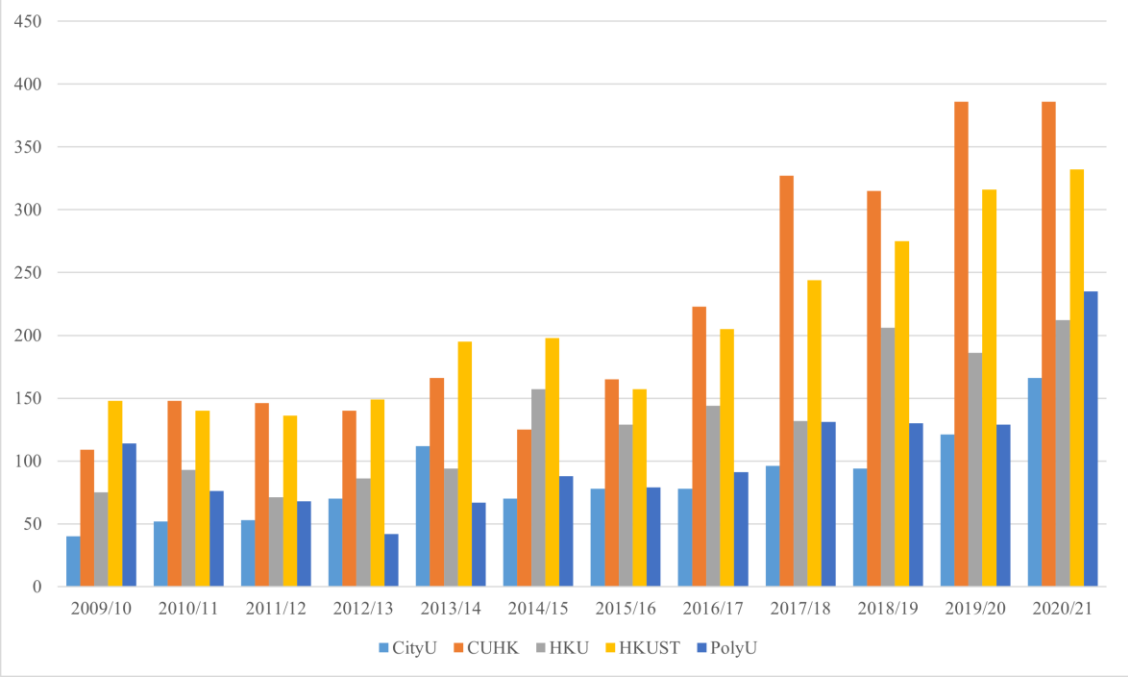


Figure 2-2 Total number of patents filed by university (2009/10 – 2020/21)

Source: Lens.org, University Grants Committee

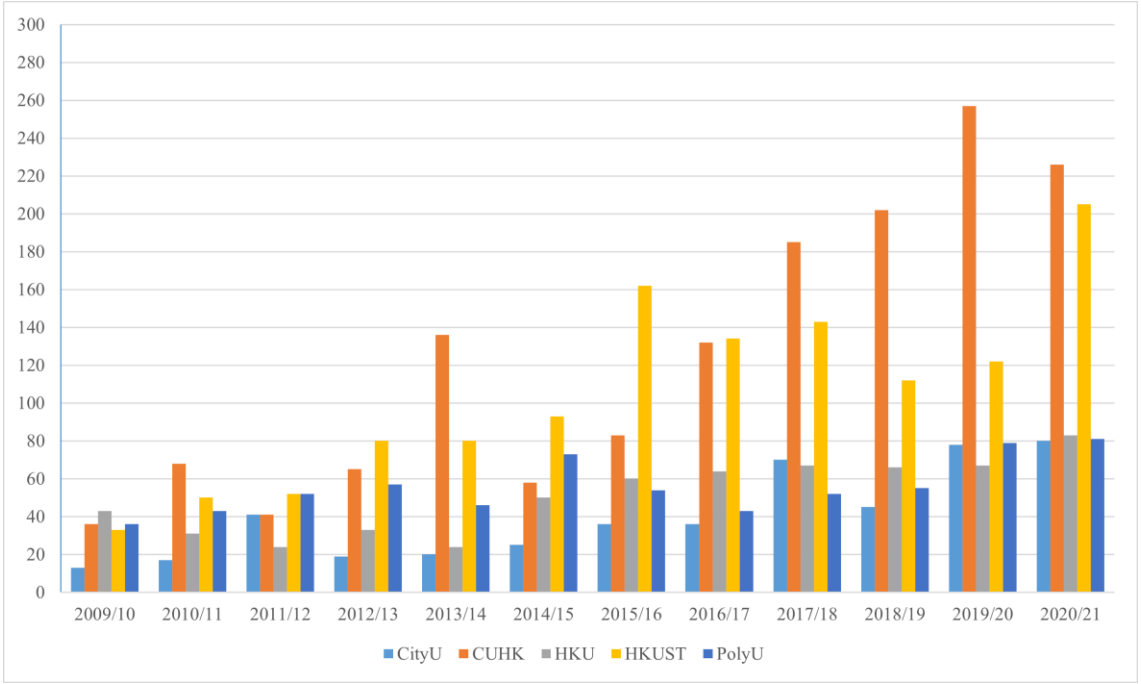


Figure 2-3 Total number of patents granted by university (2009/10 – 2020/21)

Source: Lens.org, University Grants Committee

Table 2-14 Number of newly granted licenses per year by university (2009-2021)

	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
CityU	16	18	22	19	23	17	17	-	-			
CUHK	24	26	24	48	61	57	67	90	78	91	52	80
HKU	39	45	68	63	66	75	86	102	114	120	133	-
HKUST	7	34	28	33	41	54	64	100	107	108	113	120
PolyU	6009	18	55	54	76	89	110	129	138	126	134	148

Source: University Grants Committee

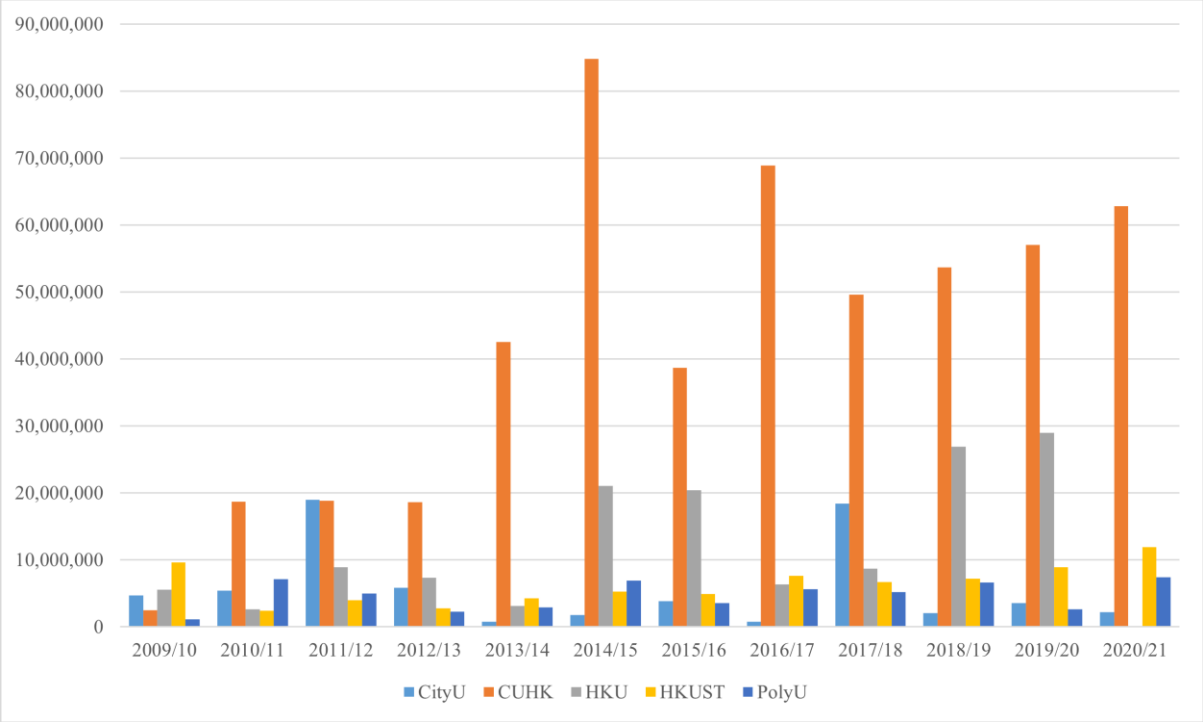


Figure 2-4 Income (cash) from licensing of university IPR (2009-2021)

Source: University Grants Committee

In majority of the five universities that we studied, the overall direction in terms of commercialization routes has been to prioritize licensing over other categories, particularly spin-offs. CityU explicitly states that faculty members focus primarily on licensing, and simultaneously discourage them from actively participating in spin-off establishment; in this regard, students are seen as the more suitable actors to establish start-ups. In CUHK, the university's existing policies do not openly encourage faculty members to prioritize licensing; instead, they have made requirements for spin-off formation by academic staff to be fairly stringent. PolyU's policies are also closely similar to those of CityU and CUHK in that the former also attaches stringent conditions for faculty members to establish spin-offs, and prefer that students drive the commercialization culture in the university. HKUST is distinguishable from most other universities as the university has provided favorable policies on spin-off formation since the 1990s, and welcomes any university stakeholders – whether faculty members, research staff, or students – to establish companies to commercialize university inventions. HKU's preference is similar to those of CityU, CUHK, and PolyU in that it explicitly prioritizes licensing as the main pathway to commercialization, but since 2015/16 academic year, the university has changed their stance and adopted a dual approach to commercialization, namely through licensing and spin-offs.

Nevertheless, the universities' overall strong preference for licensing as the main avenue to commercialize university inventions (especially patents) has not led to a corresponding increase

in licensing income. They demonstrated a mixed record when it comes to this indicator. Existing literature has shown that even when patents are of potentially high value, this does not necessarily translate into better performance in terms of IP licensing because there can be other factors that come into play, for instance, the overall absorptive capacity of innovation actors within a local region (**Azagra-Caro et al., 2017**). Some other factors include, as an interviewed TTO official has suggested, whether or not the invention is a technological breakthrough; the marketing skills or business strategy adopted by the university's transfer office; and, whether the faculty-inventor decide to pursue other modes of commercialization. Indeed, in some places (e.g. US and Australia), the patent utilization rate ranges from 40-50%, but for other reasons such as an inefficient patent system (**Sichelman, 2010**) and low-value patents (**Webster and Jensen, 2011**). As mentioned earlier, **Perkmann et al. (2015)** remark that only a small percentage of patents in Imperial College London are licensed.

Existing research has also shown that patenting has an inverted U-shaped relationship with publishing and other KT channels (e.g., collaborative research, contract research, consultancy, spin-offs); in this regard, the rate of patenting has a positive effect on the frequency of such KT activities until a substitution effect sets in (**Crespi et al., 2011**). An interview with one of the university's KT officials also provides some preliminary evidence that patenting 'distracts' researchers away from their core activities, as patenting involves much administrative work. If this were the case, a question can be raised in the future on what areas for improvement might be needed in relation to the administrative support TTO provides to scientists so that the latter can focus on their R&D work (**O'Kane et al., 2015**), e.g., by increasing the TTO's workforce size (**Debackere and Veugelers, 2005**). It is also interesting to explore the coordination mechanisms between the TTO and faculty members, particularly the presence of KT-active faculty members as boundary-spanners in coordinating the communication between the two stakeholders **(Debackere, 2000)**.

Quite interestingly, an interviewee told us that licensing, for universities, is a mostly 'money-losing' business. The interview excerpt below provided further elaboration:

"We have to agree on why universities want to patent something. This is a very important question. I always asked this question to the university management. When they said, 'we have to make money', then I will advise them, don't do the patents. Nobody makes money at all. Even across the whole world, I think more than 90% of universities cannot recover their patent costs. This is a very short-sighted view. The reason why universities patent is to provide a benefit to industry players. Let's say you have an idea for a drug, then I [the licensee] have to invest a billion dollars, develop the drug. And next day somebody in other country produce the same drug and sell. What is the benefit for me to invest a billion dollars without any protection? Patenting is just the very early part of it [further development of an invention into a product]. The value of a patent is to provide preliminary benefits to industry players in order to justify their investments. That's why it is very important in understanding the whole value chain… If you ask the university to maximize patent utilization by 100%, you will lose a lot of disruptive potential. First, we file the patents to

attract industry players. Second, to keep universities with the freedom to operate in these fields. Third, we compensate our inventors. The last one is to make money." (Anonymous. 2020. Interview with a KTO official. March 12).

The issue raised by the KTO official – that licensing is a primarily money-losing business for many universities globally – has been one that **Newby (2015)** strongly suggested for universities to carefully consider in terms of its risks and implications. As universities are increasingly expected to be more entrepreneurial in their KT/TT activities, there are concerns that universities may do so at the expense of their original missions in research and teaching missions; furthermore, there may also be governance and reputational risks given the potential downside of the universities' new approach. Therefore, **Newby (2015)** has recommended the need for a proper risk management system in this area.

Overall, the findings above bear close resemblance to concerns voiced in existing literature that when universities pay overwhelming attention on patenting and licensing as proxies for KT, there is no guarantee marginal increase of these outputs may lead to commercialization (**Geuna and Muscio, 2009**). Moreover, other works have also demonstrated that when the universities are prematurely focused on protecting their invention with IPR and/or licensing practices, they may forgo the long-term potential of further refining and developing these technologies (**Aghion et al., 2008; Azagra-Caro et al., 2017**).[19] This trend is further compounded by perception gaps that often occur among universities and industries with respect to the use and/or ownership of IP, payment of licensing fees, as well as valuation of university IP (**Crespi et al., 2011; Garnsey, 2007**).

Another insight we found from our interviews with transfer officials is that faculty may patent their inventions for the main purpose of increasing their professional reputation, i.e., adding this achievement to their CVs, and not so much to further pursue commercialization. Relatedly, university professors and scientists tend to file for patents primarily to fulfill internally set output targets that could possibly be attributed to the universities' needs to report KT activities to the UGC. One senior professor, and also an active academic entrepreneur, elaborated his thought in the excerpt below:

"Many professors in Hong Kong, when they file patents, their strategies are not quite correct. I've seen people [academic staff] file patents only in mainland China and Hong Kong, which I think shows a limited mindset, because why not cover the whole world if the invention has huge potential? I think it could be that while we should look at the potential value of these patents, it's difficult to assess [their value]… many professors treat patents as some sorts of deliverables, something to 'deliver upon and check a box'. Again, it's not a correct move. They should look at these IP as their own IP." (Anonymous. 2021. Interview with a professor. January 12, 2021).

Furthermore, universities have been criticized in the past works for being overly rigid in managing and negotiating licensing agreements with industry players (**Geuna and Muscio, 2009**). The authors suggested that universities may need to be more flexible in this matter, as patenting and

licensing only represent a small fraction of knowledge that is actually transferred from the academia to industry. This argument is also aligned with **Azagra-Caro et al. (2017)**, who provide empirical evidence that contribution of emerging technologies to regional development only occur long after the expiry of their patent protection periods, and in spite of their initially low licensing revenues. Furthermore, the authors suggested that open labs that facilitate further development of university-based technological innovations by student teams and start-ups can be one promising approach to enhance universities' KT.

Theme 3: U-I collaboration through co-publications and co-patents

Beyond patents and licenses, other relevant KT indicators are joint U-I co-publications and co-patents. Certainly, co-authorship in scientific publications is not capable of giving a full picture of the complex nature of U-I collaboration, but it has been widely accepted as a standard way to measure the collaboration between organizations due to its various advantages such as invariant and replicable character of such indicator, and accessibility of a large sample that can potentially produce results that are statistically significant (**Abramo et al., 2009**). **Tijssen et al. (2009)** also point out that U-I co-publications can be a universal indicator of universities' degree of collaboration with industry due to the serious difficulties in gathering systematic, complete, and comparable data across different institutional settings. Moreover, it is widely accepted that co-patenting and collaboration arrangements between firms, and in this case between academics and firms, can provide value-creation opportunities, for example, higher future market value for collaborating firms (**Belderbos et al., 2014**). Over time, there has been a rapid growth in the number of outputs in these two areas among all universities, particularly in joint publications. However, when benchmarking these results with those of leading universities at the regional level (e.g., Tsinghua, Todai, SNU, KAIST, NUS), Hong Kong universities are still considered to quite 'lag behind'. Further comparative analysis of the universities in East Asia will be conducted in the future. (Table 2-15**; Figure 2-5 - Figure 2-7**)

Table 2-15 Proportion (%) of publications involving university-industry collaboration

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2009-2018
CityU	3.24	3.13	3.01	3.41	3.49	3.79	3.68	3.14	3.18	4.27	3.47
CUHK	3.74	3.47	3.65	4.09	3.96	4.75	4.93	5.92	5.73	6.10	4.77
HKU	3.08	2.78	3.82	3.78	3.55	3.99	3.61	3.73	3.68	4.44	3.70
HKUST	4.27	5.03	4.71	3.54	4.24	4.56	3.95	4.08	4.72	5.72	4.52
PolyU	2.34	2.32	2.56	2.03	2.86	2.92	2.39	2.72	3.31	3.82	2.83
All 5 uni	**3.28**	**3.20**	**3.50**	**3.44**	**3.59**	**4.02**	**3.76**	**3.99**	**4.12**	**4.82**	**3.85**

Source: Lens.org

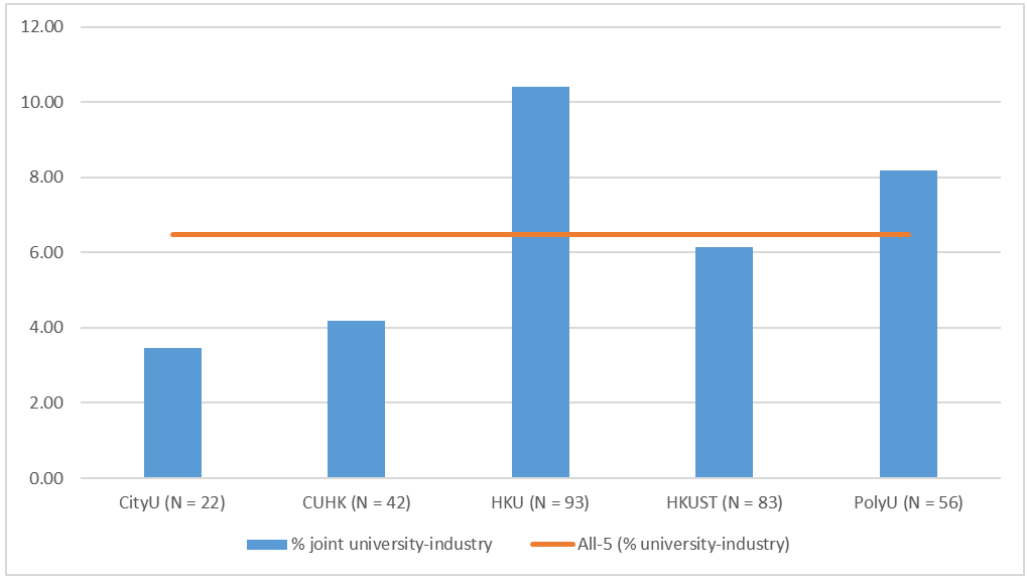


Figure 2-5 Proportion and number of joint university-industry patents by university (2009-2018)
Source: Lens.org

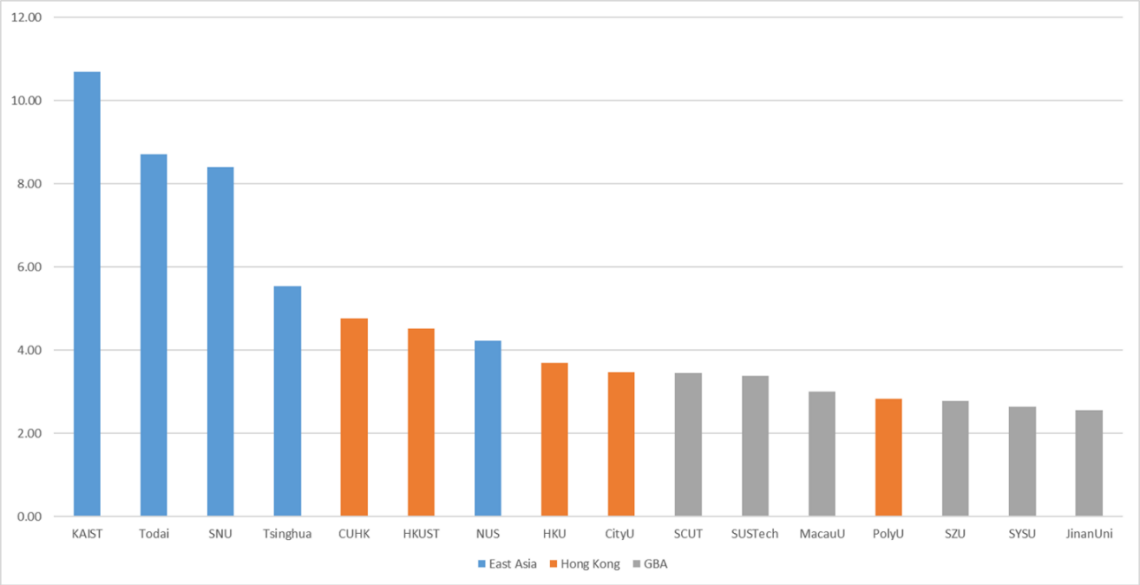


Figure 2-6 Comparison of proportion of joint U-I co-publications across universities in Hong Kong, Greater Bay Area, and East Asia (2009-2018)

Source: Lens.org

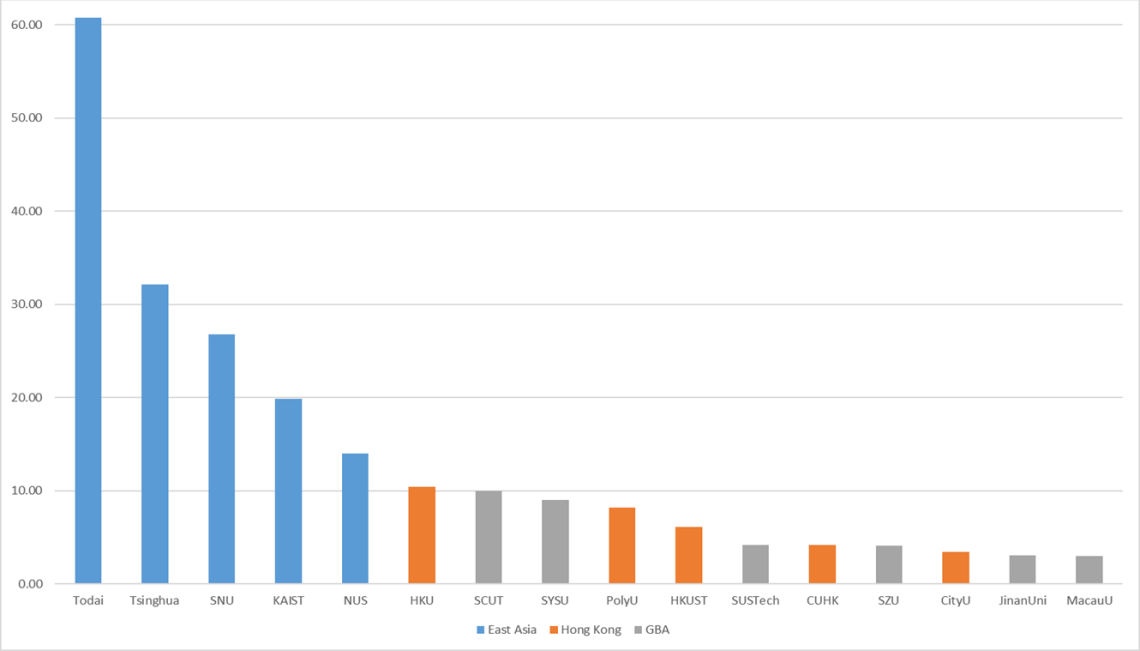


Figure 2-7 Comparison of proportion of joint U-I patents across universities in Hong Kong, Greater Bay Area, and East Asia (2009-2018)

Source: Lens.org

According to **Abramo et al. (2009)**, the reason U-I co-publications for many universities have consistently occupied a low proportion is that these works are less likely to be published in prestigious, high-impact-factor academic journals. The trend seen here might be due, for example, to the universities' preference for research that yields publications in high-quality journals, by which such co-publications may not always suffice. As an illustration, in the latest UAA with UGC, CityU's KPI seemingly pays a lot more attention on publication-related achievements and internationalization rather than TT. While KT, such as consultancies and patent grants, is also included in the assessment criteria for the promotion of faculty, it appears to be given less importance compared to research and teaching. These findings reflect the insights by **Parks et al. (2017)** and **Tsui et al. (2017)** about the tendency of most universities in Hong Kong to follow the approach in this regard, particularly given the existing academic assessment framework.

Overall, for Hong Kong universities, the trajectories for joint outputs in U-I co-publications and co-patents have been primarily positive. However, there are avenues for improvement, particularly in the context of U-I co-publications, which are still below the global annual average of 7% relative to all published journal articles (**Tijssen et al., 2009**).[20] Obviously, more efforts can be done by universities to further incentivize the exploitation of research results through U-I co-publications (**Abramo et al., 2009**), given that this KT indicator has been rated by faculty members as the most frequently utilized channel for U-I collaboration (**Cosh and Hughes, 2010**). The major challenges to be addressed, however, relate to the current incentive structure in academia, which continues to prioritize high-impact-factor-journal publications, whereas studies have shown that U-I co-publications are less likely to be published in top journals (**Abramo et al., 2009**), although they may also lead to significantly higher number of patents, licenses, and spin-offs (**Wong and Singh, 2013**). Issues with sharing ownership over jointly produced IP may also hamper further development of U-I co-patents (**Crespi et al., 2011**).

With regard to comparing and contrasting the use of U-I co-publications versus U-I co-patents, it has been that universities in Hong Kong prefer U-I co-publications as a means of KT to U-I co-patents, given that the disadvantages with the latter approach may exceed the benefits, particularly in terms of IP ownership issues. As quoted by one of our interviewees,

> "[overall] U-I co-patents [in Hong Kong] are very rare. Think of patenting as buying a property for retail. University mandate is teaching and education. Industry mandate is business. If we co-own a 'retail shop' with a company, we have the shares, but the company is the one that does actual operation." (Anonymous. 2020. Interview with a KTO official. November 24.)

While the interviewee's concern about the potential conflicts of interest resulting from such discrepancies is valid, we also note, based on the initial collection of data on U-I co-patenting using Lens.org, that some of the world's most innovative universities, particularly in East Asia,

have a higher proportion of U-I co-patents than in Hong Kong. These issues will be analyzed in an in-depth, comparative analytical perspective in the next phases of this study.

Theme 4: university spin-offs

Of all KT indicators already discussed in the analysis of Hong Kong universities, spin-offs have been singled out as a category that was very actively discussed in the annual KT reports. The rich discussions surrounding this KT category have also been enabled by the availability of financial support mechanisms by the Hong Kong government, notably TSSSU scheme. However, the extent to which spin-offs can contribute to Hong Kong's development remains to be seen, as their economic performance has been rather mixed. In most of the universities studied (as shown in **Figure 2-8** and **Table 2-16**), the net income generated from these economically active spin-off companies has been largely in the red for most of the reporting years.

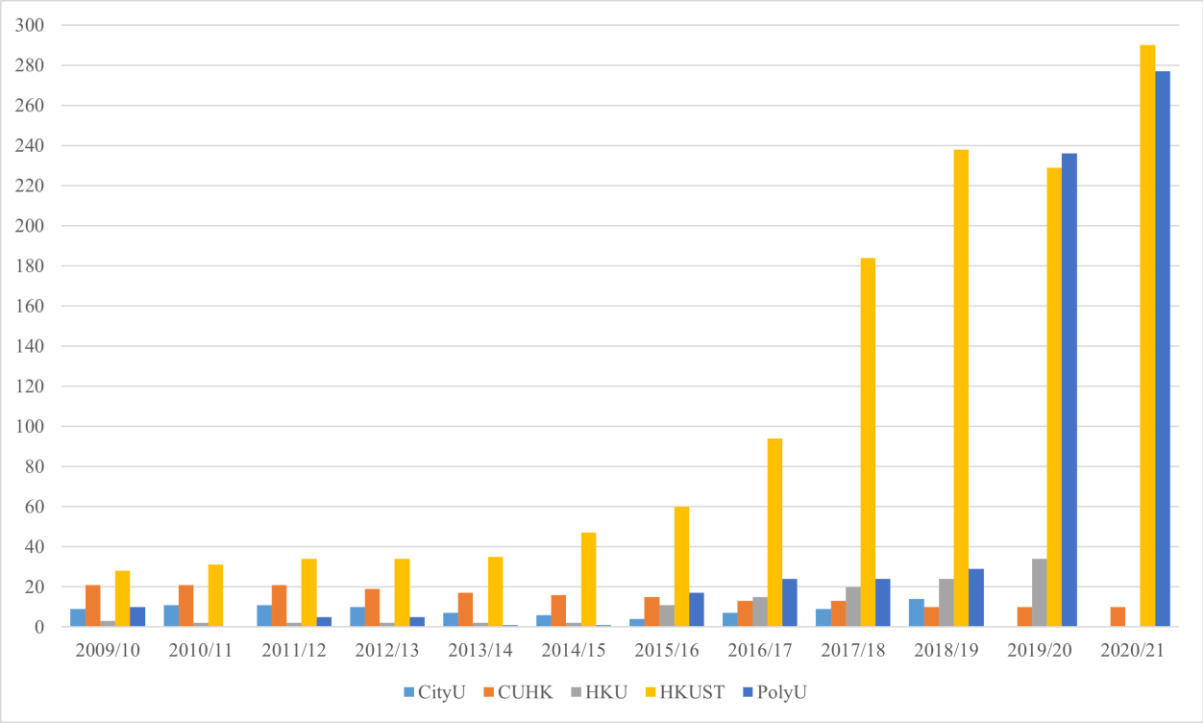


Figure 2-8 Number of economically active spin-offs by university (2009/10 – 2020/21)

Source: University Grants Committee

Table 2-16 Net income (or net loss) from spin-offs (2009/10 – 2020/21, in HKD)

	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15
CityU	-	-280,000	-5,630,000	40,000	930,000	2,500,000
CUHK	14,439,000	9,345,721	-	5,001,006	5,001,006	15,400,000
HKU	775,183	2,383,078	135,000	-581,000	778,000	346,000
HKUST	-	-	-	-	-	-
PolyU	-	-	6,916,000	-389,000	-350,000	-337,000

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
CityU	2,500,000	-	-	-	-	-
CUHK	2,300,000	9,968,505	15,585,610	15,750,000	-8,360,000	10,460,000
HKU	-819,000	-5,230,000	1,110,000	-9,400,000	-55,000,000	-
HKUST	-	-	-	-	-	-
PolyU	-282,000	-63,000	128,000	595,000	657,000	1,160,000

Source: University Grants Committee

Our interviews with KTO officials across the five universities also sheds a light on their concerns over the open-ended definition of 'spin-offs' and 'start-ups' by UGC. In terms of officially reporting the number of economically active spin-offs to UGC, all five universities adopted UGC's formal definition, which is "one that has been established by staff, graduates, or students, and is now operationally independent of the institution".[21] On the other hand, start-ups are defined by UGC as one that is also 'established by staff, graduates, or students, but is operationally dependent on the institution'. Nevertheless, given the open-ended interpretation by the KTOs, internally, each university develops their own internal definition of 'spin-offs'. In some cases, the distinction between spin-off and start-up is along the lines of institutional ownership (e.g. CUHK, PolyU, and HKUST) and who established the company (e.g. CityU and HKU); in other cases, whether these are TSSSU-supported (e.g. CUHK, HKUST, HKU) or not (e.g. CityU and PolyU). The interviewees also shared with us that in order to align with UGC's reporting requirements, the KTOs relied on their own internal definition criteria in counting the number of 'economically active spin-offs' and their income level to be reported back to UGC.

One of our interviewees, a KTO official, indeed highlighted an issue with UGC's definition of 'spin-off', particularly in how the commission defines 'control' (whether in terms of the university

owning shares, or having individiual(s) supervising them, or having someone sit on the company board). Further excerpt is shown in the paragraph below:

"We actually communicated with the government that using [UGC's] definition, this did not really reflect reality on the ground. Plus, we can only report figures that other start-up companies voluntarily share with us (and most of them are money-losing businesses). So the data you see in these reports are mostly meaningless. Say, some universities don't count start-ups that don't license [patents] from them, while others include [the licenses]. I would suggest that we need to follow industry standards when it comes to defining start-ups and spin-offs; the current definition is a bit weird." (Anonymous. 2020. Interview with a KTO official on November 24).

Linking our findings here to the insights from the commercialization sub-section above, we found that the requirements for faculty members to establish spin-offs are stringent. Some universities also made their statements explicit in terms of prioritizing students over faculty members with regard to building early-stage companies. Given such stringent requirements, we observe a tendency for faculty members to prioritize safer forms of academic engagement through active liaison with industry actors (e.g. collaborative research, contract research, consultancy). These patterns may also explain the particularly excellent performance of those universities in these areas of academic engagement, namely: HKUST and PolyU in collaborative research, HKU in contract research, CUHK in consultancy, and CityU in other KT indicators not covered in this report, notably Continuing Professional Development (CPD) courses (details on the universities' performance in other KT indicators are shown in the Appendix).

The insights we obtained from these analyses closely reflect the cautious approach suggested by **Lambert Review (2003)** regarding the importance of not placing excessive quantity-based emphasis on producing such spin-offs. Based on their analysis of KTOs/TTOs in universities across the UK, the authors found that given the highly variable quality of these offices, only a small number of universities – notably top universities represented by Oxford, Cambridge, ICL, KCL, UCL – may generate early-stage companies with maximum chances of success, but most other institutions produce firms with only short-term survival prospects.[22] In parallel with our observation in Hong Kong universities, the authors of this report also recommended that universities' senior administrators prioritize licensing over spin-offs with regard to the faculty members' modes of KT and commercialization.

Nevertheless, as already discussed beforehand, such approach underestimates the limitations inherent in licensing-based commercialization strategies. Given that the primary objective of licensing is to transfer technologies that are of immediate application to industry actors, the technologies of focus are also more likely to be incremental, special-purpose, and already mature (**Gilsing et al., 2010**). Further empirical analysis – primarily in the US – also demonstrates that universities that prioritize licensing income are significantly less likely to produce spin-offs (**Di Gregorio and Shane, 2003**), albeit long-term income from spin-offs is more likely to exceed the income generated from licensing alone (**Shane, 2004**).

The insights above demonstrate that university-generated spin-offs/start-ups may have considerable impact on the local economic development (**Benneworth and Charles, 2005**). As an illustration, **Tartari and Stern (2018)** demonstrated that the presence of top-performing research universities has a very strongly positive and also significant impact on the number and nature of spin-offs that were established within their vicinity. However, their study is limited to the context of universities in the US; our analysis of income figures earned by Hong Kong universities' spin-offs shows that the performance has been rather mixed.. Where the authors have not adequately acknowledged is that certain institutional environments, particularly in Hong Kong, can be a hardly supportive environment for the conducive formation of university spin-offs/start-ups (**Leung and Mathews, 2011**). From interviews with KTO officials, we learned that regional contexts are significant determinants of spin-offs' chances of success – echoing **Sternberg (2014)** – and with respect to Hong Kong's circumstances, a combination of small market size, management skills oriented to short-term rewards, as well as inadequate supporting financial capital may explain why the city's institutional environment has not been highly supportive of university spin-offs (**Leung and Mathews, 2011; Tsui et al., 2017**). Furthermore, given the nascent nature of entrepreneurial ecosystem in Hong Kong, most early-stage start-ups will not directly generate profits (or even revenues) in their first few years of existence.

Despite the challenges imposed by the existing institutional environment, universities can still act as strategic catalysts of local/regional economic development efforts through spin-off formation (**Roberts and Malone, 1991; Benneworth and Charles, 2005; Clarysse et al., 2005**). The big question now, from this point onward, is about how universities perceive the surrounding local environment, and how they can contribute based on their understanding of the localities and their own interests. In regions with fairly nascent entrepreneurial landscape (indicated by few successful technology start-ups and VCs), a high-support, high-selectivity approach has been suggested in nurturing university spin-offs (**Roberts and Malone, 1991**). However, given the considerable amount of resources entailed, this approach is perceived to be more of an aspirational than accessible policy (**Degroof and Roberts, 2004**). What we would suggest for Hong Kong universities to consider, in this regard, is joint efforts to pool resources and build inter-organizational partnerships (e.g. joint incubators) to support university-based start-up companies (**Degroof and Roberts, 2004**), complementing government-initiative infrastructures such as the Science Park.

In addition, universities may also want to concretize their strategic goals when it comes to nurturing these early-stage companies. Existing literature demonstrates there are at least three potential objectives given their approaches (**Clarysse et al., 2005: 1**) focus on as much job creation as possible by focusing on lifestyle-based business areas, e.g. mobile-app start-ups; 2) focus on both maximizing revenues and financial gains – primarily through short-term contract R&D and consultancy services, or; 3) focus on both maximizing revenues and establishment of platform technologies (which, in this case, will be driven by few selected spin-offs, but with the most promising high-growth potential).

In subsequent follow-up interviews with some of the KTO officials, they also shared with us their challenges in obtaining up-to-date information from companies already graduating from the universities' start-up/spin-off incubation programs. This is attributed to very low response rate in follow-up questionnaires sent by the universities' KTOs to these graduated companies (which the interviewees estimated to be only around 4-6%). With ongoing advances in ICT, and the proliferation of web pages in particular, we would suggest that the universities conduct detailed follow-up studies by profiling their company websites and examining their recent news updates there. Organizational analysis on the basis of webpages has been shown to be a promising analytical method (**Powell et al., 2016**) in determining the long-term survival of these entities.

Theme 5: entrepreneurial ecosystem development strategies

In parallel with the rising KT-oriented phenomenon is also the incorporation of the 'entrepreneurial university' concept that the higher-education institutions in Hong Kong have been increasingly paying attention to in recent years. Across all five universities, we found that a considerable amount of supporting infrastructure has been built in recent years in order to support efforts at entrepreneurial ecosystem development, e.g. Innovation Commons in CityU, Pi Centre in CUHK, House of Innovation in PolyU, The BASE in HKUST, and iDendron in HKU. Proximity to government-built innovation-supporting infrastructure has also helped, as demonstrated by the presence of joint co-working spaces and/or incubation programs in Innocentre (which is adjacent to CityU), HKSTP (sharing the same MTR station as CUHK), and Cyberport (which has collaborative programs with HKU).

Interestingly, our analysis of annual KT reports again demonstrates that these universities seemingly prioritize the development of entrepreneurial ecosystems to be mainly pioneered and led by students. Such tendency may be related to restrictions and/or lack of encouragement that faculty members face in establishing spin-offs. One example that highlights the universities' strong support in this regard is the Proof-of-Concept funding scheme, which is offered in most of the universities (except HKU).

Nevertheless, the current emphasis on promoting student-led ecosystems may lead to concerns that students lack real-world experiences, strong credentials, as well as adequate guidance, particularly in dealing with entrepreneurship-related challenges (**Pirnay et al, 2003**). As we have observed from the annual reports, efforts to build entrepreneurial ecosystem are mainly centered on educational activities, e.g. courses, workshops, seminars, and competitions. While engaging students in these areas positively influences them to have greater propensity to start new firms in the future, there is no guarantee that these students will *eventually* take actions to build them (**Bergmann et al., 2016**), especially in their immediate, post-graduation future. There has also been no conclusive evidence that enlarging the participation of students in entrepreneurship initiatives results in a higher number of start-ups (**Algieri et al., 2013**).

We suggest that the universities consider – in equal terms – multiple pathways in driving the growth of such ecosystems (**Boh et al., 2012**).[23] Moreover, it would be essential for universities to

constantly take into consideration contexts specific to the universities and the surrounding region when it comes to building entrepreneurial ecosystems (**Siegel and Wright, 2015**), which also encompass industrial, technological, organizational, institutional, policy, social, and space-time dynamics (**Autio et al., 2014**).

Some of our interviewees have also suggested 'entrepreneur-in-residence' programs (allowing serial entrepreneurs to work with the universities for a fixed period of time to collaborate with university scientists to establish companies and 'exit' the universities), as exemplified by the PolyU illustration. One of our interviewees has, indeed, suggested to the Hong Kong government about the need for support schemes to enable serial entrepreneurs assisting early-stage academic entrepreneurs. Nevertheless, at this stage, the government does not provide any resources to support this scheme. Through comparative analysis of such programs in other universities outside Hong Kong, we hope to draw useful lessons for the stakeholders here for further consideration.

2.5 Conclusions and policy recommendations

Key message 1: there remain competing interests over the need to promote KT and prioritize academic research

The KT-versus-academic-excellence debate has been well-documented in many higher-education institutions globally, particularly in the five universities in Hong Kong. The challenge, in particular, has been centered on university administrators' efforts in balancing the needs to produce outstanding research (which is relevant for university performance assessments and international rankings) and impactful research (which is vital for addressing economic and societal needs of the surrounding regions and relevant for KT). Further studies will be undertaken to investigate appropriate incentive structures that support faculty members to undertake research that is both outstanding and also impactful.

Key message 2: there is a need to comprehensively revamp the existing faculty assessment system in Hong Kong

At present, faculty evaluation systems in these five universities continue to place significant weightings primarily on research – in particular publications in high-impact academic journals, teaching, and service to a lesser extent. The inclusion of KT contribution for performance assessment, however, has been largely minimal. This finding is particularly striking given the increasing attention university administrators emphasize in promoting KT activities among the academic staff. These insights underscore the need for universities to allocate bigger portions of the faculty evaluation system components to assess faculty participation and performance in KT indicators.

Key message 3: Hong Kong universities should venture beyond patenting and licensing for avenues of commercialization

At present, most universities in Hong Kong continue to prioritize patenting and licensing as the major avenues for commercialization. Nevertheless, their subsequent performance in licensing remains to be desired. It is important for the universities, especially the KTOs, to consider strategies beyond patenting and licensing for commercializing university inventions. One suggested possibility is for the KTOs to place equal importance on both formal and informal means of commercializing university technologies through strategies such as expanding platforms for networking with industry actors, as well as establishment of open laboratories for other university stakeholders and prospective industry players in further refining and developing faculty members' university inventions.

Key message 4: steady increase of U-I co-publications and co-patents, but Hong Kong universities need to continue catching up with other leading universities

U-I co-publications and co-patents have been shown to be useful proxies for benchmarking universities' degree of knowledge exchange – both tacit (publications) and codified (patents) – with the industry actors. Over time, all five universities in Hong Kong have been increasing their participation in these two indicators, but when benchmarking their performance with other leading universities in East Asia, these universities continue to lag behind. These findings suggest that the current circumstances enabling U-I collaboration in these aspects can be further enhanced and subsequently improved, all the while considering the regional contexts of the firms' absorptive capacities. Future research will further explore the insights by other globally leading universities and lessons that will be particularly relevant for the universities in Hong Kong to consider. University administrators and KTO officials may also consider the use of these metrics in evaluating their overall KT performance.

Key message 5: strategies for university spin-offs need to be reviewed to allow these to adequately contribute to economic development in Hong Kong

Spin-offs have been discussed as a promising commercialization strategy for university inventions, but the extent to which they can contribute to local economic development is strongly contingent on the region-specific circumstances. Specific to Hong Kong, spin-offs have not been major contributors to the city's economic development. These findings could be linked to the relatively nascent nature of innovation and technology ecosystem in Hong Kong. These insights call for additional research in the future to investigate factors that support and inhibit spin-offs' contribution to local development processes. Our findings also shed light on the need for universities to revisit their strategies on what types of university-based companies they would like to support in accordance with the local conditions.

Key message 6: entrepreneurial ecosystem development strategies should not be primarily driven

by students

At the present form, university strategies to build entrepreneurial ecosystems appear to be designed to be pioneered and led primarily by students. We argue that students alone cannot be the primary drivers of entrepreneurial ecosystem development. A holistic perspective that incorporates the roles of other university stakeholders (particularly faculty members, research staff, university administrators, KTO officials, and alumni) – or even non-university actors (e.g., serial entrepreneurs) – is also no less vital in driving these ecosystem development efforts.

3 Task 2 - Comparative Analysis of Innovative Universities

3.1 Introduction

This task looks to good practices in top innovative universities overseas on mechanisms, patterns, policies, and measures to enhance the roles of public universities in the development of global innovation and technology hubs, which is the aim of Phase 2 of the project. Identifying good practices in both East Asian and non-East Asian contexts can generate valuable lessons for Hong Kong universities. Moreover, this facilitates the development of a policy framework and a roadmap for strengthening the roles of public universities in Hong Kong in fostering the development of a global innovation and technology hub in the Greater Bay Area, leading to actionable policy recommendations to local and regional innovation and policy actors.

The selected universities for Phase 2 came from the GBA outside Hong Kong, and from the Yangtze River Delta, the Beijing-Tianjin-Hebei region, East Asia outside China, the Middle East, Europe, and North America. As mentioned in the research proposal, to guide the selection of the universities, we referred to Reuters' Ranking of the World's 100 Most Innovative Universities in 2018, the Guangdong-Hong Kong-Macau University Alliance (thereafter the Alliance) and the Association of Pacific Rim Universities (APRU).

Roles of universities in developing technology hubs

We conceptualized the role of universities in the development of innovation hubs into four types: knowledge production role, technology transfer role, social development role, and platform/network development role. While these roles of universities in knowledge transfer are different from each other in terms of pathways and effects, they are not mutually exclusive. Rather,

universities may be shifting back and forth from one role to another or simultaneously performing several role-types according to institutional factors such as the availability of resources, individual universities' strategies and goals, and characteristics of the ecosystem where universities are situated.

The knowledge production role of universities is characterized by an emphasis on conventional teaching and research functions of universities. In carrying out its primary function of teaching, universities create a resource base of people, skills, and knowledge for institutional building at the local and regional levels. **Chatterton and Goddard (2000)** point out that learning and teaching activities have become more diversified, going beyond simply classroom teaching to more interactive and experiential approaches such as project work or work-based learning, much of which is location-specific. Moreover, while academics and scientists in universities tend to locate their research work within the research agenda of an international scholarship, there have been calls for increasing locally and regionally-based teaching and research. Some large comprehensive universities have the capacity to develop a teaching research capacity with a strong global perspective and maintain a resource base to engage and respond to local and regional development needs.

The enactment of laws of the Bayh-Dole Act 1980 in the US legitimized the technology transfer activities that some universities had already been actively engaged in and facilitated and encouraged knowledge transfer collaboration with industry in many other universities (**Kenney and Goe, 2004**). Prior to Bayh-Dole Act, the government retained ownership of inventions that resulted from federally funded research, which accounted for a large majority of research funding in universities. The policy was based on the principle that no single institution should enjoy exclusively the benefits derived from publicly-funded research, and therefore only nonexclusive licenses to patents were granted. However, this made academic inventions unattractive to companies because of the high risks involved, resulting in difficulty finding willing licensees to their patents. For instance, in 1978, of the 28,000 patents it had acquired, only less than 4% of these were licensed to companies (**Loise and Stevens, 2010**). Moreover, the government did not have connections with inventors whose tacit knowledge was necessary to continue developing the nascent invention and get it out in the marketplace. The lobbying of research universities already engaged in entrepreneurialism was crucial in the passage of the Bayh-Dole Act. Many argued that the Act was "as much a cause as an effect" **(Mowery and Sampat, 2005: 119)** of the growth of entrepreneurial activities in several universities, including UCB, beginning the 1960s. Bayh-Dole Act gave universities in the US the latitude to exploit the intellectual property rights (IPR) of their research, a significant proportion by which was funded by the federal government (**Grimaldi et al., 2011**). The passage of the law was followed by a wave of universities establishing their own local knowledge transfer offices. Technology transfer, and more specifically, the commercialization of university research in the form of licensing, patents and spin-offs, becomes a core mission of most universities along with traditional functions of teaching and research. The intended goal of the entrepreneurial function is to contribute to the economic growth of regions

through the creation of new firms, the renewal of existing firms, the evolution of clusters, job creation, and the attraction of new talent and capital (**Power and Malmberg, 2008; Trippl et al., 2015**). While there is a growing trend among universities to foster economic development and innovation within their local community, the traditional research and teaching are not only not diminished, but universities seek more funding to support efforts to upgrade the quality of these conventional functions (**Youtie and Shapira, 2008**). Indeed, it is argued that the research universities' ability to make a significant economic and societal impact is predicated on high-quality research (**D'Este, et al., 2018**).

Nevertheless, the weaknesses inherent in the narrow entrepreneurial roles, which all too often have focused on income-generating categories and promotion of economic benefits, have raised calls for universities to consider broader developmental roles with economic as well as social impacts (**Abreu and Grinevich, 2013; Arbo and Benneworth, 2007**). Less formal activities that generate social innovation which in turn bring about the advantage of social welfare, are common in disciplines such as social science, the creative arts, and the humanities. Nevertheless, informal channels of knowledge transfer are often overlooked by technology transfer offices and scholars in innovation studies and policymakers, which tend to promote commercialization in fields that can maximize financial gains for institutions and protect inventions through formal methods such as patents. Universities have increasingly encouraged the involvement of all faculty, regardless of academic discipline, in knowledge transfer, recognizing that innovation in less formal activities can also have both economic and social value for academics as well as external stakeholders. In addition, universities adapt their teaching and research to meet the industrial as well as the societal needs of their localities, setting the agenda for community development and working with other stakeholders or networks of actors to solve community challenges (**Chatterton and Goddard, 2000; Gunasekara, 2006**). As **Abreu and Grinevich (2013: 410)** put it

"just as with social entrepreneurship, academic entrepreneurship can encompass activities that result in an increase in social welfare, and lead to positive organisational or societal changes, in addition to achieving financial rewards for the entrepreneur."

The decision on the part of the university to undertake a social development role may depend on several factors such as the age and type of university, the regionalization of the higher education system, the nature of the region, regional identity, and networks (**Benneworth, 2013; Boucher, Conray and Van Der Meer, 2003; Trippl et al., 2015**)

The fourth type of university's role in advancing innovation hubs is the platform/network development which involves the scaling up of technology and innovation hubs. This requires a high level of integration and coordination of key players in innovation ecosystems, including those outside the hubs. Under the platform/network development type, through their programs, organizational units, and institutions that promote entrepreneurship and innovation, universities provide platforms and networks for interactions among key players in government and industry in innovation activities (**Etzkowitz and Leydesdorff 1997; Etzkowitz et al. 2000; Mars and**

Hoskinson, 2010). Thus, the platform/network development function of universities emphasizes, among others, the boundary spanning roles of organizations that help connect universities with elements in the environment in which both operate and interact. Boundary spanning roles are carried out by technically competent individuals who develop a wide range of networks inside and beyond the organization, such as the university. They facilitate links between researchers and scientists with innovation actors beyond the university such as VCs, entrepreneurs, and industry companies. Moreover, global platforms for knowledge transfers tap into innovation resources, such as talents (**Wong et al., 2011**) and patents for IP-bundling to enhance the value of patents (**Siegel et al., 2003**), outside the hubs they are located.

Task 2 set out to systematically collect information from world-leading innovative universities with the aim of identifying regional and global good practices with significant relevance for Hong Kong universities. Moreover, the comparative analysis of this task was intended to identify the factors that contribute to the innovative universities' outstanding performance in innovation, which can illuminate current practice and deficiencies in Hong Kong and contribute to the formulation of policy recommendations appropriate in the local context. Informed by existing literature, the design of the comparative analysis of Task 2 considered the relationship between government, universities, and universities' performance. Chapter 3 provides further details of faculty survey that we conducted for a select group of universities in Hong Kong, as well as in East Asia, Europe, North America, and Israel, with the purpose of highlighting variation in perception about universities' roles in promoting knowledge/technology transfer activities.

The comparative analysis is also informed by case studies and narratives of individual universities outside Hong Kong, some samples of which are provided in Section 3.4. The narratives of the individual universities outside Hong Kong reflect some of the features of one or more of the four roles mentioned above of universities. The narratives also highlighted some of the other outstanding characteristics – though not necessarily unique to these universities – we found in individual universities. For example, some of the features we found worthy to highlight are the decentralized operations of knowledge transfer in KU Leuven which resulted from the 'professor-run' nature of the university operations as a whole; the existence of a variety of licensing products prior to the signing of a full license in the University of Washington Seattle the enterprising composition of the Tel Aviv University's technology transfer office, which include seasoned VCs and serial entrepreneurs. Further details of unique features of individual universities are provided in Section 3.4.

The narratives were informed by the logic model of inputs, process, and outputs/outcomes, similar to what was done in the Phase 1 preliminary report. Thus, these outstanding features relate to four types of factors. The first type includes factors pertaining to the relationship between universities and their governing entities, for example, the governing structure, funding arrangements, and regulations. The second type includes the organisational factors at the university level, such as leadership, missions and goals, culture and norms, and incentive systems. The third includes activities related to innovation, such as technology transfer, university-industrial collaboration,

and entrepreneurial development. The last type relates to output/outcome indicators, such as papers and citations, patents and licenses, new products, spin-offs, consulting, entrepreneurs, and royalty shares.

The case studies also included findings and insights collected from semi-structured interviews with technology transfer officials and faculty in relevant universities. Overall, the analysis in Sections 3.3 and 3.4 is a useful source for learning and meaningful formulation of initial policy recommendations (see Sections 3.5).

3.2 Survey Analysis

To identify the regional and global good practices that could be applied for universities in Hong Kong, we used a survey method to systematically collect information from selected world-leading innovative universities. The proposed survey was targeted to senior academic leaders and faculty members with the level of Research Assistant, Assistant, Associate and Full Professors from all Science-, Engineering-, and Medicine-related disciplines at the universities. We also conducted the survey with faculty members from Social Science-related disciplines, such as Business, Economics, Political Science, Psychology, and Sociology. The comparative analysis of faculties' responses will reveal the factors contributing to innovative universities' outstanding performance in innovation and help identify the gap between Hong Kong universities and leading innovative universities. For the purpose of the comparative analysis, we have compared the six local universities selected in GBA with the universities from East Asia outside China (namely Japan, South Korea, and Singapore), Middle East (Israel), Europe (Belgium and United Kingdom), and North America (United States). Both East Asian and non-East Asian contexts can generate useful lessons for Hong Kong universities regarding their innovation and technology hub development efforts. For reference, we reproduced below the 16 universities from 5 regions selected for the project (Table 3-1).

Table 3-1 Universities chosen for comparative analysis of research universities and innovation hubs

Region	**University Name**	**APRU**	**Reuters' Ranking, 2019**
GBA	City University of Hong Kong	No	Not included in top 100 world Innovative universities
	The Chinese University of Hong Kong	No	
	The Hong Kong Polytechnic University	No	
	The Hong Kong University of Science and Technology	No	
	The University of Hong Kong	No	
	University of Macau	No	
	Lingnan University	No	
East Asia outside China	KAIST	Yes	34
	National University of Singapore	Yes	58
	Seoul National University	Yes	29
	University of Tokyo	Yes	26
Europe	Imperial College London	No	10
	KU Leuven	No	7
Middle East	Tel Aviv University	No	91
North America	University of California Berkeley	Yes	13
	University of Washington Seattle	Yes	5

3.2.1. Survey design

A survey instrument was developed using a tailored design method (Dillman 2011), which combines a set of procedures for conducting successful, self-administered surveys that produce high-quality information and ensure high response rates. The preparation of the questionnaire took several months, from February 2021 until June 2021, and included the analysis of the existing survey instruments, a pilot survey, and several internal discussions with HKUST professors, project co-investigators, and project advisors. After several iterations based on generated feedback, the developed questionnaire included questions for the faculties from STEM-related academic areas and faculties from social sciences, businesses, and humanities domains. The difference in questions in these two academic streams is that some of the questions for non-STEM respondents were skipped, as technology transfer-related questions were relevant only for STEM-related faculty members. The survey was implemented online through the Qualtrics, a survey software tool that allows to build a personalized survey design and to collect more quality data. Before the official launch of the survey, a pilot survey was carried out among professors and researchers at HKUST, where the respondents were encouraged to provide comments. We obtained 14 responses during the pilot stage with the recommendations regarding each question that were incorporated into the design of the final version.

3.2.2. Content of the survey

The final version of the survey includes five sections. The respondents can choose the survey relevant to their academic expertise (See Appendix 1 for the survey instruments: Survey 1 – for STEM professors and Survey 2 – for non-STEM) in the first part of the survey that mainly includes the general information about the respondent, his/her position, teaching and administration obligation at the university. The second part of the survey is related to the factors pertaining to the relationship between professors and funding arrangements. The third part includes the questions about the involvement in knowledge transfer activities. The fourth section incorporated questions regarding professors' motivation to be involved in technology transfer. A good number of questions from ENTRE-U scale design (**Kalar and Antoncic 2015; Todorovic, McNaughton, and Guild 2011**), a comprehensive tool for measuring the entrepreneurial orientation of universities, were also included. The fifth section is dedicated to questions on the barriers in university-industrial collaboration, entrepreneurial development, university regulations and policies that the professors have encountered. The final part is optional and includes one open question about any additional information that was not covered by the questionnaire. Here, we also asked the respondents to provide comments and/or feedback on the survey, the overall state of knowledge/technology transfer practices in their universities, and other relevant matters.

3.2.3. Data collection and sample size

Before the survey distribution, the research team manually collected emails of faculty members from the selected universities from the official university websites. The total number of the survey population consisted of 15,306 professors (all ranks), the details of which were elaborated as follows: 4,527 at six universities in the GBA region, 3,455 at four East Asia universities, 5,979 from the three universities in Europe and Middle East, and 1,345 from two universities in the United States, the full list by which was shown in Table 3.1.

The survey was administered in July-August 2021. Respondents received a request through email to complete an online questionnaire through the Qualtrics with the deadline stated. To avoid any possible problem due to the confidentiality of information from the professors, we highlighted in the beginning of the survey that the data would be collected in an anonymous manner.

We sent the survey invitations in batches for better management of the process, with the first batch sent to STEM-related faculty in mid-July. The invitation included an introduction email from the core research team members of the project, endorsing the study. To improve the response rate, we made a follow up email after 2 weeks with the reminder to fill in the survey for those who still did not do this. In the second batch on early August, we distributed the questionnaire for non-STEM professors, followed by an email reminder sent in mid-August. We obtained 20 failure messages indicating that email addresses were invalid or our message could not be sent, and 3 emails from the respondents that indicated they have changed their places of work. Thus, our usable population of respondents was reduced to 15,283 Professors.

Finally, we received 1,313 responses in total (or 8.59 % of the usable population). After excluding incomplete responses, our final sample consists of 1284 research scientists who fully completed the questionnaire, or 8.4 % of the usable population of which 764 at GBA universities and one from Macau, 294 at four East Asia universities, 112 from the universities in the EU and 69 from Middle East, and 44 from the two USA universities.

3.2.4. Full Sample

Table 3-2 presents the characteristics of 1283 respondents of this survey. Among all of the respondents, the majority are male (80.4%), from STEM field (66.2%), having teaching obligations (95.2%). About 38.4% are professors, 25.0% are associate professor, 27.4% are assistant professor, and the rest of 9.2% are mainly research assistant professors. Around half (49.2%) of the respondents have administrative positions. Looking into the respondents in different regions, the percentage of respondents that is full professor is always the largest except for universities in GBA area. In GBA, respondents who are ‘assistant professors’ account for the largest percentage at 36.1%.

Table 3-2 Characteristics of respondents

	East Asia		EU		GBA		Middle East		North America		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Field												
STEM	259	88.1	81	72.3	423	55.4	50	72.5	36	81.8	849	66.2
SOSC	35	11.9	31	27.7	341	44.6	19	27.5	8	18.2	434	33.8
Title												
Assistant Professor	59	20.1	6	5.4	276	36.1	4	5.8	6	13.6	351	27.4
Associate Professor	80	27.2	12	10.7	208	27.2	15	21.7	6	13.6	321	25
Others	5	1.7	26	23.2	67	8.8	19	27.5	1	2.3	118	9.2
Professor	150	51	68	60.7	213	27.9	31	44.9	31	70.5	493	38.4
Gender												
Female	24	8.4	19	17.1	171	23.4	19	27.9	10	22.7	243	19.6
Male	263	91.6	92	82.9	561	76.6	49	72.1	34	77.3	999	80.4
Teaching obligations												
No	11	3.7	12	10.7	31	4.1	5	7.2	3	6.8	62	4.8
Yes	283	96.3	100	89.3	731	95.9	64	92.8	41	93.2	1,219	95.2
Administrative position												
No	168	57.1	48	42.9	387	50.8	28	40.6	20	45.5	651	50.8
Yes	126	42.9	64	57.1	375	49.2	41	59.4	24	54.5	630	49.2
No. of Universities	4	25.0	2	12.5	7	43.8	1	6.3	2	12.5	16	100
Total	294	22.9	112	8.7	764	59.6	69	5.4	44	3.4	1,283	100

Table 3-3 presents the mean value of answers to different survey questions. Overall, the major funding sources received by the respondents is domestic government funding, of which 84.9% of respondents received. The second major funding source is the industry funding sources from companies, and 42.8% of respondents received such funding. As for the adequacy of the funding sources, 66% of respondents think the domestic government funding is adequate, and 49.9% thinks the industry funding is adequate. We also found that 30.5% of respondents believe difficulties of building linkages with industrial organizations is a big barrier.

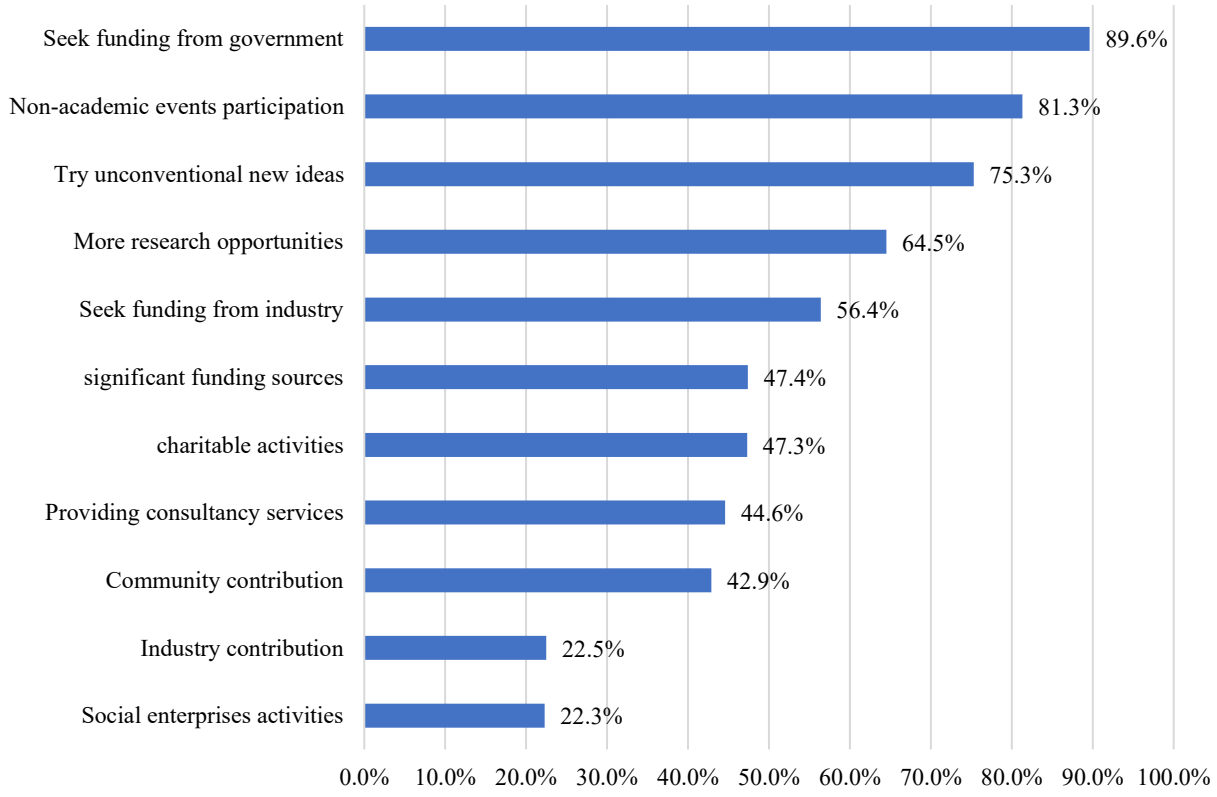


Figure 3-1 Percentage of respondents agree the statements about benefits of knowledge transfer activities

Figure 3-1 shows the percentage of respondents agreeing with the statements about benefits of knowledge transfer activities. The majority (89.6%) of respondents agree with the statement that the knowledge transfer activities help them to seek funding from the government research funding agencies. And 81.3% thinks knowledge transfer activities bring opportunities for the respondents to participate in professional non-academic events. In addition, over three-quarters of the respondents (75.3%) believe that engagement in knowledge transfer allows them to experiment with novel research ideas. With regard to the benefits for industry, however, the results are mixed. Only 56% of respondents agree with the statement that knowledge transfer allows them to seek additional funding from industries. Furthermore, even fewer (22.5%) of them think these activities contribute to the industry. Respondents' perception about how knowledge transfer can enhance universities' social development role is also fairly low: less than 50% of them believe knowledge transfer helps them to enhance charitable activities (47.3%) and contribute to the community

(42.9%). And only 22.3% agree that the knowledge transfer activities help them to be involved in activities with social enterprises.

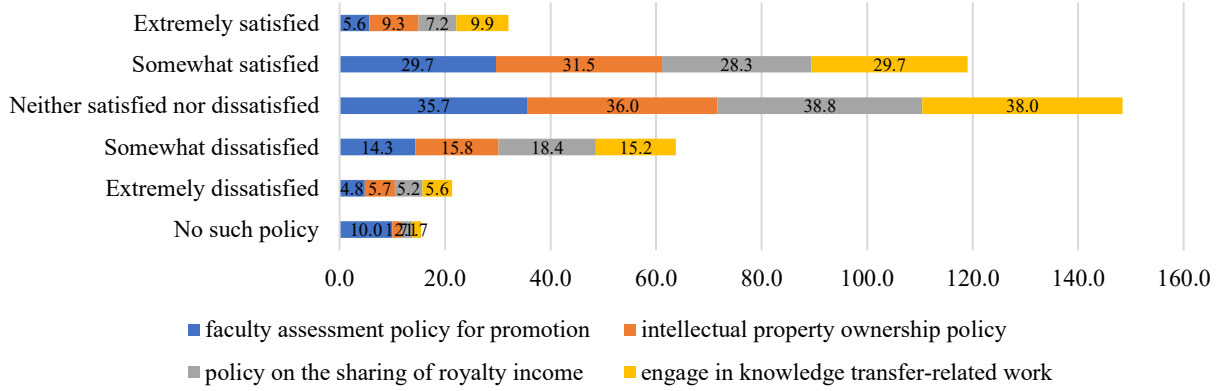


Figure 3-2 Satisfaction level with different policies

Figure 3-2 shows the score of satisfaction of various university policies. We use a six-scale measurement of satisfaction in our survey: 0-No such policy; 1-Extremely dissatisfied; 2-Somewhat dissatisfied; 3-Neither satisfied nor dissatisfied; 4-Somewhat satisfied; 5-Extremely satisfied. From the results we found that some of the respondents think the all of these policies neither satisfied or dissatisfied. And 10% of respondents said there was no such policy in their university with regard to faculty assessment policy for promotion.

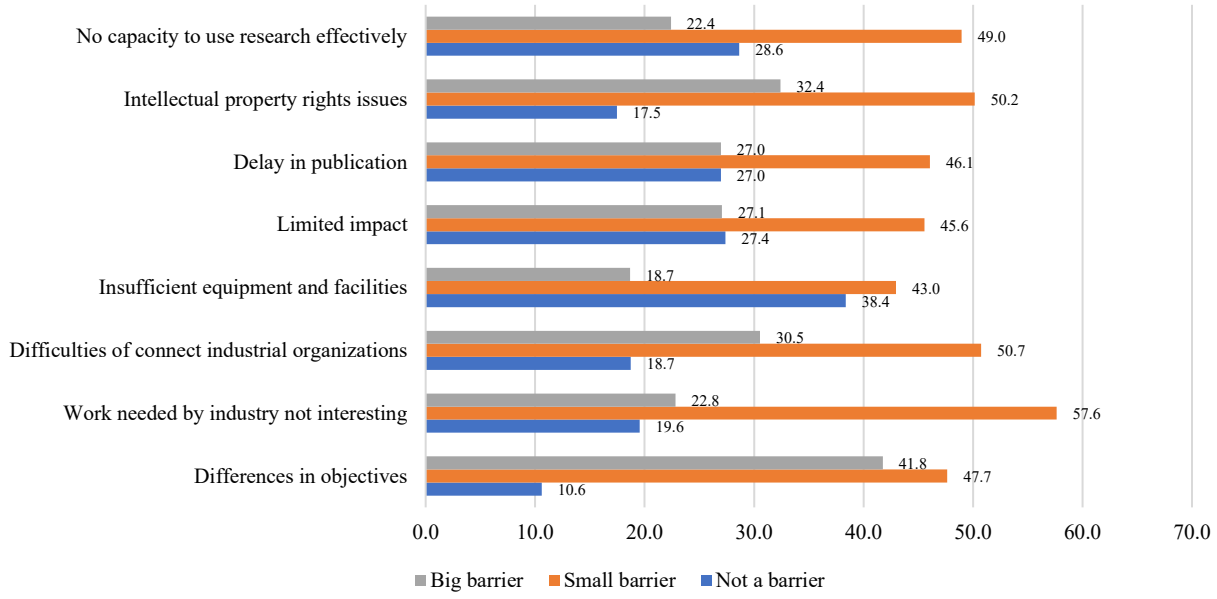


Figure 3-3 Barriers for engagement with industry

According to Figure 3-3, among all different barriers, half of the respondents think these are small barriers. According to the results, the biggest barrier is differences in objectives between industry and academia, followed by intellectual property rights issues and difficulties of getting in touch with relevant industrial organizations. Much fewer people think insufficient equipment and facilities can be a barrier for engagement with industry. Interestingly, differences in objectives between industry and academia appear to be among the biggest barriers, as indicated by 41.8% of respondents who opted "big barrier" for this category, the biggest among all 8 barriers listed. Another no less significant barrier relates to intellectual property (IP) issues, in which 32.4% of respondents perceive it as a big barrier.

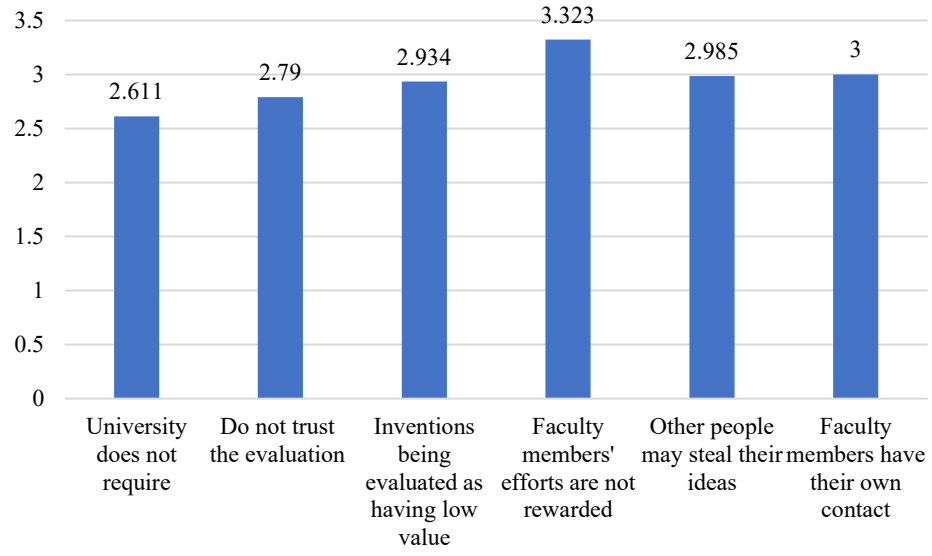


Figure 3-4 Reasons not to disclosure inventions

Figure 3-4 shows the reasons not to disclosure inventions. The most significant reason according to the survey results is that faculty members' efforts are not rewarded. People also regard "inventions being evaluated as having low value" and "other peoples may steal their ideas" as the reasons that they decide not to disclose their inventions. We use a five-scale measurement of agreement in our survey: 1-Strongly disagree; 2-Somewhat disagree; 3-Neither agree nor disagree; 4-Somewhat agree; 5- Strongly agree. We calculate the average number of their answers. Among all reasons, "faculty members' efforts are not rewarded" has the highest average score, followed by "other people may steal their ideas", and "inventions being evaluated as having low value".

Towards two types of support from universities' technology transfer office, more people are more satisfied with administrative support than they are with marketing support.

Table 3-3 Distribution of responses across different groups

	Field		Gender		Title			Teaching obligations		Administrative position		Total	
	STEM	SOSC	Female	Male	Assistant Prof	Associate Prof	Professor	Yes	No	Yes	No	N	mean
Funding source													
Domestic Government	0.886	0.776	0.806	0.857	0.786	0.918	0.910	0.85	0.824	0.881	0.817	1185	0.849
Industry	0.548	0.188	0.328	0.451	0.248	0.415	0.604	0.422	0.574	0.51	0.348	1076	0.428
Private Sources	0.248	0.302	0.287	0.258	0.190	0.287	0.318	0.268	0.25	0.335	0.203	1017	0.267
International Sources	0.306	0.358	0.323	0.319	0.226	0.324	0.402	0.319	0.435	0.389	0.261	1058	0.324
Adequacy of funding source													
Domestic Government	0.648	0.682	0.633	0.669	0.643	0.626	0.704	0.659	0.685	0.651	0.669	1199	0.660
Industry	0.547	0.398	0.475	0.502	0.428	0.457	0.588	0.491	0.647	0.495	0.502	1053	0.499
Private Sources	0.365	0.418	0.391	0.378	0.421	0.34	0.452	0.382	0.413	0.388	0.38	993	0.384
International Sources	0.456	0.489	0.477	0.465	0.399	0.418	0.545	0.461	0.592	0.454	0.481	1031	0.468
Knowledge transfer benefits													
Industry contribution	0.232	0.212	0.198	0.233	0.125	0.252	0.298	0.221	0.308	0.272	0.177	1120	0.225
Seek funding from industry	0.666	0.363	0.463	0.589	0.513	0.556	0.619	0.562	0.615	0.614	0.513	1125	0.564
Community contribution	0.442	0.405	0.404	0.44	0.212	0.459	0.582	0.431	0.392	0.513	0.344	1120	0.429

Seek funding from government	0.927	0.834	0.847	0.91	0.878	0.901	0.917	0.897	0.865	0.908	0.884	1132	0.896
Providing consultancy services	0.45	0.44	0.406	0.462	0.276	0.505	0.551	0.447	0.431	0.529	0.362	1120	0.446
charitable activities	0.441	0.537	0.555	0.456	0.341	0.518	0.511	0.472	0.5	0.558	0.387	1114	0.473
Social enterprises activities	0.179	0.309	0.271	0.211	0.174	0.254	0.239	0.22	0.269	0.284	0.16	1109	0.223
Non-academic events participation	0.829	0.782	0.822	0.809	0.736	0.857	0.839	0.812	0.84	0.858	0.767	1127	0.813
More research opportunities	0.634	0.665	0.654	0.642	0.620	0.698	0.634	0.643	0.673	0.692	0.596	1128	0.645
significant funding sources	0.507	0.407	0.432	0.484	0.405	0.498	0.501	0.469	0.577	0.508	0.439	1125	0.474
Try unconventional new ideas	0.845	0.572	0.664	0.773	0.708	0.779	0.778	0.752	0.788	0.767	0.74	1123	0.753
Informal network contribution													
Create collaboration with industry	3.752		3.807	3.739	3.788	3.736	3.745	3.76	3.628	3.777	3.73	727	3.752
Cooperation in research	4.102		4.06	4.105	4.038	4.043	4.151	4.104	4.07	4.219	3.997	724	4.102
Barriers													
Differences in objectives	1.312		1.342	1.31	1.437	1.327	1.253	1.315	1.262	1.297	1.326	680	1.312
Work needed by industry not interesting	1.033		1.051	1.034	1.071	1.075	0.988	1.032	1.049	0.976	1.086	675	1.033

Difficulties of connect industrial organizations	1.118	1.19	1.109	1.218	1.137	1.088	1.123	1.048	1.162	1.077	678	1.118
Insufficient equipment and facilities	0.803	0.782	0.803	0.796	0.868	0.770	0.806	0.762	0.828	0.779	675	0.803
Limited impact	0.997	1.051	0.978	1.303	1.138	0.800	0.998	0.976	0.884	1.103	676	0.997
Delay in publication	1	1.114	0.979	1.141	1.166	0.872	0.997	1.048	0.982	1.017	675	1
Intellectual property rights issues	1.149	1.278	1.137	1.155	1.152	1.136	1.15	1.146	1.183	1.117	676	1.149
No capacity to use research effectively	0.938	0.873	0.94	0.979	1.062	0.887	0.94	0.905	0.899	0.974	674	0.938
Reasons not to disclose inventions												
University does not require	2.611	2.429	2.638	2.723	2.662	2.555	2.61	2.634	2.575	2.646	669	2.611
Do not trust the evaluation	2.79	2.645	2.806	2.815	2.819	2.785	2.794	2.732	2.745	2.833	662	2.79
Inventions being evaluated as having low value	2.934	3.052	2.917	3.015	3.056	2.82	2.931	2.976	2.878	2.988	667	2.934
Faculty members' efforts are not rewarded	3.323	3.325	3.322	3.397	3.507	3.224	3.329	3.238	3.302	3.344	665	3.323
Other people may steal their ideas	2.985	3.182	2.96	3.073	3.118	2.865	2.971	3.195	2.957	3.012	665	2.985
Faculty members have their own contact	3	2.87	3.011	3.066	3.049	2.95	3.002	2.976	2.953	3.044	659	3

Satisfaction with policies													
faculty assessment policy for promotion	2.958	2.713	2.883	2.869	2.898	2.722	2.937	2.855	3.208	2.879	2.863	1032	2.871
intellectual property ownership policy	3.179		3.342	3.163	3.175	3.154	3.169	3.167	3.366	3.175	3.183	664	3.179
policy on the sharing of royalty income	3.075		3.076	3.078	3.058	3.042	3.073	3.062	3.262	3.046	3.103	668	3.075
engage in knowledge transfer-related work	3.186	3.161	3.265	3.169	3.159	3.004	3.31	3.158	3.562	3.245	3.105	995	3.178
Satisfaction with supports													
Administrative support	3.405		3.472	3.41	3.427	3.333	3.385	3.404	3.429	3.44	3.365	459	3.405
Marketing support	2.948		3.074	2.944	3.159	2.837	2.883	2.942	3.036	2.972	2.919	458	2.948

3.3 World Leading Innovation Universities

The narratives below present the evaluation of the leading innovative universities in the world located in the USA, EU, East Asia, Middle East and China. The information is based on the analysis of major policy documents such as the annual reports on knowledge transfer (KT), IP policies, promotion and tenure policies of selected universities as well as the interviews with the leaders from University technology transfer offices.

3.3.1. University of Washington

The University of Washington (UW) is a public research university, established in 1861, with campuses in Seattle, Tacoma, and Bothell. Tacoma is the largest satellite city of Seattle; Bothell is part of Seattle metropolitan area. UW in Seattle is one of the two largest universities in Washington State, the other being Washington State University. UW's student body reaches over 50,000 annually. In recent years, UW has been actively promoting courses in science, technology, engineering, and mathematics (STEM). For instance, 2015, 38.2 percent of UW students were pursuing degrees in STEM-related majors. To expand its capacity to serve STEM students, UW embarked on the construction of a new molecular engineering and sciences building, a new life sciences building and a second computer science and engineering building.[24] Since the first Reuters 100 Most Innovative Universities ranking was issued, UW has landed in the top 10 in overall ranking - 5th in 2019, 2018, and 2016, 4th in 2015, and 7th in 2017. It has also held the highest rank among American public universities in the list.

In 2017, UW ranked 7th out of 200 U.S. research institutions in a report published by Milken Institute, a not-for-profit and independent think tank, founded in 1991 and named after its founder. Based on data from a survey conducted by the Association of University Technology Managers, Milken Institute examined four indicators, namely, patents issued, licenses issued, licensing income, and number of start-ups formed, and ranked UW among the universities with a strong innovation ecosystem that supports students and faculty. The report also highlighted that the UW School of Medicine attracted the largest research funding, and that start-ups in the biotech and healthcare sectors, as well as IT and software, were dominant in CoMotion Labs, managed by CoMotion, UW's technology transfer office.[25]

Long before Bayh-Dole Act, UW had already been a major source of scientific discovery and technological advance, some familiar examples of which were kidney dialysis, medical ultrasound, treadmill heart test, and bone marrow transplantation. As pointed out by **Berman (2008)**, the Bayh-Dole Act can be considered as a deeper institutionalization of the technology transfer initiatives that some American universities had already been actively engaged in, among them was UW. **Collins (2001)** remarked that UW's licencing and start-up companies based on university research has generated a considerable impact on the economy of Seattle and Washington State. UW's technology transfer system comprises both internal and external organizations. It has its own technology transfer office that provide innovation spaces, incubation programs, mentoring, and legal and business advice. In addition, UW has received valuable support from external organizations both at the federal level and state level. In Washington State, UW has been supported by the Washington Technology Center, Washington

Technology Foundation, and Washington Technology Alliance. These organizations have provided needed assistance to UW and other research institutions in the state in terms of significant funding to enhance marketability of start-ups, office spaces, and opportunities to connect with industry firms.

Talent-based approach to maintaining top position for federal research funding

Among U.S. public universities, UW receives the most federal funding for research. In fiscal year (FY) 2016, UW received US$995 million in federal research funding, comprising more than 72 percent of the university's total $1.37 billion in research awards.[26] In FY2018, the federal research funding received by UW reached more than US$1.35 billion.[27] Federal funding for research and development (R&D) is concentrated in a few departments and agencies. In FY2020, the Department of Defence and the Department of Health and Human Services accounted for about two-thirds of the total R&D funding. Among the agencies that receive and administer federal R&D funding is the National Science Foundation, established by Congress in 1950 as an independent federal agency. The National Science Foundation is the primary source of federal support for U.S. university research in science, technology, engineering, and mathematics (STEM). The foundation also provides support to students and programs in STEM-related academic fields. Three of the foundation's six appropriations accounts in which research funding for universities is included are the Research Related Activities (the main research account), Education and Human Resources, and Major Research Equipment and Facilities Construction. These three accounts combined account for about 90 percent of the funding request for the foundation.[28] Federal funding has helped UW to promote innovation and to commercialize inventions by its faculty, students, and alumni.

Moreover, as pointed out by the transfer official we interviewed, "money isn't the most important thing… The government doesn't just throw money into UW," meaning what UW does is to attract principal investigators (PIs) who are competitive, i.e., innovation oriented and translational research oriented, because these attract federal funding and they have the capacity to produce high quality innovations and getting these innovations out in the market can be more easily achieved. (Anonymous. 2021. Interview with a knowledge transfer official. August 27.)

UW also owes its high performance in technology transfer to the support it receives from private entities in Washington State. These private entities served not only as funding sources, but also platforms for university-industry (U-I) collaboration. The collaboration of individual and organizations in the various institutional spheres of government, university, and industry is an important factor in regional innovation (**Zhou and Etzkowitz, 2017**).

Thus, apart from its high quality PIs who apply and are able to attract federal funding, UW also owes its high innovation and technological performance to the ecosystem where it is situated in, which in our interview is described as a very innovative and very developed one in terms of the presence of VCs, entrepreneurs who are looking for projects, as well as the public and private organizations in Washington State that will be briefly discussed below.

Mapping out resources available in the innovation ecosystem

As mentioned, the ecosystem in Seattle has benefitted UW's high performance in translational research. UW has continued to give importance to mapping out the resources available in the ecosystem, so that they can be aware of the resources that they can tap into. UW has emphasized the importance of maintaining close relationships with innovation actors in the ecosystem beyond the university – public and private funding organizations, industry firms, VCs, and entrepreneurs – which has contributed to establishing its solid record of technology transfer.

UW has relied on both internal and external organizations in the state of Washington to support their innovation ecosystem (**Collins, 2001**). External support for research in UW comes from specific federal agencies mentioned above as well as private organizations in Washington State (

Table 3-4). One of the external organizations was the Washington Technology Center, a state-funded technology-based economic development enterprise as well as a non-profit organization established in 1983, which "fosters the growth of high impact companies through providing access to new ideas, to capital and to specialized facilities."[29] Washington Technology Center encouraged and provided incentives to UW faculty researchers to respond to the needs of local industry. Washington Technology Center also sought to match private firms in the state with university research partners to enhance the marketability of faculty inventions.

Washington Research Foundation, a private not-for-profit foundation founded in 1981, invests in start-ups based in Washington State. The establishment of the Washington Research Foundation was made possible by the commercialization of a big UW invention that generated a huge amount of revenue. Washington Research Foundation and Washington State decided that they would support research in Washington State. Washington Research Foundation Capital "works with entrepreneurs, research institutions, other investors and industry partners to transform great ideas into successful Washington-based businesses."[30] It has supported UW's technology transfer in terms of seed capital, management advice, and business support to facilitate company formation by faculty inventors. Washington Research Foundation's aims

> "to capture the value of inventions coming out of the University of Washington and other nonprofit research institutions in the state: by licensing inventions from these organizations to companies that would use the technologies commercially, then returning proceeds to the originating institutions to fund additional research and scholarship."[31]

Washington Research Foundation has also built and managed the Venture Center where office space or business facilities are made available for lease at affordable costs to technology-based early stage start-ups.[32] UW has tapped into the assistance provided by these public and private entities in facilitating and enhancing collaboration with firms. At times, technology transfer offices of universities rely on third parties to market its IPs as well as negotiate the licensing terms with potential firm licensees (**Siegel, 2003**).

Table 3-4 External sources of funding for research in UW

	Public	**Private**
Federal	National Science Foundation (primary source of research funding for universities)	-
Washington State	Washington Technology Center (non-profit; state funded)	Washington Research Foundation (non-profit) Washington Venture Center (founded by Washington Research Foundation)

Seattle's innovation hub has benefitted from the presence of many entrepreneurs, as well as private organizations that facilitate connections between innovation actors, particularly universities, entrepreneurs and VCs. One of the many examples, as mentioned in our interview, is Cambiagrove, a life science oriented entity based in Seattle, whose main purpose is to bridge the gap between innovation actors in the healthcare sector. UW considers Cambiagrove and similar entities as very valuable resources.

> "And it's very, very useful, what they do and they bring to events. They bring companies, large companies to do reverse pitches and talk about the needs in the healthcare industry. So if you just go to their events and meet people, you learn about the need, they learn about what you do… And there are many, many other such. The lesson there from the University perspective is to do a proper mapping of what your ecosystem offers and find ways to integrate into those resources." (Anonymous. 2021. Interview with a knowledge transfer official. August 27.)

The internal support of UW's innovation ecosystem is provided by its own technology transfer office. CoMotion's mission statement is to "partner with the UW community on their innovation journey, providing tools, connections, and acumen to transform ideas into economic and societal impact."[33] As of July 2021, CoMotion has a staff size of 49, and its personnel is divided into smaller teams according to their areas of expertise, for example, IP, training, and marketing. The largest team is composed by innovation managers and administrators with advanced learning in engineering, life sciences, and business. CoMotion has a team of innovation managers with the relevant expertise to match the area of research of individual members of the UW community.[34] Some scholars stress the importance of the critical size for

the technology transfer office which can have a positive influence on the organizational performance, particularly in terms of licensing income (**Macho-Stadler et al., 2007**) as well as number of invention disclosures (**Thursby et al., 2001**). In addition, having a mix of staff in terms of the relevant professional expertise is one of the critical organization factors for university technology transfer offices (**Debackere and Veugelers, 2005**). Apart from the regular staff employed at CoMotion, UW has team for industry connections. While these are not part of CoMotion, they are active in connecting researchers with companies to do sponsored research works. What they do

> "is tangential to what we do… It's very beneficial for the PI to connect with the industry. But they're not marketing university patents or anything but they are connecting them with the industry." (Anonymous. 2021. Interview with a knowledge transfer official. August 27.)

As a collaborative innovation hub, CoMotion is dedicated to helping UW innovators to translate their discoveries into impact. Its main functions are providing innovation training, legal advising on IP protection, funding, mentoring, licensing, and incubation for start-ups. CoMotion works closely with UW inventors whose inventions have commercial promise to provide the adequate support they need for further developing their innovations and working towards eventual IP protection and licensing. For instance, in 2016, broke the record for start-up formation in UW's history by launching 21 start-ups based on UW's research technologies. Between 2006 and 2016, CoMotion hub incubated 126 start-ups.[35] CoMotion has supported the innovation projects and entrepreneurial activities of UW innovators through its wide range of funding schemes and programs that it manages (Table 3-5).

Table 3-5 Some of CoMotion's funding programs

Funding program	**Brief description**
Innovation Gap Fund	The Innovation Gap Fund is jointly supported by CoMotion and the Washington Research Foundation (a private investor that supports early stage companies) to provide significant funding to projects, i.e., $50,000, that show potential of making an impact and need gap funding to launch its product. The fund has helped project teams in various ways such as to create prototypes, conduct market feasibility studies, and complete software coding. The Innovation Gap Fund particularly fund projects in life sciences, engineering, software/IT, and Fintech, and social impact. Applications to the Gap Fund are evaluated based on the marketability and potential impact of the product.[36]
CoMotion DubPitch	Held twice yearly, the CoMotion DubPitch connects investors and VCs with UW start-ups and innovations. The event provides funding opportunities for companies in various stages

	of development from pre-seed to Series A[37]. During the event, the innovators give 10-minutes pitches, followed by Q/A and time for networking. According to CoMotion, in 2020, "UW spinoffs and CoMotion Labs companies raised more than $1.7 billion from angel investors, VCs, and the public markets, and over half the companies who have presented at CoMotion DubPitch have had follow-on meetings with investors."[38]
WE-REACH	With a matching fund of US$ 4 million from the National Institutes of Health, UW established the Washington Entrepreneurial Research Evaluation and Commercialization Hub (WE-REACH), to support scientists involved in research projects in the life sciences to commercialize their innovations.[39] Apart from mentoring, WE-REACH provides financial support of up to USD 200,000 to each of the selected four to six biomedical entrepreneurs on an annual basis. Aside from the National Institutes of Health, other units such as CoMotion and research institutes in UW are involved in WE-REACH. CoMotion acknowledges that the expertise and funding made possible by such partnership has enabled UW to spin innovations in life sciences out of research institutions and to contribute to improvement of health in communities.[40]
Commercialization Fellow Program	The Commercialization Fellow Program is a one-year highly competitive Fellows program. Through this program, graduate students or postdocs work closely with both their faculty advisor and the CoMotion project team in exploring the commercialization potential of the innovation they helped to develop. During the fellowship program, they can focus on the commercialization journey, and not have worry about the obligation of seeking academic grants or jobs after graduation. Fellows participating in the program receive assistance in various areas such as assessing marketing opportunities, pursuing business development funds, and filing patents. They can obtain advice from mentors who have experience in building their business, obtaining funding from investors, and product development.[41]
Other programs	CoMotion connects UW innovators with federal funding programs such as National Science Foundation's Innovation Corps; Grant Opportunities for Academic Liaison with Industry that promote U-I partnerships; Partnerships for Innovation – Accelerating Innovations Research-Technology Transfer program to help commercialize research discoveries;

	and, Small Business Innovation Research and Small Business Technology Transfer programs, which are particularly helpful to start-ups in their product development and translational research.[42]

CoMotion's innovation managers assist UW innovators who seek advice on how best to protect their innovations. Innovation managers deal with different types of innovations, such as mechanical devices, materials, software, digital media, literary works, artworks, photography, music, and website content.[43] CoMotion also provides innovation training to both staff and student that include lecture series on the basics of start-up formation, business models, and due diligence. They also organize workshops where staff and students can interact with entrepreneurs and receive useful advice on how to pitch their ideas to VCs, commercialize their research, establish start-up companies, and so on. Past lectures, presentations, and training videos are archived in the website of CoMotion, so that those who are interested can easily access these materials.[44]

CoMotion also has the important function of running mentoring and incubation programs for start-ups. CoMotion has an Advisor Program which invites mentors, who are entrepreneurs from the local community, "to help promote entrepreneurial thinking, innovation mindsets, creative problem solving, and team-based learning." Mentors can provide mentoring assistance in the CoMotion Labs, which are incubators hosting start-ups inside and outside the UW community. These incubators host an average of between 60 to 90 start-ups at any given time. These start-ups employ 2 to 15 people each, and are variously headed by students, faculty, and community leaders.[45]

CoMotion Labs comprised three innovation spaces — two in Fluke Hall which focus on life sciences and hardware; one in Start-up Hall, focusing on IT, software, and Fintech.[46] The incubator in Start-up Hall was established in 2016. According to an official of CoMotion, these incubators have created both opportunities for collaboration and social and economic impact beyond the university.

> "CoMotion Labs is seeding the Innovation District with innovators, entrepreneurs and start-ups that are challenging the status quo with real-world solutions. Having them here not only allows for collaboration and partnerships with the most innovative public university in the world, but also creates jobs and economic opportunity for the citizens in Washington State."[47]

UW prefers proactive approach to regulatory obligation to engage faculty

It was clear in our interview that CoMotion puts a lot of emphasis on winning the trust of faculty members of UW where, as policy, researchers and inventors are not required to disclose inventions. Unlike in other universities where there is a strict policy on invention disclosures,

UW has adopted the approach whereby inventions disclosures come out from building relationships of trust rather than from regulatory obligations and sanctions. Even when faculty disclose their inventions, they have no obligation to pursue commercialization. They can opt to just publish what they do.

Perhaps the most important task of innovation managers is to build trust with UW's faculty and PIs (as well as firms seeking to license UW inventions), which they try to do by providing the support they need in terms of funding and training, as well as being transparent based on standardized rules. During the application process for funding, CoMotion links faculty interested in commercializing their inventions with mentors mostly from the Seattle area who have subject matter expertise in the industry that they come from. They teach these scientists how to pitch their ideas to a panel of entrepreneurs and to answer sometimes very tough questions. The process they go through helps researchers to organize their thoughts, present their ideas in an attractive fashion and to explain very technical stuff to an audience who may not be familiar with their technology, and adjust their initial expectations of what might be needed or useful to the industry and society. This also entails scientists interacting with, particularly by making phone calls, as our interviewee mentioned, different people and companies who are actually involved in the supply chain relevant to the specific technology of which the faculty is specializing. As an illustration, our interviewee explained,

> "So if you're in the healthcare space and you develop a diagnostic device, then you may want to talk to clinicians obviously to validate the clinical need for your diagnostic device, and that the information that you're providing is actually actionable to the clinicians… You maybe need to talk to someone from the purchasing department in hospitals in order to confirm that you know this is a problem that is perceived as such by them. Maybe you talk to insurance companies…and to the extent it is relevant to insurance companies… And so they have to go to jump through hoops… When they pitch, they have to communicate what they have learned from real clinicians, real purchasing department managers, real insurance company representatives. They have a higher chance to actually get funded." (Anonymous. 2021. Interview with a knowledge transfer official. August 27.)

To build the trust of potential licensees, CoMotion has standardized the terms of the licensing agreements. They avoid anyone feeling discriminated against because he/she is not a good negotiator, by building a process where the terms that are used in licenses are formulated in a very structured way. For example, in the case of royalty rates, CoMotion uses a database with a VC firm which works with all the major universities here in and outside the US, providing statistics for royalty rates per industry and per level of development of technology. CoMotion takes the median number in that database as the royalty rates in negotiations with firms. In this way, they are seen as fair and not greedy and not optimizing every single deal.

Furthermore, based on the knowledge of our interviewee, who has worked in CoMotion for around seven years, UW does not have policy for industrial leave to engage in commercialization activities. The usual scenario is that either a postdoc or graduate student

starts the company and the PI gets involved by consulting with a company. In addition, as a matter of policy, UW does not require the PI or faculty to disclose revenue they obtain from their outside work, regardless whether a company they are associated with involves innovation or technology they helped developed or simply providing consultancy services. UW faculty have the right to engage in outside work, and they are not required to disclose how much they make, provided they are not in breach of UW's conflict of interest policy. They only need to disclose the fact that they are associated with specific companies. Moreover, UW's policy on faculty evaluation for promotion and tenure does not incorporate their performance in knowledge transfer. Our interviewee is of the opinion that performance in knowledge transfer should not be tied to their prospects for tenure or promotion, for one because this might encourage submission of more patent applications the quality of which are likely to be dubious. Another, if we

> "…decide to not continue with filing for patent…, because the project is just not the right one, it only affects the commercial aspects of the project. But if you tie that to a person's tenure, all of a sudden us telling them 'no, we're not filling for a patent' which could be a good conversation with a PI – it's not just telling them no, it's also explaining why we're making the decision, together with them; we have to be super honest [about] why a project should not be further supported in terms of patents, but bring me the new one, I want to hear about the new one; the relationship should not be tainted – now, the PI's promotion depends on it. He will want me to file a patent and whatever. That's a problem." (Anonymous. 2021. Interview with a knowledge transfer official. August 27.)

Indeed, based on the examination of UW's *Faculty Code and Governance*, the criteria for promotion or tenure of faculty is mainly based on teaching, research, teaching. Research performance is measured in terms of "scholarly investigations, contribution to professional fields, receipts of grants, awards, and fellowships; professional and/or public impact of their work; and their success in directing productive work by advanced students and in training graduate and professional students in scholarly methods."[48] Furthermore, while the service component may have more influence on promotion to Full Professor than to Associate Professor, this criterion refers to "work performed primarily in the role of a representative of the Department, College,"[49] and does not include knowledge transfer.

Waiving rights to compensation to support project development

UW's policy on license income sharing ensures that relevant innovation stakeholders who invested in research programs receive an equal share of benefits. After deducting 20 percent from the licensing income to cover patent costs and other expenditures due to commercialization services provide CoMotion, the remaining 80% of the proceeds from a license are shared equally among the inventors of the technology (26.67%), their departments and schools (26.67%), and the Provost (26.67%).[50]

UW's top revenue-generating licenses help to finance the other licensing activities, a practice,

as **Collins (2001)** noted, that is also typical in other large research universities in the country. However, some UW faculty have expressed their concern about this practice, arguing that the licensing income should be used to strengthen the basic academic mission of the university, rather than invested in start-ups to make more money (**Collins, 2001**). Based on the interview with a transfer office official, the current policy of UW is to respect the right of innovation actors in the university to waive their right to individual compensations, including the university. In that case, the entire 80% will go towards a project budget. and to further the development of the project itself. "And I would say, there is not much contention about any of this. This is pretty much agreed." (Anonymous. 2021. Interview with a knowledge transfer official. August 27.)

UW also allows students to own the IP of innovation solely developed by them as students or outside of any direct assistance from the university, unless they are under some kind of employment arrangement. For instance, graduate students working under funded research projects are subject to the university's IP policy. They must comply with the terms of the sponsored research contracts, and they are subject to the same IP obligations as other regular staff with respect to their inventions.[51]

Furthermore, as **Collins (2001)** observed, UW prioritizes public interest by avoiding entering into comprehensive partnerships that provide any single firm an exclusive access to research of an entire academic unit or department. In the past, UW has ordered a university scientist, who was seen by his colleagues as being too profit-oriented, to donate all his founder's stock to charity. This action illustrates how UW manages the tensions arising from different normative cultures of the academic world, which stresses universality, and commercial world, which is mainly concerned with single-minded focus on gaining large profit in the short-term (**Jain and George, 2009**). It also indicates the prerogative UW confers to the primary role of teaching and academic research vis-à-vis the role of technology transfer of some faculty may also have.

UW utilizes soft methods to engage industry stakeholders

CoMotion stresses the importance of building trust with UW student, faculty, and staff who founded spin-offs and to whom eventually UW IPs are licensed, by promoting an open, transparent, efficient, and easy-to-understand negotiation process. The licensing agreements are simplified and standardized ones. The term sheets use standard sector-specific terms and are vetted by a team of attorneys coming from several local law firms. CoMotion tailors licensing agreements to address the business needs of licensees, but it also retains enough control to maintain a strong IP protection throughout the life cycle of an innovation. Moreover, CoMotion has the practice of granting exclusive or non-exclusive licenses to more established firms wanting to strengthen their innovation pipeline with UW technologies.

UW provides licensing products that allow prospective licensees to conduct test runs or market feasibility studies prior to entering into a full license. Prospective licensees who need more time to test run or evaluate the commercial viability of UW technologies can sign Option and/or Evaluation licenses with UW CoMotion.[52] Under the Option license, prospective licensee is

guaranteed to have exclusive access to a technology for a certain period of time, during which the prospective licensee can negotiate and discuss its business interests with UW CoMotion. For the Evaluation license, the potential licensee will be given access to the relevant technology including materials, program services, IP rights, devices, software, or confidential information regarding the relevant technology. This gives the prospective licensee the opportunity to conduct a test run, to evaluate the level of risk involved, as well as the saleability of the technology.[53] Technology licensing is one of the more challenging and time-consuming work of technology transfer offices. The role of technology licensing officers is important in effectively marketing IPs to private companies (**Siegel et al., 2003**). Equally important are the availability of licensing agreements that sufficiently allow for the negotiating licensing terms and test-running of relevant inventions.

Aside from the above licensing agreements, there is another agreement called the Materials Transfer Agreements which CoMotion is responsible for reviewing and approving. The Materials Transfer Agreement allows for the transfer of research materials to or from an institution or corporate entity which is interested in developing technology. The transfer itself is free of charge. The research materials may involve pharmaceuticals, proteins, and chemicals. Materials Transfer Agreements are important because these promotes the protection of UW IPs, limit UW liability, and give due recognition to the developer of materials.[54]

Regarding the risk arising from the potential licensee using the information when he/she decides not to proceed to signing a full license, the interviewee indicated that while the risk does exist, whereby the company decides to ignore confidentiality agreements and/or steal information, there is a strong power to reputation which is far more important to the firm.

From 2015 to 2020, CoMotion successfully facilitated close to 2,000 licenses; by December 2020, the 40th anniversary of Bay-Dole Act, CoMotion had more than 5,000 licenses in its portfolio. UW acknowledged that the Bayh-Dole Act has had a positive effect on its performance in bringing UW technologies to the market.[55] CoMotion provides information of non-exclusive licences and end-user agreements through an online database that can be accessed by interested companies.[56]

UW CoMotion has helped to launch spin-offs and start-ups. From 2015 to 2020, CoMotion successfully facilitated nearly 75 spin-offs. Until recently, the number of UW spin-offs is a little more than 100, employing close to 4,100 employees in total. In addition, from 2015 to 2020, UW students and alumni launched 450 large and small start-ups which managed to raise more than US$85 million in revenue.[57] According to the Association of University Technology Managers, in 2017, UW ranked 9th across the U.S.A. in start-up formation. It has been quite common for some of these start-ups to be acquired by firms outside the region or even by foreign firms (**Collins, 2001**). In some cases, the new owners decide to move the technology and corporate assets out of the region. In other cases, they may choose to stay in the region either because of the high quality of life or the need to stay in close contact with the original inventor of the technology that gave rise to the establishment of the company.

The patents filed by UW from 2009 to 2017 were consistently led by innovations in

pharmaceuticals and biotech and agriculture, forestry and food, with medical devices and healthcare coming in third place. In general, the success rate of patent applications by UW is between 30 and 40 percent.[58] Furthermore, the impact of basic research originating from UW on commercial R&D activity, measured in terms of academic papers cited in patent filings, in general scored nearly 50. **Collins (2001)** reported that in the late 1990s software licenses were a large and growing component of the overall licensing activity of UW. To date, software licenses continue to be relatively large based on the current catalog of licenses, accessible via CoMotion's Express Digital Content.[59] Presumably, software licensing products continue to generate significant licensing and royalty income. In addition, most of the licensing activity of UW are in medicine and the life licenses, and the technologies in these same fields of study are also at the top in terms of revenue generation. It is interesting to mention that a number of UW's molecular biology laboratories are located in Lake Union, outside but within a few kilometres southwest of the Seattle campus (**Collins, 2001**).

Regarding UWs impact on the economy of Seattle and Washington State, many of the sectors, especially biotechnology and medical instruments, owe their origin to research conducted in UW laboratories (**Collins, 2001**). Many of the top firms in the region have benefitted from their collaboration with UW. Not to mention the many graduates produced by UW that has provided the human capital equipped with various professional skills and competencies to sustain the region's economy. UW's impact on the economic development and growth of industry in the region can also be seen in the number of firms with which the university has collaborated in terms of co-publications and co-patenting. The data collected from Lens.org on joint publications and joint patenting with industry firms, to be provided in the report related to Task 3, indicate that UW has been active in this area.

Our interviewee pointed out that they try to get as many success stories out to encourage innovation among faculty and researchers.

> "I think the one key factor that encourages inventions disclosures and encourages engagement is seeing what others are doing and listening to success tools. And so we make sure that we communicate success stories efficiently, not to brag about them. You can talk about successes in an honorable way and that's what we do, because if you hear about a colleague of yours, who is spitting out, you know, companies, like popcorn. At some point, you start to wonder…why wouldn't I do it. And so we would take that approach. We wouldn't push or pull hard on people, but use soft methods to get people to engage with us." (Anonymous. 2021. Interview with a knowledge transfer official. August 27.)

UW features in its website 'success stories' of start-ups, some of which are as follows – Proprio (a spin-out that developed an innovative platform for machine learning and computer vision to improve surgical navigation; co-founded by UW faculty, post-graduate students, and alumni); PvP Biologics (a spin-out that developed an oral enzyme for the treatment of celiac disease; acquired by a Japanese pharmaceutical company which had funded the first phase of its clinical trial; co-founded by UW post-graduate students and faculty); A-Alpha Bio (a start-up that is developing drugs to treat respiratory and intestinal diseases; co-founded by two UW graduate

researchers); Membrion (a spin-out that makes membranes that can convert some types of salty water into fresh water; founded by an UW lecturer); Spira (a start-up that developed a SMS COVID-19 tracker and is planning to develop a coronavirus screening tool; founded by two UW teenage students).[60]

With its sizable seed venture fund, generated by its portfolio of licenses, Washington Research Foundation invests in start-ups that collaborate with UW and other non-profit research institutions in the state. The Washington Research Foundation has also acted as an agent in patenting UW inventions that have commercial promise and licensing these to industry.

Another organization that helped UW inventions to bear on the problems of the local community was the Washington Technology Alliance, a statewide, non-profit organization comprising leaders from Washington's technology-based businesses and research institutions.[61]

Summary and conclusion

UW has consistently been at the top among US public research universities in Reuters' The World's Most Innovative Universities. It has also received the largest federal funding for research among public universities. Apart from government funding, UW has also relied on the support of private organizations in Washington State. UW start-ups benefited from private institutions particularly in terms of seed capital, office space and establishing connections with firms in the region. The funding support from government and private entities are channelled through various funding schemes to support and assist in the entrepreneurial efforts of faculty, students, and staff such as prototyping, conducting market feasibility studies, company formation, and commercialization activities. Internally, UW's technology transfer activities are supported by CoMotion, which has a team of innovation managers possessing the relevant expertise to match the specific needs of faculty coming. UW's licensing policy prioritizes the overall interest of the university over profit, and thus the net licensing income is shared equally among the inventors, host department, and university. UW provides a range of licensing products that allow interested firms to first sign an Option and/or Evaluation licence to learn more about the invention, negotiate the terms with CoMotion, and to conduct a test run or a market feasibility study, before signing a full license. CoMotion tailors licensing agreements to the needs of relevant companies; it maintains a certain level of control to protect IPs throughout the life cycle of the innovation. CoMotion manages an impressive license portfolio, which is perhaps attributable not only to high quality IPs but also to licensing agreements that facilitate trust among firms. Since the 1990s, software products have been a major component of UW's licensing activity. There is also a significant number of licenses in medicine and life sciences. As practiced in other US activities, part of the income generated by the more successful licenses are used to support other licensing activities of UW. UW's spin-offs and start-ups has contributed to regional economy in a significant way particularly in terms of job employment as well as the revenue generated by these companies. The majority of patents filed by UW were in the areas of pharmaceuticals and biotech and agriculture, forestry and food.

3.3.2. Imperial College London

Imperial College London (ICL) was established on July 8, 1907, and has long been known as a prestigious research university on par with their counterparts at Oxford and Cambridge. Its history traced back as far as 1845, when its earliest predecessor, the Royal College of Chemistry, was established. Imperial College at its current form was founded with the assent by the royal family as a strategy for the United Kingdom to compete against other major rising powers – notably Germany – in scientific and technological arenas. The College was a constituent unit of the University of London system until 2007, as they decided to chart their own path as an independent university.[62] Since their founding, ICL has been credited for many world-changing scientific and technological breakthroughs, such as penicillin (by Alexander Fleming, then a medical scientist at the School of Medicine), fiber optics (invented by Harold Hopkins and Narinder Singh Kapany in the School of Engineering in 1953), and more recently, the COVID-19 transmission simulation model by professors Robin Shattock and Neil M. Ferguson. The simulation model has been utilized by numerous government agencies across the globe with regard to their policy responses to the pandemic, and credited for saving millions of lives that would have otherwise been affected by the virus.

Financial and organizational resilience in spite of internal and external challenges

The College's performance – in terms of education and research – has remained remarkably solid, despite financial pressures and political uncertainties brought forward by the 2008-2009 global financial crisis and Brexit-related events. As stated in their annual reports since 2009, the College leadership has persistently been faced with questions on financial viability, as the UK government has significantly reduced their funding support to universities and colleges across the country in the aftermath of the financial crisis. Given the reduction in public funding, the College has been embarking on numerous efforts to diversify their income sources, such as expanding their enrolment to international students (particularly from European Union and non-European Union countries/regions), raising tuition fees (even amidst economic contraction during the height of the crisis), securing philanthropic donations from alumni and business communities, attracting collaborative and contract research with major industry firms from the UK and the rest of the world, as well as selling their shareholding at Imperial Innovations, the university's technology transfer company established in 1986 that was once traded at London Stock Exchange (LSE) until it was restructured in 2017, the elaboration by which is provided in the next pages shortly. Such phenomenon perfectly describes what Middlehurst (2004) has argued as the 'inevitable' shift in the governance of British universities towards one oriented on the maximization of operational efficiency.

Nowhere is the emphasis on keywords like 'tight financial management' and 'efficiency' more obvious than in the College's annual reports, particularly in the first four reporting years from 2009 to 2012. The university's sharp focus on resource efficiency was further boosted with the appointment of Muir Sanderson, a former consultant at Booz Allen Hamilton (also known as Booz and Co.), as the College's Chief Financial Officer (CFO) in 2011/2012 reporting year. The shift was evident in 2012/2013 annual report, as the 'financial review' section became

longer and consumed a bigger proportion of report content, with a strong emphasis on risk mitigation, income diversification, and maximizing efficiency.

Another area by which impacts from the resulting external changes have been substantive (for British universities in general) is the leadership structure and approach (Middlehurst, 2004), and ICL is no exception. In the case of the College, 2012/2013 academic year was once again the 'watershed' period as – in addition to Sanderson's appointment – the senior administrators embarked on significant reorganization of the top leadership positions, with the 'Rector' role substituted by two new seats: 'President' and 'Provost', and the former's authorities divided among the latter. The 'President' would be responsible for envisioning the university's strategy and forging external engagement with government(s), industry firms, philanthropists, as well as alumni networks. Simultaneously, the 'Provost' would be in charge of executing the university's strategic plans and overseeing their overall internal operations. The president-provost leadership model – the approach by which is adopted from US higher-education institutions – has been imprinted and subsequently institutionalized in Imperial College's leadership structure (Lockett et al., 2015).

Elaborate, but flexible, policies on faculty performance and engagement with knowledge transfer

Faculty assessment policy

Imperial College London offers several pathways to promotion for academic staff based on their career status (whether as academic staff, full-time researchers, or practitioners / professors of practice). For academic staff engaged in both teaching and research duties, there are four levels of academic position provided by the College throughout their career progression, namely: 1) Lecturer; 2) Senior Lecturer; 3) Reader (or Associate Professor in the case of Imperial College Business School, and finally; 4) Professor. Assessment criteria for career promotion of these academic staff depend on four criteria, namely: 1) teaching / education (e.g. significance in teaching contribution); 2) research; 3) leadership and management (e.g. experience with developing effective management skills while leading departments / divisions / university-related programs and initiatives), and; 4) profession and practice (e.g. developing new techniques and/or tools, industrial/commercial application of research findings). [63] Specific to profession and practice, these are the following indicators that are taken into consideration, as shown in the bullet points below:

- Medals received (for public service or other categories)
- Consultancy activities
- Innovative input and feedback in projects
- Experience in patenting and licensing
- Spin-off establishment
- Pioneering innovations of worldwide recognition (with particular interest in healthcare applications)

- Service as expert witness (in government agencies, parliamentary hearings)
- Demonstration of leadership in respected institutions, organizations, and/or other peer-reviewed bodies

Interestingly, faculty promotion applies not only for regular academic staff, but also for those who are not in the regular promotion route. In the case of Professors of Practice, their performance – and prospects of promotion – are contingent on their outstanding contribution to the Imperial College in any of the three areas as follows: 1) teaching; 2) leadership and management, and/or; 3) profession and practice (e.g. contribution to society through the person's expertise and engagement in regular profession beyond his/her university position). There is also a separate promotion pathway for academic staff entirely focused on research track, from Research Fellow to Senior Research Fellow (or Principal Research Fellow).

Leave policy

The College also suggests, while founders cannot be fully involved in the spin-offs' day-to-day operation, that they be involved in part-time positions in the short term in order to help grow the companies at their early stage. In accordance with the "Register of External Interests and Annual Declaration Policy", staff at ICL can undertake external positions, provided they already receive approval from their respective heads of departments. In case they decide to act as 'consultants' for the spin-offs they found, the policy relevant to this purpose will be on Consultancy Policy.

ICL also allows faculty members to take a temporary leave of absence for full-time work focus on the spin-off companies, provided that they, again, secure approval from their heads of departments to do so. Beyond the approval grant, faculty members also ought to abide by ICL's conflict of interest policy. Furthermore, they may occasionally be requested to lead Scientific/Technical/Research Advisory Boards or non-executive director positions in the companies, and in the early stage, their roles may more likely be hands-on. The university strongly advises them to be aware of potential implications. For those taking leave of absence to work for industry or spin-offs, academic staff also have to make arrangements stipulated under Register of Interest Policy, by which we will elaborate in the paragraph below.

It is worth noting that the leave of absence is unpaid (but it can be fully paid or partly paid under exceptional circumstances, with procedures on their own), with significant variation in terms of duration (special procedures apply for those working in the Faculty of Natural Sciences). In general, for leave of absence lasting one month or less, faculty members only require consent from their respective heads of department/division. Otherwise (in the case of leave of absence exceeding one month), faculty members must receive approval from not only heads of department/division, but also their respective faculty deans.[64]

Beyond the leave-of-absence option, faculty members can also apply for sabbatical arrangements for personal refreshments, but this will be a 'one-off' arrangement only. Another possibility is that faculty members can apply voluntarily to do part-time work by reducing their college-related workload.[65]

Register of External Interests and Annual Declaration Policy

This policy is equivalent to the 'outside practice policy' that we observe in most other universities. In the case of Imperial College London, this policy applies to any individual working on behalf of the College, ranging from full-time academic staff, contract-based honorary researchers and lecturers, to external members of the university's council and their affiliate committees. Several circumstances that suffice for College members to adhere to this policy are: 1) in the condition where the academic staff concerned has received external funding – whether from national or foreign funding agencies; 2) when faculty members, researchers, or any other academic staff have shareholding of less than, or above, 5% in companies that conduct business directly with the College, and for which the individual has a major influence in the company (in other words, the company may be a university spin-off), and; 3) the situation where the College member holds a commercially-oriented directorship in an external organization, regardless whether the organization conducts business with the College or not. In addition, ICL also strongly recommends that faculty members engaged in consultancy work with external parties to direct their work to Imperial Consultants Limited (ICON), a consultancy arm of the university.[66]

IPR and royalty-sharing policy

Similar to most other universities we have analyzed in Task 2, Imperial College London also adheres to the principle that any employees affiliated with the College who is/are involved with inventive activities in relation to research projects within ICL will require to assign their patents on behalf of their employer. In other words, the College reserves rights to 100% ownership of patents invented by their employees.

Table 3-6 College's Reward to Investors Scheme

Cumulative College Revenue (i.e. gross revenue costs, fees and tax)	Investors	Department
First £50K	100%	0%
Over £50K	80%	20%
Over £1million	60%	20%**

** A further share of surplus net revenue may be distributed to the Inventors' Departments

Imperial College has a large and complex organizational structure to support knowledge transfer and commercialization

Before we elaborate about ICL's organizational structure, we shall note that the current Imperial Innovations is completely different from its publicly listed predecessor (also sharing the same name). The latter has been renamed Touchstone Innovations since 2017, which in turn was acquired by IP Group plc, an intellectual property (IP) commercialization company, and subsequently delisted from London Stock Exchange.[67] The newly-formed Imperial Innovations is now a technology transfer company fully owned by Imperial College Enterprise Division, the university's primary technology transfer parent organization. This division consists of 11 teams (and slightly above 140 full-time employees), the details by which are

elaborated below. At present, the Enterprise division is currently led by Dr. Simon Hepworth. A PhD graduate of the University of Oxford, Hepworth has had considerable work experience in the corporate field, with a particular concentration in automobile and electronic industries. He was a former business executive at Ford Motor and Visteon before the appointment as Enterprise director.

Table 3-7 List of organizational units under Imperial College London Enterprise Division

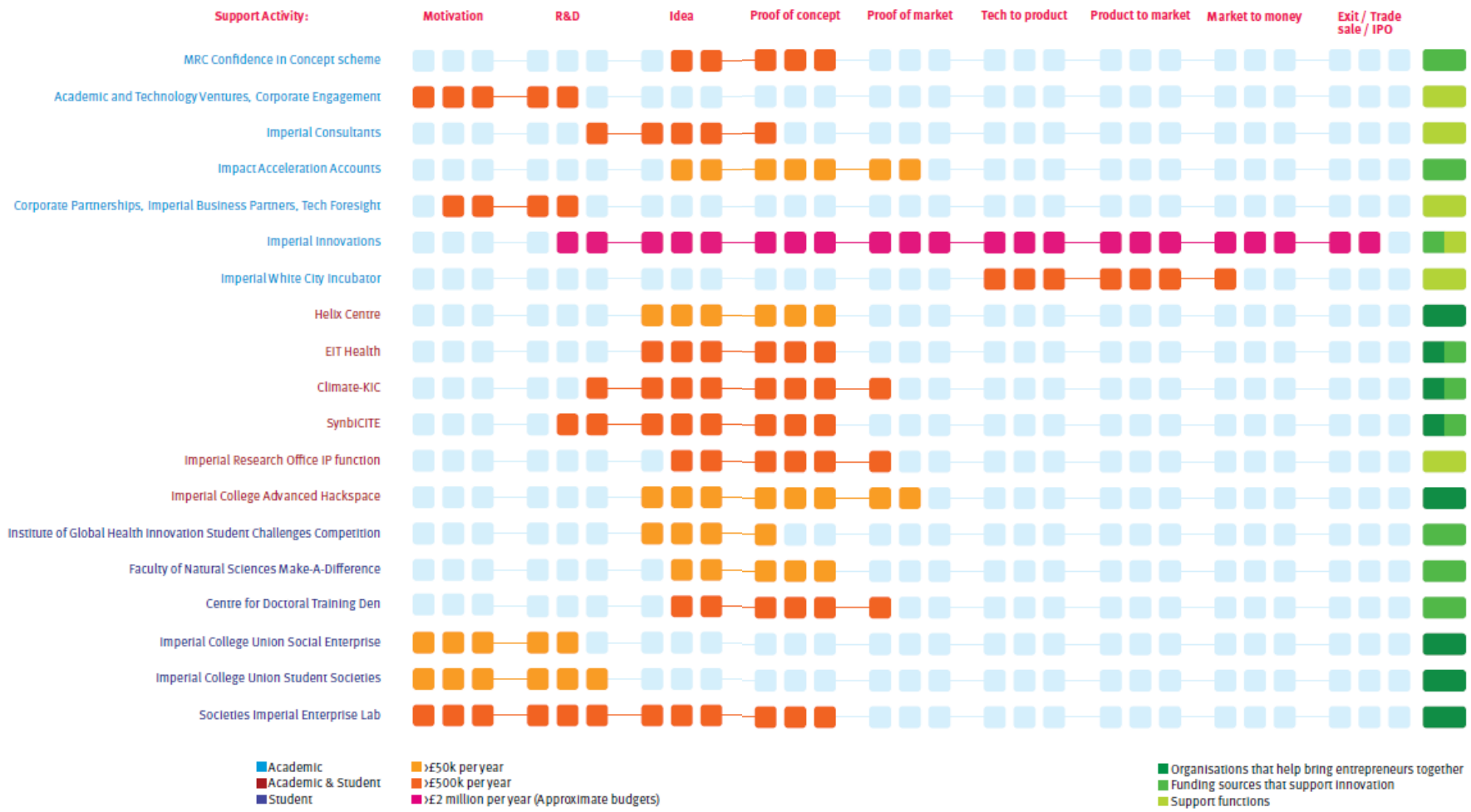
Organizational unit	Number of staff	Affiliated unit	Targeted clients
Academic and Technology Ventures	19	Advanced Hackspace	For businesses For academic staff For students
Entrepreneurship	12	Imperial Enterprise Lab MedTech SuperConnector	For academic staff For students
Enterprise Engagement	15	Imperial Business Partners	For businesses
Imperial Projects	13	-	For academic staff For students
Imperial Consultants	23	-	For academic staff
Industry Partnerships and Commercialization	35	Imperial Innovations (no. of employees: 16)	For businesses For academic staff
In-House Lawyers	2	-	For academic staff
NHS Tech Transfer Service	1	-	For NHS For academic staff
Patent and License Management	5	-	For businesses For academic staff
Research Project Management	13	-	For academic staff
Startups and Investments	4	-	For academic staff For students

The organizational units under Imperial College Enterprise are involved in a diverse array of knowledge transfer management activities on behalf of the university, ranging from

entrepreneurship (linked to Entrepreneurship, as well as Startups and Investments), engagement with industry firms and other private-sector organizations (under the purview of Academic and Technology Ventures, Enterprise Engagement, Imperial Projects, Imperial Consultants, Industry Partnerships and Commercialization, as well as Patent and License Management), brokering between academic staff and industry actors for consultancy services (under Imperial Consultants), legal services (as performed by In-House Lawyers), to dealing with faculty research projects that are linked to industries (by Research Project Management). Of all 11 units, Industry Partnerships and Commercialization comprises the largest, with more than 30 full-time staff employed (over half of whom are also affiliated with Imperial Innovations). This team also builds close linkages with each of the four schools of the College, with several Enterprise staff serving as intermediaries between faculty members of the schools and the division themselves. Overall, the university adheres to the mixed structure of organizational technology transfer as described by **Brescia et al. (2016)**, by which the university runs an external company (run directly by the Enterprise division) for dealing with licensing and commercialization, and multiple internal units to provide support on research application, consultancy, patenting, spin-offs, etc.

Figure 3-5 below visualizes in detail the full set of programs and incentives that shape the innovation and entrepreneurship ecosystem within the Imperial College London campus. The distribution of initiatives on the basis of targeted, supported groups (academics only, open for academics and students, students only) is by and large equitable. The types of support activity offered by most of these programs are limited to the proof-of-concept stage, with the exception of Imperial Innovations and White City Incubator. Imperial Innovations is vastly different from the other knowledge transfer and commercialization-related programs given their extensive, start-to-finish nature of support (from R&D support all the way to exit / trade sale / IPO stage). They are also the only program that provide customized support for academic entrepreneurs with grants starting at £2 million and above. The most recent White City Incubator – which began operation in October 2016 as the biggest incubation facility ever built in ICL's history – also distinguishes itself from other programs in the sense that the support they provide takes place at more advanced stages, commencing from technology-to-product stage, which relates to product prototyping.

Figure 3-5 Components of technology transfer and commercialization in Imperial College London's innovation ecosystem



Source: Imperial College London Review of Enterprising Activity (2016-2017)

A vibrant entrepreneurial ecosystem with diverse and extensive support programs

With regard to entrepreneurship, ICL has been considered outstanding compared to most other British universities given their strong emphasis on generating spin-offs to commercialize university research that dated back to the 1970s. ICL also strongly favor spin-offs given that they demonstrate significant evidence of "demonstration of societal impact", especially as 20% of government funding allocation to UK universities and colleges is determined on the basis of this category in the UK REF evaluation.[68] Based on Figure 3-5 above, ICL has several interesting programs in place to promote entrepreneurship, as summarized in Table 3-8 below.

Table 3-8 List of entrepreneurship centers, programs, and initiatives at ICL

Name of program	Target	Summary
White City Incubator	For academics	The incubator is considered as the biggest ever built in Imperial College's history. The building consists of prototyping facilities, co-working spaces, start-up incubator, as well as rented spaces for start-ups graduating from White City's incubation program.
Helix Centre	For academics and students	Helix Centre is a joint innovation-lab program founded by Imperial College London and Royal College of Art with an emphasis on innovations in digital healthcare. Led by Professor Lord Ara Darzi, the Centre is currently engaged in projects relating to personalized medicine, digital technologies for healthcare, as well as development of therapeutic tools. Start-ups have been created to commercialize technologies based on these projects.
EIT Health	For academics and students	EIT Health is a health technology-oriented Knowledge and Innovation Community (KIC) established by the European Institute of Technology and Innovation of the European Union. Imperial College Union is 1 of 150 member organizations that participate in this program. This program aims to promote innovation and entrepreneurship for health innovators in Europe. One of their signature programs is EIT Health Start-Up Platform.

Climate-KIC	For academics and students	Climate-KIC is a Knowledge and Innovation Community (KIC) established by the European Institute of Technology and Innovation of the European Union to support green economy, renewable energy, and climate change-addressing clean technologies. Imperial College Union is 1 of 450 member organizations comprising the KIC. They are involved in providing start-up capital, support for research and innovation, as well as education on climate change.
SynbiCITE	For academics and students	SynbiCITE is a start-up accelerator based in the Imperial College London. It was established by a consortium of 98 universities, companies, and government agencies across the UK with the aim of creating a synthetic biology-driven economy. The accelerator supports early-stage companies that commercialize synthetic biology technologies.
Imperial College Advanced Hackspace	For academics and students	Advanced Hackspace is a makerspace that allows students and staff alike to tinker, and experiment, with hardware devices and other technologies. It consists of prototyping facilities as well as co-working spaces for members. Advanced Hackspace is currently based in the White City Incubator.
Imperial College Union Social Enterprise	For students	A social entrepreneurship program established by Imperial College Union to help support student-led social enterprises with basic seed funds.
Imperial Entrepreneurs	For students	An entrepreneurship program founded by Imperial College Union to help incubate and support early-stage companies founded by students that seek to commercialize disruptive technologies.

Imperial Enterprise Lab	For students	It is an innovation and entrepreneurship program directly established by Enterprise Division to provide support for aspiring student entrepreneurs, from idea generation to business incubation. Two major initiatives comprising the Enterprise Lab are Techcelerate and MedTech SuperConnector, with the latter focused on medical technologies.
Imperial Venture Mentoring Service	For academics and students	Imperial Venture Mentoring Service is a pro bono (free-of-charge) mentorship program intended for student and faculty entrepreneurs based in the university. Using an approach based on a similar program at MIT, the Mentoring Service assigns 2-3 mentors for each start-up company for an 'open-ended' period (as long as needed).

The College also uniquely distinguishes themselves from other British universities through their emphasis of keeping their equity ownership at university spin-offs at a very low rate. Such approach is exemplified from their recent establishment of Founders' Choice program in 2017, by which spin-off founders may opt to retain their equity ownership at their start-ups up to 95%, the rest by which (5%) is assigned to the university. In addition, Imperial Innovations (the College's technology transfer unit) has also successfully raised more than £300 million worth of capital from their listing at Alternative Investment Market (AIM) in the London Stock Exchange to support ICL's spin-offs that seek to commercialize university-developed technologies.[69] To the best of our knowledge, only Imperial College London thus far has had their technology transfer company publicly listed in a stock market. However, as we have stated in the beginning, the current 'version' of Imperial Innovations is different from the previously listed company of the same name, which has been restructured and acquired by another IP commercialization firm. This is also evident from what we observed in the university's annual reports, in which the College progressively reduced their stakes at the listed company (from 50% in 2009/10 reporting year to only slightly above 20% in 2014/2015 reporting year) to raise further capital to support their spin-offs.

An active participant in collaboration with industry and commercialization of science

Imperial College London has been actively involved in collaboration with both domestic and foreign industry actors. Their annual reports have frequently provided illustrations of their

partnerships with major incumbent multinational corporations, e.g. Royal Dutch Shell (a British-Dutch oil and gas firm), Huawei (China), NEC (Japan), AstraZeneca (a British-Swedish pharmaceutical company), Microsoft (United States), etc. In the case of publications, university-industry co-publications have been shown to be a salient indicator for benchmarking performance across research universities worldwide with regard to their intensity of collaboration with industry partners (Tijssen, 2006; Perkmann and Walsh, 2007; Tijssen et al., 2009).

Another table below – sourced from the Enterprise division's Review of Enterprising Activity – provides the comprehensive evaluation of all knowledge transfer indicators of the university, the earliest data by which was only publicly available from 2012/13 reporting year onward. It appears that half of the KT indicators of interest relate to start-ups/spin-offs founded by the College professors, research staff, and/or students. Unlike Hong Kong universities, which – following UGC's guidelines – differentiated 'spin-offs' and 'start-ups' separately, ICL simply classified these spin-offs into two categories: 1) IP-based startups (referring to companies that are established to commercialize university research by licensing their patents), and; 2) student-based startups (companies formed by students that do not necessarily make use of university research).

Throughout the reporting period, the number of student-based startups has been growing at a faster pace than that of IP-based startups, and this trend is particularly evident in the 2017/18 reporting year, with 41 new companies founded by students vis-à-vis 10 other entrants that license university IP. At the same time, however, IP-based startups have also been attracting bigger capital funding compared to their student-based counterparts, as the startup investment subsection of Table 3-9 below displays. Indeed, at one point these enterprises received up to £363 million worth of financing from VCs and other investment funds. These findings align with **Roberts and Malone (1996)** and **Degroof and Roberts (2004)** in the sense that this approach resembles the 'high-support, high-selectivity' model of supporting university spin-offs. The substantial gap between funding support for student-based start-ups and their IP-based counterparts can also be attributed to the more complex nature of technologies developed by researchers, which may require additional resources to refine them further to be closer to market application (**Hockaday, 2020**). Beyond investments, these two company types also differ with regard to the number of jobs created, with the latter hiring new employees 3-5 times larger, on average, than the former.

Table 3-9 Indicators of knowledge transfer performance by Imperial College London

Metric	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18
Inventive Output						
Inventions disclosed	306	323	296	310	332	376
Patent applications filed	43	57	66	73	68	77

Patents issued (patent grants)	78	98	47	59	49	47
Active inventions in portfolio	832	977	1,007	1,021	1,009	1,026
Active patents in portfolio	325	373	394	404	429	435
Licensing Performance						
New licenses signed	29	27	39	39	46	43
Active licenses held	170	175	193	202	205	198
Licenses generating income in the period	48	71	74	70	64	71
Royalty and fee income generated / licensing revenue (£m)	1.3	1.6	2.8	2.1	3.0	1.9
Startup Formation						
IP-based startups formed	5	7	8	6	9	10
Student-based startups formed	6	8	18	16	16	41
Incubation Performance						
Startups housed by university incubators	18	16	18	13	9	19
Startups graduated from an incubator program	2	2	2	4	10	1
Active incubator graduate companies	13	15	17	21	31	29
Startup Investment						
Investment funding acquired by IP startups (£m)	26	254	363	114	124	87.5
Investment funding acquired by student startups (£m)	0.5	0.8	4.5	8.4	1.1	17.6
Startup Companies Performance						
IP startups still active	71	73	74	70	76	79
Jobs supported directly by IP startups	490	645	814	1,002	974	1,273
Student startups still active	7	14	29	44	60	122
Jobs supported directly by student startups	98	163	252	305	342	-

Realized income from sale of shares in IP startups (£m)	0.4	-	1.9	1.6	6.4	1.6
Ratios						
Invention disclosures per £100m of research income	93	92	68	88	92	103
Patents filed per £100m research income	13	16	15	21	19	22
Patents issued per £100m research income	24	28	11	17	11	13
Licensing and realized income as % of research income	0.5 0%	0.4 0%	1.1 0%	1.1 0%	2.6 0%	1.0 0%
IP startups per £100m research income	1.5	2.0	1.8	1.7	2.5	2.7
Student startups per £100m research income	1.8	2.3	4.1	4.3	4.4	-
Other income						
Research income (£m)	330	351	436	351	361	364
Commercial research income (£m)	-	46	55.7	53.6	61.1	61.4

Summary and Conclusions

Imperial College London, throughout their existence, has significantly contributed to the UK's scientific and technological achievements, and has continued doing so even in spite of financial pressures facing most UK universities in the aftermath of the global financial crisis and Brexit events. The university administrators' focus on maximizing resource efficiency, as well as broadening sources of financial support, has enabled them to embark on ambitious campus expansion programs and research initiatives. Such reforms were further boosted by the shift in leadership structure, which increasingly follows a combination of US-based university leadership model and corporate management structure, with new positions such as 'President', 'Provost', 'Chief Financial Officer' (CFO), etc. Nevertheless, as **Middlehurst (2004)** has pointed out, such changes are themselves not controversy-free, given the tremendous impacts they impose on universities' original missions.

One example – in the case of ICL – relates to Imperial Innovations, the university's TTO. Originally structured as a technology transfer company, Imperial Innovations achieved a breakthrough that no other university TTOs had done: public listing at a stock exchange. At one point raising capital worth £300 million, Imperial Innovations had – nevertheless – ended up delisted from the stock exchange due to uncertain financial returns from commercializing novel technologies originating from university research, as well as to provide more personalized services for university researchers. Eventually, ICL administrators had to reduce,

and eventually remove, the remaining shares at Imperial Innovations in order to improve their financial situation. By 2018, the university decided to wholly revamp their technology transfer organizational structure by forming a new TTO under the new name of Imperial Enterprise, and this time in the form of a university administrative unit, rather than an independent company.

Nonetheless, such events hardly affected the university's engagement in knowledge and/or technology transfer in a significant way. The number of spin-offs commercializing university research and student start-ups has continued to increase annually, and the amount of investment funding they attracted has more than multipled in recent years. Moreover, ICL continues to maintain their faculty tenure policy, which explicitly recognizes faculty members' achievements in KT/TT activities (particularly in spin-off establishment), and has actively invested in expanding entrepreneurship-related infrastructure through initiatives such as White City Incubator. Incentives for innovation/entrepreneurship are expected to grow.

3.3.3. University of California at Berkeley

Introduction

UC Berkeley (UCB), the oldest campus of the University of California System[70], was established in 1868, resulting from the merger of the College of California and Agricultural, Mining and Mechanical Arts College. UCB is one of the leading campuses in the UC system in terms of providing support for and promoting technology commercialization. From the start, UCB attracted young scientists and retained excellent scholars by providing financial support for their research. In 1912, Frederick Cottrell, a professor and scientist at UCB, used the profits derived from his invention of the electrostatic precipitator to establish a private foundation – Research Corporation for the Science Advancement[71] – to manage the commercialization process, because at that time the university did not have a policy on inventions. Cottrell also believed that doing business was beyond the role of the university. This understanding of the role of the university eventually evolved, as UCB had been performing commercialization activities for their inventions from early 1900s. The passage of the Bayh-Dole Act in 1980 legitimized the existing technology transfer activities that some universities, including UCB, had been engaged in. The Bayh-Dole Act also prompted many other universities to establish their own local technology transfer offices and to get more involved in technology transfer.

In the 1920s and 1930s, the number of scientists and inventors who assigned patents to their inventions to the Research Corporation steadily increased and the revenue generated based on the patents were used for the advancement of scientific research. In 1917, UC received its first patent donated by a professor, although the policy on invention disclosure was not introduced until 1926. In 1943, the university created the Board of Patents to oversee patenting. Further developments between 1950 and 1975 included the establishment of the University Patent Fund to finance patent-related expenditures; the introduction of the policy on protecting all patents

resulting from sponsored research; and, the requirement of reporting inventions from unsponsored research by students and staff to the UC patent program.

Early success stories of commercialization in UCB came from its engineering and computer science departments. However, when the software company Berkeley Computer Corporation[72] failed, causing losses for UC of $1 million worth of investments, the University became more cautious and decided that it would invest in start-ups only through established venture capitalist funds. Another measure that was adopted was not to accept equity in exchange for the use of its intellectual property to avoid any liability in the event that the licensee company went bankrupt. UC changed this policy in the mid-1990s when it saw the potential capital gains that successful firms could generate (**Kenney and Goe, 2004**).

UC has adopted a combination of centralized and decentralized/distributed approach to manage its technology transfer operations. The Knowledge Transfer Office, under the President's Office, is responsible for centralized system-wide services. Major policy decisions with regard to IP, invention disclosures, and licensing, regulating technology transfer for the entire UC system, are centrally made. All patents are centrally assigned to the 'mother' campus – University of California – instead of individual UC campuses. The individual campus-based semi-independent knowledge transfer offices handles the promotion of entrepreneurship and innovation through various campus-based initiatives. The following discussions indicate the items or actions specific to either UC or UCB.

UC adopts both centralized and distributed approaches as a strategy to enhance resilience of technology transfer operations

UC was among the few US universities which had already been active in patenting and licensing decades before the passage of the Bayh-Dole Act in 1980. In the 1970s, UC's licensing revenues were increasingly attributed to biomedical patents (**Mowery and Sampat, 2004**). During the same period, some other US universities began to assume a more direct responsibility for the management of their patenting and licensing activities. UC established its central Technology Transfer Office in 1978, providing technology transfer services to all its campuses.

Currently, at the system-wide level, there are four organizational units, directly under the Office of the President, providing support to innovation, entrepreneurship, and technology transfer: Knowledge Transfer Office[73], UC Investments (Office of the Chief Investment Officer of the Regents), Research Policy Analysis and Coordination (RPAC), and UC Legal (the Office of General Counsel). Through these offices, the Office of the President exercises oversight of the entire UC system, sets the rules and policies on legal, licensing, and commercialization issues, as well as conducts policy reviews of technology transfer and patenting.

The money received by UC for research is managed by UC Investments. UC investment provides fiduciary oversight. UC receives research funding from federal funds, state and other government funds, non-profits, and private industry. For example, in 2012, Discovery Grant Program, a funding program supported by UC and industry sponsor matching contribution,

inaugurated the first system-wide Proof of Concept Grant program to promote key experiments to demonstrate the strong commercial viability of UC's inventions (**UC, 2011**). Discovery Grant Program has been able to enhance university-industry (U-I) collaborations.[74] In 2016, the Governor of the state of California approved Assembly Bill No. 2664, giving permission to invest US$22 million in UC for the strengthening of innovation and entrepreneurship in each of its campuses (**UC, 2016**).[75] More recently, UC announced the Governor's decision to propose the largest state investment in UC's history, i.e., more than $807 million.[76] Private funding gifts are channelled to venture funds to support programs such as start-up and technology seed funding, lab and incubator space, and opportunities in internship. UC Investments has incorporated material environment, social, and governance risk factors into its investment process to better anticipate risk-adjusted returns.[77] UC Investments also manages the equity acquired through campus licensing arrangements. Equity is held in the name of the Regents of the UC and any proceeds are returned to the campus.[78] In 2015, UC Investments planned to invest over $20 million in various investment funds aimed at helping promising seed and early-stage companies coming out of the UC campuses. UC has also made a separate investment of $250 million in a new venture capital fund whose primary purpose is to support start-ups initiated by UC community entrepreneurs. Former UC President Janet Napolitano remarked that UC is committed to investing "in all elements of technology commercialization: patents, proof-of-concept, early stage investment in UC start-ups – everything that can help move our research in the market…"[79] It would be interesting to ask in interviews whether UC Investments monitors fund usage and evaluates company performance as part of its fiduciary duty and how it carries out this duty in this regard.

RPAC is a unit under the Vice President for Research and Innovation (formerly, Vice President for Research and Graduate Studies, under which RPAC was first established during the fiscal year 2008-09 (**UC, 2009**)), responsible for supervising and assisting in the development, interpretation, and implementation of policies and external rules governing research projects at UC that have received external funding.[80] The Office of the Vice President for Research and Innovation aims to leverage the scale and diversity of UC's ten campuses, five medical centers, and three affiliated national laboratories to promote the culture of entrepreneurship across the entire UC system. Its priorities are to stimulate system-wide innovation and creativity; invest in infrastructure that promotes innovation and entrepreneurship; to identify and support entrepreneurs who intend to establish companies; and, actively promote the culture of entrepreneurship.[81] UC Legal provides system-wide legal services, including representation, advice, research, and training. It also advises the Board of Regents, administration, and staff on legal matters.[82]

In 2018, the Knowledge Transfer Office was established in the Division of Academic Affairs which is under the Office of the President in order to improve the collaboration between the Office of Innovation and Entrepreneurship and the Division, and to enhance innovation and knowledge transfer from all UC sites (**UC, 2018**). The Knowledge Transfer Office supports the knowledge transfer operations in various UC campuses in terms of the provision of information systems, legal services, assistance in financial and IP management, as well as the tools to connect external partners to UC's inventions.[83] The technology transfer office is a

boundary-spanning organization, bridging the gap between university scientists and industry firms. The main roles of university transfer offices is to determine which research results are patentable, how to market these discoveries to industry, and how to incentivize faculty to participate in commercialization activities (**Youtie and Shapira, 2008**).

In the 1990s, the UC knowledge transfer program saw a change of approach from a highly centralized network to a decentralized, or distributed, network of campus-based technology transfer programs. Initially, technology transfer services for the various campuses were centrally provided by the Technology Transfer Office, located in the San Francisco Bay Area. The centralized approach provided the advantage of being able to concentrate resources in a specific program and facilitate its early success (**Bennett and Carriere, 2007**). Research programs in the different campuses grew in the 1980s. The lack of direct connection with researchers and the technologies at the distant campuses made it difficult to maintain a highly centralized structure. While UC maintained a central transfer office, it also began in the 1990s the process of setting up local offices of technology transfer on each of the campuses. In 1990, UCB and UC Los Angeles each established local transfer offices. UCB set up the Office of Technology Licensing. Since 2004, it has been called the Office of Intellectual Property and Industry Research Alliances (IPIRA).

Former Executive Director of the Knowledge Transfer Office, William Tucker, is the term 'collaborative management' to describe the organizational structure for technology transfer program in UC which consisted of the combination of centralized and distributed elements (**UC, 2013**). UC's Office of the President, the 10 UC campuses, and Lawrence Berkeley National Laboratory share the responsibility for UC's technology transfer program. Tucker noted that UC's decentralized campus-based licensing operations, enabled it to weather the severe global economic downturn in 2009 (**UC, 2009**). In addition to the central Knowledge Transfer Office under the UC Office of the President, each of the UC campuses has a technology transfer office which functions relatively independently of the others.

UCB's transfer office IPIRA, established in 2004, aims at promoting campus interactions with industry, innovation, and commercial uptake of inventions. IPIRA focuses on marketing university patents to the industry (technology push) as well as attracting private companies through industry partnerships (technology pull).[84] IPIRA consists of two peer divisions, namely, the Industry Alliances Office and the Office of Technology Licensing. The former "works with UC Berkeley employees and companies to enable innovative research relationships, negotiating all research contracts with private industry;" the latter "maximizes the commercialization of UC Berkeley's innovations by establishing relationships and contractual agreements that benefit the public, support campus research and education, and reward inventors for their [e]ngenuity."[85] At the time of writing, IPIRA has a staff size of 18 with some positions labelled 'vacant.' IPIRA is headed by an Assistant Vice-Chancellor for Intellectual Property and Industry Research Alliances, who is a member of the Knowledge Transfer Advisory Committee. IPIRA is directly under the Vice-Chancellor for Research who is also a member of the Knowledge Transfer Advisory Committee.

UCB has an active, entrepreneurial faculty which in 2015 had more than 60 faculty members

who have started one or more companies. UCB has received significant funding for its entrepreneurial activities from government, non-profits, private industries, and from UC. Some examples of funding programs created with private gift are Bakar Fellows and Signatures Innovation Fellow Program. UCB actively promotes industry partnerships through various means, not only through licensing and collaborative research, but also through industry affiliate programs and through its organized research units, namely, research institutes and centers. The Bay Area Council Economic Institute noted that "industry-sponsored research is…closer to the market and to commercial applications than research purely originating through federal grants."[86]

Apart from its own wide range of activities and programs to encourage campus-level involvement in innovation and entrepreneurship, it also has joint collaborations with other campuses. Among others, UCB participates in two – QB3 (California Institute for Quantitative Biosciences), CITRIS (Center for Information Technology Research in the Interest of Society) – of the four projects[87] by the Governor Gray Davis Institutes for Science and Innovation network (also known as California Institutes for Science and Innovation), the largest and most significant UC system-wide initiative, established in 2000 by then-Governor Davis. (Table 3-10)

Table 3-10 Examples of major UCB-based initiatives to promote entrepreneurship and innovation, as well as system-wide programs in which UCB participates and benefits

Type	**Name**	**Brief description**
Competition	Big Ideas@Berkeley	Business plan competition
Training	Berkeley-Haas Entrepreneurship Program	It provides on-campus entrepreneurial training and support for business students
Training and competition	LAUNCH	Start-up accelerator competition, preceded by a three-month long rigorous accelerator training – from scalable business model design to start-up law to networking and pitching investors – accompanied by mentoring from serial-entrepreneur mentors
Bootcamp	Bay Area NSF Innovation Corps	Organized in collaboration with UC San Francisco and Stanford, it is an immersive one-week training course for early-stage entrepreneurs
Startup accelerator	SkyDeck	Located on-campus, it is UCB's first start-up accelerator and co-founded by Hass, UCB's School of Engineering, and the Office of the Vice Chancellor for Research
Course	Pantas and Ting Sutardja Center for Entrepreneurship & Technology	Began in 2005, it is organized by UCB's engineering school, a program of courses and lectures, focused on the study and practice of technology-based innovation and entrepreneurship; it brings together industry, academia, students, investors, and entrepreneurs
Courses and lab space	Jacobs Institute for Design Innovation	Opened in 2015, it provides courses and lab spaces for entrepreneurs involved in design and technology projects
Seminar course	Berkeley IP Lab	Launched in 2015 by Berkeley's law school, it provides seminar courses on IP law to help biotechnology start-ups; supervision provided by recruited lawyers from other law firms and by start-ups for the practice project

Training program	Cleantech to Market (C2M)	Begun as a student-led initiative, it is a semester-long training program in company formation, funding, and licensing provided to clean tech entrepreneurial teams selected from UCB graduate programs; the program receives the support of professionals with deep expertise in relevant areas
Network	Biomedical Manufacturing Network	Formed in 2013 and convened by a partnership of regional entities, it aims to support small biotech companies in their entrepreneurship, manufacturing, and commercialization efforts; participating companies are given access to specialist advisers in IP, fundraising, financial planning and projections, and federal grants
Funding program	Bakar Fellows	Created in 2010 with a gift to UCB, it is an internal competitive funding program to support early-stage start-ups and technology licensing activities by faculty
Funding program	Signatures Innovation Fellows Program	Launched with philanthropic support, it supports project by UCB faculty and researchers in the data science and software fields
Incubator	CITRIS Foundry	Founded in 2013, it is an applied tech incubator providing work space, equipment, prototyping facilities, mentoring, and a small amount of financial support
Workspace	Berkeley Startup Cluster	Organized in collaboration with external entities to help UCB- (and Lawrence Berkeley National Laboratory-) affiliated start-ups to find resources in the local community, including commercial and co-working spaces
Workspace	Design Engineering Collaborative	A student-run initiative, providing student entrepreneurs with on-campus workspace and community support to develop and prototype ideas
Accelerator	Free Ventures	A student-run accelerator providing hardware start-ups with mentors who are primarily alumni and investors, as well as several thousand dollars in support
Funding program	Bay Area Dorm Room Fund	A venture fund created by a private firm providing funding to selected start-ups of currently enrolled or recently graduated students of UCB (and Stanford). In order to mitigate risk, the donor company does not demand the failed company to return investments, but rather if they in future successfully start a company, the debt held by the fund will be converted into equity in the new company
Funding, workspace, and mentorship program	Berkeley Founders Group	Founded by a UCB alumna, it is a private entity fund supported a number of competitively selected UCB start-ups with pre-seed funding, office space, mentorship, and access to business networks

UC proactively engages external stakeholders

UC has formed two advisory bodies allowing it to take advice from both internal and external experts and stakeholders. The internal body is the Knowledge Transfer Advisory Committee, chaired by the Provost and the Executive Vice President for Academic Affairs. This standing committee advises the UC President on the general thrust and strategies in entrepreneurship,

innovation, technology commercialization, and other relevant professional services.[88] The external one is the UC Innovation Council, established in 2014, consisting of investment and business executives, venture capitalists and technology experts outside the university. This external group of advisers supports the UC President's Innovation and Entrepreneurship Initiative.[89] To fully harness the strengths of UC's campuses, research centers, and national labs, the Innovation and Entrepreneurship Initiative identifies important research areas and provides funding to researchers and students in UC who wish to undertake research in any of specified areas.[90] The Innovation Council advises "the university on options that support both the needs for innovation research and education, and further enhance the development of technologies, products and processes that benefit society" (**UC, 2014: 2**). By having an advisory body external to the university, research and technological projects in the university can be aligned with the needs of society, which UCB regards as a matter of strategic importance. The external advisory body can be a means that enables the university to establish a close link with industry, which enables the university research to contribute effectively to economic growth and to solve societal problems (**Wechowska, 2015**).

UCB adheres to a strict conflict of interest policy in licensing

UC has adopted a stringent conflict of interest policy covering various aspects such as invention disclosures, patents, reporting by faculty members of their sources of income, and acceptance of equity in licensing agreement. In accordance with the Standards of Ethical Conduct adopted by the Regents of the University, faculty members are expected to disclose, if any, their outside professional activities or personal financial interests, in order to avoid any conflict of interest between the University's mission and an individual's private interests.[91] Upon the implementation of the 1974 Political Reform Act, originally intended for state employees and politicians, to UC faculty, UC began to require faculty members to report their sources of income. The Chancellors, or his/her delegates, of individual campuses, who report directly to the UC President, have the responsibility for deciding conflicts of interest, instead of the chair of individual departments as previously practiced (**Kenney and Goe, 2004**).

In 2007, UC endorsed the "Nine Points to Consider in Licensing University Technology," making it party to, along with other institutions, to this set of principles formulated by the Association of University Technology Managers.[92] The action also reflected the importance given by the University to conflict of interest issues. UCB has set up a mechanism and taken action to implement these principles and to facilitate timely reporting of conflicts of interest arising from licensing agreements that involve companies founded by faculty, students or other staff. Exclusive license can encourage firm investment and development as well as promote the development of technology (**Baglieri et al., 2018**). UCB has allowed exclusive licenses, but it also implements measures to balance the licensee's legitimate commercial needs and the University's goal of broadly disseminating inventions. For instance, UC schedules regular reviews of objectives set out in the agreement; penalize breach of diligence obligations with termination or switch to non-exclusivity arrangement; allow mandatory sublicensing to third parties to address unmet obligations. UC is also careful to avoid 'patent trolls'[93] ensuring that inventions are licensed to patent aggregators who are genuinely interested in the development of technologies and taking them to the market. UC tries to bear in mind its primary mission of

promoting technology development for the benefit of society, especially when, due to unavoidable circumstances, it has to enforce intellectual property through litigation. In adherence to the above set of principles, UC has committed itself to ensure that the design of licensing arrangements does not impede developing countries from having access to medical innovation due to the product cost, in order to address the unmet needs of neglected patient populations or people located in certain geographic areas.

UC has also formulated its own set of "University Licensing Guidelines,"[94] which it considers as good practices that go into the complex licensing decision-making process. These guidelines overlap with some of the nine principles (as shown in the endnotes), in terms of designing license agreements in ways that are consistent with the University's teaching and research mission; making research results and information readily available to the academic community; and, avoiding conflicts of interest by adopting measures such as assigning the invention case for management to a licensing professional without a financial interest, but if the involvement of the inventor who has personal financial interest is necessary for a successful commercialization due to his/her expertise, his participation should be limited to providing technical or scientific know-how. In addition, UC's technology managers are responsible for, among others, assessing the potential licensee's technical, managerial, and financial capability to bring the invention to the marketplace; and, ensuring the provision of due diligence measures to prevent delays possibly due to the licensee's lack of commitment, and inadequate technical and financial resources. Generally, the value of consideration attributed to the University is, among others, based on the licensee's sale or distribution of products or licensed services. While there are other factors may come into play in the negotiations, such as type and stage of development of technology, patent costs, and royalties, technology managers have adopted a flexible approach, in order to avoid the two extremes of being too aggressive which may impede commercialization, on the one hand, and undervaluing a commercial license which goes against the principle of seeking a fair return, on the other. In sum, these good practices reflect the importance given by the University to its primary mission. UCB emphasizes the importance of avoiding conflicts of interest, enhancing societal benefit of University technologies, developing inventions and taking them to the marketplace, and balancing the interests of stakeholders.

In addition, in line with the Bayh-Dole Act, UC's Patent Policy has made it mandatory not only for all employees, but also for those who are not employees but use its research facilities, and those who receive gift, grant, or contract funds through the University, to assign inventions and patents to the University. Exemptions from this policy may be authorized primarily for reasons such as "when the mission of the University is better served by such action; overriding obligations to other parties are met; and, such exemptions are not inconsistent with other University policies."[95] UC staff are obliged to promptly report and fully disclose inventions to the University which in turn reserves the right to elect to patent or not an invention. If the decision is not to patent an invention, the University may choose to release the patent rights to the inventor barring any overriding obligations to outside sponsors of the research and subject to the inventor's acceptance of the assignment.

It is also important to note that adopts a multi-dimensional metric for measuring licensing performance, in order to cover, among other things, follow-on inventions. Interestingly, UC includes first and secondary filings for its U.S. patent-related statistics in its annual technology commercialization reports.

"...often a *first filing* [emphasis added] in the U.S. takes the form of a provisional application, a type of application which preserves U.S. patent rights and secures the benefits of an early filing date for a period of 12 months at a relatively low cost as compared to the cost of filing a regular application. A provisional filing is likely to be made during the time period when then invention is being marketed to potential licensees. Once a license agreement is in place, the licensee usually bears the cost of seeking and maintaining patent protection. *Secondary filings* [emphasis added] frequently lead to the issuance of multiple patents related to a single invention. In addition to being to converting a provisional filing into a regular filing, secondary filings are often necessary in order to cover all aspects of the invention and to secure the broadest possible patent protection for it, and may include the filing of divisional applications and of continuation applications where new matter is added…" (**UC, 2010: 6**).

In 2009, UC also decided to report the number of inventions licensed or optioned, in addition to the number of executed licenses and options. According to the UC's Knowledge Transfer Office,

"Although a new invention typically is the subject of a new agreement when there is commercial interest in it, various related inventions can be the subject of one agreement and new inventions can also be added to existing agreements. In particular, since UC inventors often make follow-on inventions that are closely related to their earlier work, it is common for existing utility licenses and options to be amended in order to incorporate these follow-on inventions" (**UC, 2010: 11**).

Thus, since the number of inventions licensed or optioned, based on follow-on inventions, captures the new inventions added to existing licensing agreements, it can better reflect the transfer of technology from university to industry. This practice can also perhaps be interpreted as a recognition of the continued efforts made by scientists to develop initial inventions further leading to new discoveries in other aspects of the earlier inventions.

Moreover, UC adopts a multi-dimensional metric for measuring licensing performance. UC incorporates several indicators to measure licensing performance operationalized into letters of intent, option agreements, and licensing agreements. As the Knowledge Transfer Office of UC explained,

"A letter of intent is a type of agreement generally used to confirm a company's intent to negotiate a license and often commits a company to pay certain fees or patent costs while negotiations are underway. Option agreements, playing a similar role to letters of intent, offer a more detailed and formal commitment to protect a potential licensee's interest in an invention while the potential licensee performs in-depth technical or marketing research" (**UC, 2010: 8**).

In addition to the above technology transfer agreements, UC also provides a short-term secrecy agreement with the concerned potential licensees, by which they are given access to

confidential information while they are still conducting marketing research. Such an agreement assists potential licensees in their decision-making on whether or not to pursue a license for a given technology. The above technology transfer agreements indicate the way in which the campus licencing offices interact with the business community. In addition, they show UC's understanding of the difficult decision-making process that potential licensees go through before deciding to license university inventions. While the option agreement can be useful in reducing uncertainty about an invention and help a firm in its decision-making, there is a risk that a firm uses the information it has acquired when it decides not to buy the license (**Macho-Stadler et al., 2007**). It would be interesting to ask in interviews what measures are adopted by UCB to avoid such risk.

UC provides generous incentives to promote faculty engagement in technology transfer

The components of UC's faculty evaluation criteria for appointment, promotion, and appraisal include quality of teaching; new ideas and original scholarly research and other creative works; public service which includes the role played in the administration of the University and formulation of policies; and, excellence in one's professional field of competency. Regarding the fourth criterion, assessment committees are particularly keen on looking for any evidence of the candidate's contribution to the advancement of his/her professional field in terms of coming up with new approaches or techniques in solving professional problems, particularly affecting those of the field's underrepresented groups.

Given the heavy demands that the spin-off formation process can exert on the time and energy of UC's faculty, the University provides a type of leave, i.e., industrial leave, by which UC professors wishing to serve in a corporate office or a start-up company can take a longer leave of absence. However, as a general rule, assistant professors would not be granted leave of absence that exceeds a year (**Kenney and Goe, 2004**). The leave of absence policy of UC indicates that normally only Professors, Associate Professors or equivalent ranks can apply for leaves of absence exceeding one year.[96] For example, according to the leave policy of UCB's Faculty of Electrical Engineering and Computer Science (EECS), a faculty member who wishes to work for an outside commercial company for a period of time that exceeds the one day per week guideline as established by the UC policy should apply for an industrial leave without pay. UCB's EECS encourages and cherishes the involvement of a faculty member in company formation, because this contributes to regional economic development, real world application of scientific research is important, and it is an evidence of a faculty member's impact.

While a faculty member's request for a one-year industrial leave without pay is normally granted without question, UC leaves policy discourages excessive leave defined as any leave exceeding one year for every four years of full time service. UC reminds faculty members considering whether to apply for extension of their leave beyond one year to be mindful of the unfair consequence that fellow colleagues might have to bear such as having to take on heavier teaching and administrative responsibilities. They also need to consider the impact of such extension on the academic progress of their graduate students. When applying for an extension beyond the one year leave of absence, the concerned faculty member has the obligation to assist

his/her department to look for substitute instructors for his/her courses. In addition, the faculty member has to include a plan for the continued financial and mentoring support of their affected students.[97] While the leave of absence policy facilitates faculty in engaging in knowledge transfer and allows them a longer leave of up to one year, or, in the case of Professors and Associate Professors, more than one year, faculty members are also reminded to responsibly look after their teaching, mentoring, and administrative duties in the university. While UCB has implemented a leave of absence policy that enables university scientists to commercialize an idea, it would be interesting to find out (through interviews) whether there is funding assistance provided for hiring teaching relief. In Norway, the government provides a leave of absence scheme that includes a leave of absence grant to cover the cost of the employer, e.g., university or university scientist, for making 20% to 100% of the researcher's position available to work on commercialization project (**Rasmussen and Rice, 2012**).

Regarding the faculty's primary duty of teaching, UC's policy allows for making adjustments to the teaching responsibilities of an academic staff. For instance, in UCB's EECS Faculty, a research appointment is allowed to get a partial relief from teaching to allow the concerned faculty to pursue research work more intensely. A standard research appointment is 25% over an academic year and 50% over a semester. However, EECS's policy does not permit a 50% research appointment for an entire academic year, unless the faculty is the Principal Investigator of a major multi-PI research project or center. Moreover, a research appointment of more than 50% is not allowed without exception.[98]

According to UC's policy on the distribution of licensing income, following the assignment of inventions and patent rights to the University, UC will pay annually the inventor/s 35% of the net royalties and the inventor's campus or laboratory 15% of net royalties. When there are two or more inventors, the distribution of the licensing income among them will be decided by them. Their decision is to be put down in writing. In the absence of any decision, by default, their share of royalty will be equally divided among them.

Summary and Conclusions

Since organizational reforms in 1990s to cope with the increasingly extensive growth of research at the various campuses, UC has adopted a combination of centralized and distributed approaches to the development and management of its technology transfer program. **Bennett and Carriere (2007: 1735)** noted that "the development of a distributed institutional network of campuses that operate under a common policy framework and share certain resources, but function relatively independently" is one of the distinctive features of UC's technology transfer system from which lessons can be drawn for good practices. In particular, **Bennet and Carriere (2007)** observed that under the centralized-distributed network system mix, UC centralized certain elements of technology transfer to minimize financial and legal risks and to achieve economies of scale. On the other hand, UC decentralized other technology transfer programs if proximity to major research centers is advisable to achieve success. Specific elements of technology transfer for which the centralized approach was adopted included financial management, information technology services, legal oversight, and policy analysis and development. These functions are essential, but they can effectively be performed without intensive interface with innovation actors inside or outside the university. Other programs or

activities that were found to be suitable for the decentralized approach included invention disclosures, evaluation, patent prosecution, licensing, and commercialization activities. In addition, individual campuses actively managed their invention portfolios, fostered relationships between inventors and industry firms, and promoted entrepreneurial culture within their local innovation ecosystem.

UCB (and the UC system) has adopted practices that encourage faculty engagement in entrepreneurial activities, particularly through the industrial leave policy, allowing academics who apply to take a leave of up to one year, or even more in the case of professoriate-level above assistant professor, to engage in commercial pursuit, in particular company formation. In addition, faculty can avail of the relief from teaching duty policy of up to a maximum of 50% over a semester, in order to engage in translational activities for inventions developed based on their research work in the university. As pointed out, the above policies are considered to be significantly helpful to faculty, since commercial pursuits require of them a demanding attention, in terms of time and effort.

UC has also adopted a multi-dimensional metric for evaluating licensing performance, which enables a better appreciation of interactions between the university and industry firms, as well as the challenges that went into the negotiations during the licensing process. Letters of intent and option agreements are the technology agreements that are able to effectively capture the aspects of the work done prior to the signing of licensing agreements.

3.3.4. KU Leuven

The university's tight-knit relationship with the city and its research institutes, as well as rich funding sources

KU Leuven is closely integrated with the city of Leuven itself. A college town with population approximately 100,000 people, Leuven hosts not only the university, but also other public research organizations that develop tight-knit relationships and research collaboration with KU Leuven, primarily Interuniversity Micro-Electronics Center (IMEC) and Flanders Institute of Biotechnology (VIB). The city has also been home to several major science parks, most of which are built and operated by the university. At present, KU Leuven owns stakes in the Arenberg Science Park and Haasrode Science Park. The former, located in close vicinity to IMEC, aims to commercialize research on micro- and nano-electronics originating from both the institute and the university. The latter, meanwhile, hosts a large proportion of KU Leuven spin-offs, as well as major business operations by multinational corporations, notably NXP (Netherlands) and Terumo (Japan). In partnership with Leuven municipal government, as well as municipal authorities of neighbouring cities like Genk, Hasselt, and Tienen, the university is in the stage of developing three additional science parks, with one currently under construction and the other two under intensive planning.

Funding schemes to support research, technology transfer, innovation, and entrepreneurship in KU Leuven are also abundant. Under the Leuven Research and Development (LRD), the

university's technology transfer office (established in 1972), there are two organization units that administer funding information and application for KU Leuven researchers, as well as legal, administrative, scientific, and financial support. The former, Flemish and Federal Government Funding Unit, manages project funding administration for schemes by Flemish and Belgian federal government.[99] Relevant funding agencies of these authorities are Flanders Innovation and Entrepreneurship (VLAIO), Flanders Research Foundation (FWO), and The Brussels Institute for Research and Innovation (INNOVIRIS), a Brussels-based institution that conducts scientific research and engages in technological innovation. Of those three agencies, VLAIO offers the most comprehensive support, with funding and collaboration options with high-technology small- and medium-sized enterprises (SMEs), research agreements with Flanders Make, IMEC, VIB, and VITO (Flemish Institute for Technological Research).[100] The latter, European and International Government Funding, offers similar services, with a specific focus on schemes offered by European Union (EU), United States, United Kingdom, etc. Notable examples include EU Horizon 2020 (to be replaced by Horizon Europe), Marie Curie Postdoctoral Fellowships, funding schemes offered by US federal government research agencies (such as National Institutes of Health), European Institute of Innovation and Technology (EIT), Wellcome Trust (based in the UK), etc.

All-out holistic assessment approach in faculty recruitment and promotion policies

The university's policies on faculty recruitment and promotion are also interesting in the sense they do not provide specific numerical-based weighting on the hiring and promotion criteria as we observe in the approaches undertaken by Hong Kong universities. In our interview with the LRD official (July 13, 2021), he stated that KU Leuven adopts a very holistic view on university academics, and does not rely on the numerical-based weighting of their work across multiple dimensions with regard to their overall performance. Indeed, these academics – whether prospective or those up for promotion and/or tenure – will be required to submit their CVs to the committees responsible for their recruitment and performance assessment. Here, the CV template must comprise any of up to 55 assessment criteria that these applicants can include under their own discretion. These 55 criteria are diffused across five dimensions that the university looks for from prospective and existing faculty members: research, teaching, service to society, "bio-sketches" (which we will elaborate shortly after), and leadership capacity.

In the research dimension, prospective applicants are required to list out their research publication records. However, in recent years, the committees have been increasingly requesting that these academics also list out – among their publication list – up to 5 'most impressive' journal articles they have written. In addition, the applicants may also elaborate their work and research aspiration for the coming 5 years, as well as their existing research achievements and other forms of recognition given their work.

The second dimension – teaching – focuses on faculty applicants' teaching experiences. The interviewee added that the committees are increasingly looking at not only their course teaching work, but also their participation in teaching workshops, seminars, laboratory sessions with students, as well as other forms of outside-the-course 'lifelong interaction' that they engage with both university and non-university actors. In the CVs submitted to the committee, assessed

candidates may also highlight their efforts to disseminate their expertise through popular press-related activities, such as science communication, education communication, public speaking events, participation in industry-specific workshops, etc. Overall, KU Leuven is increasingly trying to incorporate lifelong learning activities based on OECD standards into the assessment of faculty performance with respect to their teaching.

The third dimension – service to society – is where many of the categories most relevant for knowledge and/or technology transfer are concentrated. Some of the 55 criteria categorized under this dimension include patents, licenses, spin-off creation, etc. Nevertheless, the interviewee added one caveat in this dimension, as commercialization-related KT/TT indicators comprise only a minor fraction of this dimension. Evaluation committees also seek to account for, whenever possible, faculty members' involvement in non-profit activities, e.g. involvement with public agencies, NGOs, university hospitals (specific for academics at the Faculty of Medicine), etc.

Fourth, the 'bio-sketch' section is among the most interesting dimensions considered by evaluation committees. Here, every candidate (whether for faculty recruitment or tenure) is asked to write, in 3-5 pages, a 'sketch' of what the candidates inherently value with respect to their career development and aspiration. In addition, they are also asked to elaborate in details future ambitions, goals, and personal aspirations that they would like to achieve in the coming years. The bio-sketches themselves have to be closely related to the first three dimensions already shown in previous paragraphs. This assessment dimension, according to the interviewee, is particularly suited for early-stage, junior faculty members given their lack of experiences and exposure to academic practices.

Fifth, and finally, prospective and incumbent faculty members are reviewed based on their leadership capacities. Here, candidates are enquired about contemporary issues in the society that strongly deserve consideration for future research and problem-solving. Faculty members seeking and/or having experiences with leadership position at scientific societies, civil society organizations, European Union-funded projects, and various other organizations are strongly recommended to explain in their CVs their perspectives under this dimension.

Beyond these five dimensions, the university is also steadily moving away from individual assessment and increasingly taking into consideration the characteristics of the members comprising these faculty members' research and/or teaching teams. The evaluation committees are especially interested in the dynamics of team relationships among these academic staff (and research students in the case of research groups) and their perception about the assessed faculty members. The committees broadly take into account the dynamics of relationship among the team members over a period of 4-5 years in the case of existing faculty members up for promotion and/or tenure.

Increasingly, similar to other universities studied for this project, KU Leuven is now offering research professorship positions with their own career promotion pathways. While there is no fixed amount of percentage assigned, the assessment committees emphasize a heavier 'weighting' with regard to their reviews of research performance of individuals undertaking this alternative position.[101] At present, out of 1,600+ professors in KU Leuven, close to 10%

(approximately 150-160 faculty members) are currently on research professorship track.

Open encouragement for faculty members to engage in outside practices

In terms of engagement with outside practices, KU Leuven largely conforms with the existing norms of adopting 'one-day-a-week' policy by most other research universities worldwide. However, despite the university's adherence, there are some interesting caveats that we learned from our interviewee. In general, with respect to the 'service to society' dimension in faculty recruitment and performance evaluation, outside practice activities are not rigorously defined as such. Instead, the common practice is that the more senior the faculty members are, the more they are expected to perform outside practice activities, e.g. serving as a member of board of directors, starting a consultancy, establishing a spin-off to commercialize research, etc.

Nevertheless, in order to avoid potential conflicts of interest, faculty members are required to declare their outside activities for the upcoming academic year and submit the declaration form to the university council for reviews and deliberation. Specifically, faculty members must indicate whether their positions – in relation to outside practices, e.g. as member of boards of directors or part-time engagement with start-ups – are remunerated, without having to specify the amount of financial compensation offered. In case university council members do identify potential scope for conflicts of interest, the council members will immediately request a one-on-one discussion with the faculty members of concern. Council members reserve the final rights to either approve or reject faculty members' declaration of interests. The more active the academic staff are, the more they are required to declare and elaborate their interests in detail. Even academics who do not participate in outside practices are also required to fill in their declaration forms and submit them to the council.

Alternatively, faculty members may request that their academic appointments be reduced from full-time to part-time basis (to 50-70% of what they normally do in KU Leuven). In the circumstances where faculty members undertake public service or government positions, they may request a further reduction of their academic duties to only 20-50% of the normal level.

There may be concerns that faculty members and/or university researchers in general, when collaborating with industry actors in their outside work practices, may be unscrupulously exploited by their counterparts (**Perkmann et al., 2019**). The interviewee shared with us about preemptive action undertaken by KU Leuven LRD in order to mitigate the possibility of such exploitation as shown below:

"That's why we hire a large number of lawyers [in LRD]. Everything [about the contracts] must follow the terms and clauses already stipulated in the contracts. Say, researchers are allowed to publish their results from U-I collaboration. Of course there is a lot of tacitness, and contracts are inherently incomplete. That being said, we are in continuous contact with researchers executing the contracts. In case the contract leads to dysfunction, they will report to us, and we will reach out to the industry partners. Oftentimes, we just break the contracts. We have been asked to break the contracts, or at least tell the industry partners to behave themselves." (Anonymous. 2021. Interview with a technology transfer official. July 13, 2021)

Sustainable IP policy to support university research (and broader regional development)

Similar to other universities we have studied, invention based on university research that utilizes university resources at KU Leuven must be fully disclosed to the LRD. Under such circumstances, only the university – and not the inventors – have ownership rights over the resulting IP. In return, as mandated by Belgian law, the university is obliged to pay a certain amount of royalty income to university inventors. According to the interviewee, the share of licensing income paid to these inventors is based on the cumulative amount of income within four specified criteria listed in Table 3-11 below.

Table 3-11 Distribution of licensing income to KU Leuven inventors

Cumulative amount of licensing income	Proportion of income paid to inventors
Below 5 million euros	40%
5-25 million euros	30%
25-50 million euros	20%
Above 50 million euros	10%

Interpreting from Table 3-11 above, we learned that the higher the cumulative licensing income resulting from these inventions, the lower the income proportion will be paid to the respective inventors. The interviewee reasoned that such approach is implemented partly in order to allocate sufficient financial resources to support KU Leuven's infrastructure, development, and other supporting funding grants, and partly as a requirement of the Belgian law on university technology transfer. In addition, LRD is also the office that deals with the drafting, negotiation, and signing of licensing and consultancy agreements. How LRD sets the pricing on licensing deals is contingent on industry contexts and characteristics of the organizations that initiate the licensing with KU Leuven.

Given KU Leuven's principle that university inventions eventually should be owned by the university, they – in general – are less welcoming of the idea of patent co-ownership with industry partners. Despite the finding that university-industry co-patents are shown to be a promising indicator for firms' future valuation (**Belderbos et al., 2014**), there have also been concerns about the potential scope of disputes and conflicts of interest with co-owned patents (**Hagedoorn, 2003**). The university is seemingly concerned in particular with the latter, as one of the co-owners may unilaterally develop the technology unbeknownst of the other co-owners. The quotation below highlights the interviewee's concerns with such patents:

"[At KU Leuven] we have almost no patents [that are] co-owned with industry. The reason is that industry doesn't like co-owning patents with universities. Once you co-own, you give mandate to one of the owners to exploit the patent. For example, if a pharmaceutical company owns a patent with KU Leuven, and they want to do something, they need our agreement. Even then, KU Leuven can still withdraw their mandate, and this company will run into problems. Our approach is that either we own the patents and provide exclusive licensing deals with the

firms, or we transfer the patent rights to them. We are pretty binary in this respect: either we own or we fully transfer [the ownership]." (Anonymous. 2021. Interview with a technology transfer official. July 13, 2021).

Nevertheless, there are exemptions when it comes to inventions jointly developed by researchers at KU Leuven and their counterparts at government-funded strategic research centers (namely IMEC, VIB, and Flanders.Make – the third center being a research institute focused on latest innovation in manufacturing technologies). As stipulated by the Belgian government, the resulting patents from these joint inventions are to be co-owned between KU Leuven and any of these centers, whereas the rights to further exploit these patents is fully determined by the Flemish regional government on behalf of these research centers. In other words, patent co-ownership is openly practiced for collaboration between universities and government research institutes.

Another reason KU Leuven is fairly strict regarding the principle of full IP ownership over university inventions is related to their objective of minimizing possible scope for conflicts of interest when ownership rights are transferred to other stakeholders. There may be concerns that university inventors license their technologies simultaneously to their own spin-offs, as well as other industrial licensees. In the circumstances where university researchers are entangled in such situation (which according to the interviewee is highly unlikely, given that all licensing requests must go through LRD), they may have violated the contractual obligation with respect to their roles as university employees, and there will be disciplinary sanction mechanisms to deal with such cases. Instead, the interviewee highlighted that actual conflicts of interest, in practice, are much more subtle than the scenario described early in the paragraph, given that researchers – and faculty members in particular – oftentimes run their own consultancy practices. While consultancies are not entitled to KU Leuven's IP, the scientists responsible for these inventive efforts may unwittingly disclose the more tacit (thus less codifiable) aspects of knowledge relevant to the invention to their clients, which may indirectly contribute to conflicts of interest in the future should the technologies resulting from these clients bear an unexpected degree of resemblance with those developed, say, by these academic consultants that subsequently build their own spin-offs. In such scenario, the interviewee acknowledged that KU Leuven LRD has little control over these potential issues, and 'has no view' about the true extent of such phenomenon.

A technology transfer office fully integrated with the university's interdisciplinary lens

At present, knowledge and technology transfer activities at KU Leuven are performed by Leuven Research and Development, or simply abbreviated as LRD. Established in 1972, LRD – one of the earliest TTOs in Europe – has been pioneering unique models in integrating industry linkages with academic research. LRD operates as a highly autonomous unit in the university, for which the division determines their budget and human resource management largely under their own discretion (**Debackere, 2000; Debackere and Veugelers, 2005**). The office itself is also highly decentralized, exemplified from their 'matrix' model of integrating LRD central operation with hundreds of faculty members from different faculties grouped

under over 80 ‘divisions’, which are structured in accordance with their scientific and technological specialization (**Debackere and Veugelers, 2005**). By and large, each of these divisions is interdisciplinary and autonomous by its own virtue.

LRD is currently led by Koenraad Debackere, a management professor and innovation expert based in the Faculty of Business and Economics. Interestingly, Debackere continues to serve as LRD director and a full-time professor simultaneously. He has authored multiple scholarly works that describe KU Leuven’s unique approaches to knowledge and technology transfer, as illustrated from the references above.

The main strategy employed by LRD central administration in maintaining close contacts with these divisions is to utilize the role of ‘innovation managers’. Supported by Industrial Research Fund (IOF), which is a special university fund by the Flemish regional government worth €52 million to support translation from academic research to industrial and commercial application, these managers – also known as IOF Fellows – serve as important bridges between academic members of these 80-plus divisions and LRD. At present, IOF supports 41 areas of specialization under 7 areas of interest, led by 35 innovation managers (also known as IOF Fellows). Some of these managers are responsible for two areas of specialization. As Table 3-12 below demonstrates, every one of these innovation managers is specialized in niche technological areas that closely align with the research scope performed by these LRD divisions.

We asked the interviewee whether there are concerns over potential differences that arise between researchers in the LRD divisions and these innovation managers regarding the perception about the potential commercial value of technologies being researched on, and the interviewee provided his response as shown from the excerpt below:

“IOF is not independent of LRD, but is supervised by LRD. IOF managers are co-selected by LRD and Research Policy Office [of KU Leuven], and are always embedded in the LRD divisions. They do not work against LRD, [and indeed] they cannot do this, because they are a part of the KU Leuven ecosystem.” (Anonymous. 2021. Interview with a technology transfer official. July 13, 2021)

Table 3-12 Areas of interest supported under IOF for knowledge and technology transfer

Area of interest	No. of innovation manager	Specialization
Culture	1	• Musical heritage
Energy, materials & chemistry	8	• Industrial ecology • Sustainable chemistry • Membranes & functional surfaces • Sustainable energy and intelligent

		energy • Innovative materials for a circular economy • Materials performance & non-destructive testing • Functional nano-scale imaging • Valorization of side and waste streams
Economy, law & society	1	• European Institute of Technology (EIT) Health, EIT RawMaterials, and EIT Food
Manufacturing & ICT	8	• Dynamics of mechanical & mechatronic systems • Computer security & industrial cryptography • Leuven ICT research center • Advanced manufacturing • Computer Science – Distrinet • Microelectronics and sensors (MICAS) • Declarative Languages & Artificial Intelligence
Medical technologies	6	Medical imaging research center Clin-IC: Medtech Solutions for Patients Skeletal biology and engineering Integrated diagnostics & life science research tools Center for Dynamical Systems, Signal Processing, and Data Analytics (STADIUS) Leuven Health Technology Center
Biosciences, food and agriculture	5	• Leuven Institute for Beer Research (LIBR) • Agrifood Industry 4.0

		• Food LFoRCe • Postharvest Technology • Food chemistry and biochemistry
Human health	12	• Center for Drug Design and Discovery • Molecular virology and drug discovery • Prevention and treatment of viral infections • Antivirals and therapeutics • Parkinson's disease drug discovery • Zebrafish platform for drug discovery and safety • PharmAbs – KU Leuven Antibody Center • Functional genomics and proteomics • Center of Microbial and Plant Genetics • Cytogenetics and genome research • Skeletal biology and engineering • Integrated diagnostics & life science research tools

LRD has also been openly encouraging university-industry collaboration for decades. From a 2019 LRD report (titled "Advancing the Impact of Research Results"), we learned that back in the 1980s and 1990s, LRD's arrangement for university-industry collaboration was that the office entered into bilateral agreements with industry partners, by which the resultant intellectual property from the jointly developed technologies was subsequently conferred to these firms, in exchange for the naming rights of university researchers as inventors on these patents, as well as appropriate bonuses whenever these patents were licensed to other entities. Subsequently, this practice was considerably adjusted in order to provide more favorable outcomes for academic scientists, as well as to encourage them to patent on their own accord.

Another interesting aspect about LRD – particularly about the research divisions – is that each of these 80+ groups enjoys a high degree of autonomy in their financial and resource management, as well as dealing with knowledge and/or technology transfer activities. Faculty members in these divisions have their own discretion in making use of the resources to support and finance early-stage development and research exploitation projects.

In case the investigators do not have sufficient funding for securing intellectual property for their inventions, they can apply for subsidies from KU Leuven Patent Fund, with fees payable only after the resulting patent(s) is/are licensed to external entities. Furthermore, these research divisions may also access technology transfer platforms offered by LRD, many of which are generously funded by local governments and European Union funding schemes. Two notable examples of such platforms are Center for Drug Design and Discovery (CD3) and PharmAbs (a transfer platform focused on development of monoclonal antibodies).

There have been concerns over whether faculty members that are preoccupied with science and technology commercialization activities may do so at the expense of their research and teaching obligation (**Dasgupta and David, 1994; Slaughter and Leslie, 1997**). Thus far, in the case of KU Leuven, this does not appear to be the case; a study by **Van Looy et al. (2006)** of the university's inventors demonstrates that academic researchers actively engaged in patenting activities, in general, are more productive in terms of scientific publication output. Indeed, faculty publishing and patenting are oftentimes complementary.

Strong focus on promoting academic entrepreneurship through spin-off formation

KU Leuven pays strong attention on supporting the establishment and development of spin-offs that commercialize university research. The university defines a spin-off as "a company that executes technology transfer by which the university's intellectual property is transferred, translated, and subsequently commercially utilized, whether in the form of goods and/or services". Unlike what we observe from Hong Kong universities, which explicitly differentiate 'spin-offs' from 'start-ups', such distinction does not apply in the case of KU Leuven. As long as these companies are created within the university premises, they are treated as spin-offs. Both the founder(s) and research group(s) may generate financial gains from these companies through their equity stakes, the degree to which depends on several major factors, such as the technologies' potential returns, IP protection, the presence of commercial contracts, profiles of the spin-offs' management team members, etc.

Prospective founders – whether they are academic staff, researchers, or students – who aspire to build such spin-offs are encouraged to have discussions with their respective 'innovation managers' (IOF Fellows) about the technologies they aim to commercialize. As a follow up, LRD issues guidelines to the founders about business plan preparation, and based on several rounds of iteration, the Division will calculate the amount of financing that these early-stage companies require. A commonplace start-up funding option offered by LRD is Gemma Frisius Fund, a seed capital fund jointly established by KU Leuven, BNP Paribas, Fortis Private Equity, and KBC Bank to provide early-stage financing to these enterprises.

On paper, a faculty member can work full-time for both the spin-off and the university, but KU Leuven has made it explicit that such practice is not encouraged. For academic staff who insist on building the companies in their early stage, LRD suggests that the staff engage in both academic and commercial work on a part-time basis, with an additional condition that they do not receive basic research grant(s) throughout their engagement period.

Furthermore, the university has also warned that academic staff simultaneously involved in spin-off founding activities and contract research may be liable for future conflicts of interest.

Such conflicts may arise particularly due to the content of the technologies/knowledge transferred to both the licensee(s) and the spin-off(s), which may have a substantial overlap. Given such concern, KU Leuven strongly advises faculty members not to engage in these activities at the same time.

Over time, these spin-off(s) will transform into business entities that are separate and independent of the university. Nevertheless, one additional perk of being a KU Leuven spin-off relates to their entitlement to exclusive licensing arrangement with the research team(s) responsible for creating – and subsequently transferring – the technologies. Such arrangement is made possible so long as both parties have established boundaries on aspects of the technologies to be maintained by the researchers, and those acquired by the licensees.

The LRD – in collaboration with KU Leuven's Student Career Center – also offers a comprehensive entrepreneurship training program (titled "KU Leuven KICK") for the faculty, students, and alumni. It offers major and/or minor courses in entrepreneurship and technology innovation, as well as postgraduate programs for final-year students aspiring to be entrepreneurs, particularly those in science and engineering departments. KU Leuven KICK also provides a special program ("Postgraduate Tech Innovations in Ventures & Teams") by which final-year students can enroll in postgraduate courses that directly lead them to build start-up teams centered on technologies of their expertise. Beyond courses and postgraduate programs, KU Leuven KICK also organizes workshops and competitions, such as Product Innovation Project (which relates to problem-solving approaches in incumbent companies), Learning Garage AR/VR (which assist faculty, students, and staff with designing business plans and presenting technologies to broader audience), and KICK Challenge (business plan competition centered on UN Sustainable Development Goals / SDGs).

Whether a university, through their spin-offs, can transform their respective locality into a burgeoning business ecosystem, however, remains inconclusive (Clarysse et al., 2014). Based on their studies of over 130 technology spin-offs in the Flemish region – where KU Leuven is based, the authors found no significant evidence that universities play a strategic role as actors bridging knowledge ecosystem with business, commercial ecosystem. In other words, there is no guarantee universities are best positioned as strategic actors that catalyze the commercialization of research into tangible economic outcomes. In this regard, the scholars strongly recommended that the region diversify their funding options beyond the existing, predominantly government-funded schemes.

Strong emphasis on technology transfer through spin-off formation for regional development and societal impact

Figure 3-6-Figure 3-9 below are screenshots based on the "Advancing the Impact of Research Results" (2019) report that LRD staff shared with us. The report did not provide any numerical figures beyond the graphs, but these pieces of information remain illustrative in highlighting the dynamics of knowledge and/or technology transfer activities performed at KU Leuven. One obvious pattern we observed across the figures is the near-exponential growth of LRD by the end-1990s/early-2000s, particularly in LRD's financial turnover, number of researchers working for LRD divisions, and the cumulative count of university spin-offs and employees.

LRD's speedy growth in turnover and number of employees also appears to reinforce each other, much of which is attributed to LRD's unique approach in integrating research teams and specialization with their objectives (Debackere and Veugelers, 2005).

Invention disclosure and patenting activities also recorded significant growth throughout the 2005-2018 period, but the pace was comparatively slower than what we saw in the number of new collaborative research contracts and university spin-offs. It appears that with respect to technology transfer approach, KU Leuven has not been highly reliant on patenting and IP licensing alone, but has proactively sought to disseminate impacts of their research through company formation. The amount of financial support that these spin-offs receive, in return, has also been substantial: throughout the same period (as shown in the beginning of the paragraph), these 120+ spin-offs have attracted external investments – beyond Gemma Frisius Fund and KU Leuven's other schemes – that are cumulatively worth over €1 billion. We interpret this phenomenon as one by which the university's technology transfer office does not aim to limit their main activities to patenting and licensing, given that patenting offers no guarantee of technological application, let alone commercialization (Geuna and Muscio, 2009).

Figure 3-6 LRD's annual total revenue (1975-2018)

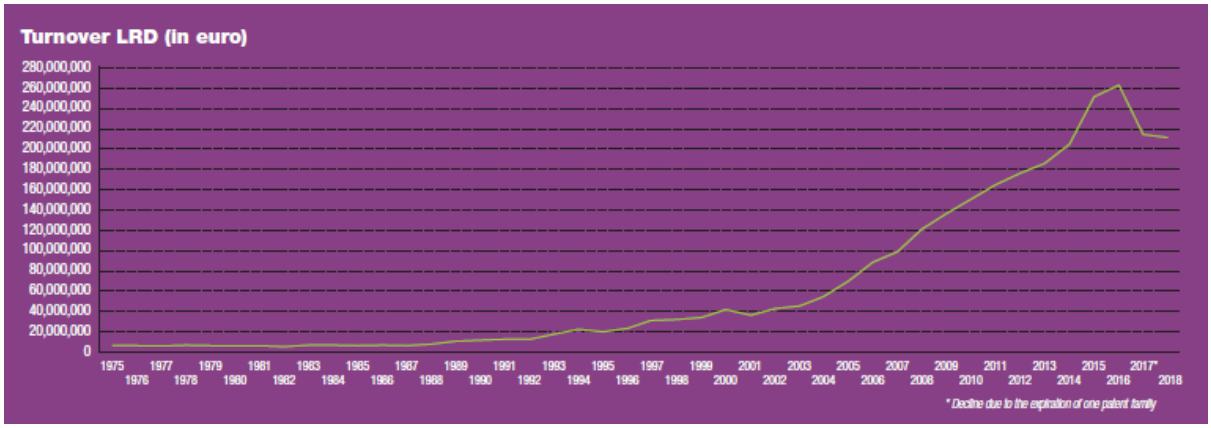


Figure 3-7 Number of researchers and supporting staff at LRD (1984-2018)

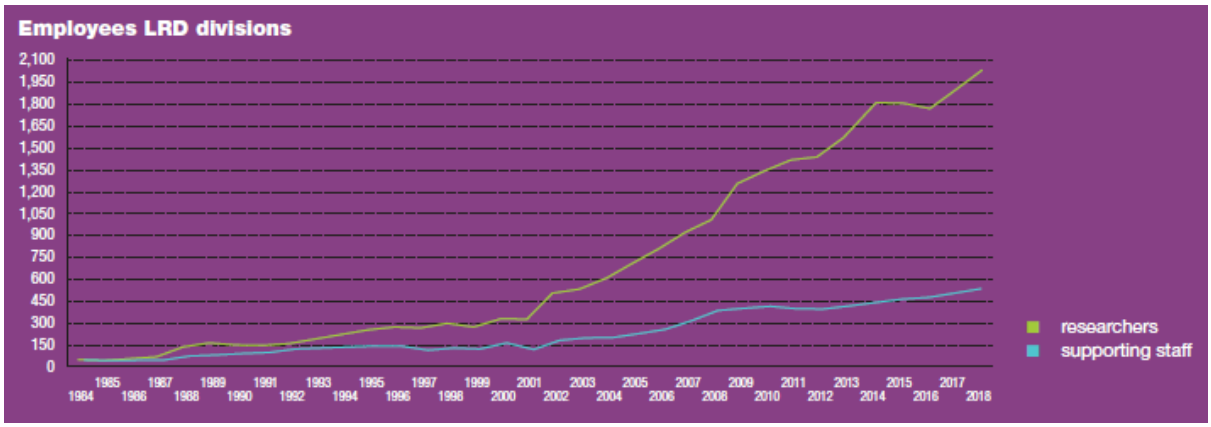


Figure 3-8 Number of new collaborative research contracts (2005-2018)

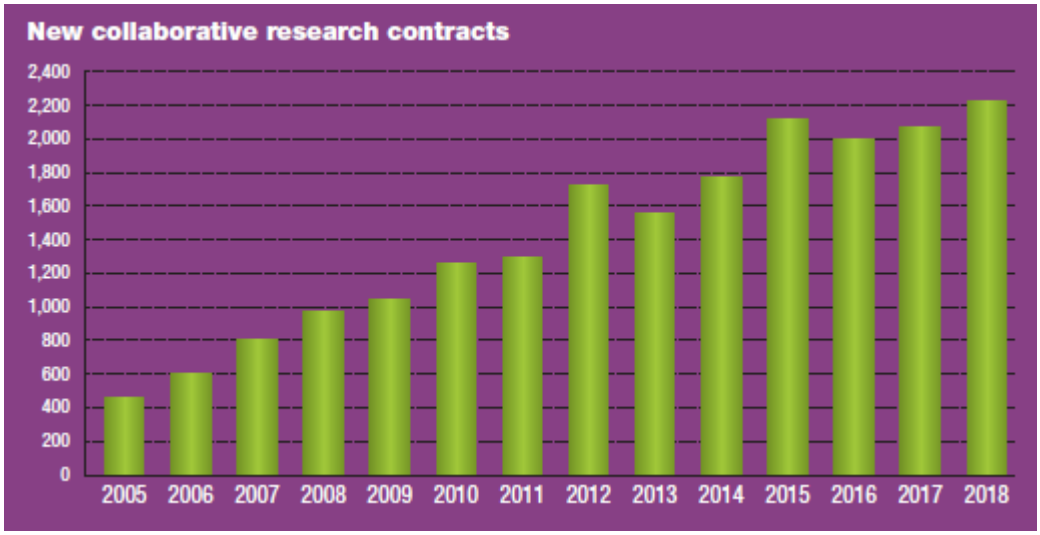


Figure 3-9 Number of new invention disclosures and patent families (2005-2018)

Two illustrative success stories of KU Leuven-generated spin-offs are LayerWise and reMYND. LayerWise is an additive manufacturing (3D printing) company with an emphasis on medical implants based on selective laser melting technology (a technique that transforms metal powder into metal objects). It was established in 2008 based on PhD research by Peter Mercelis and Jonas Van Vaerenbergh. As stated in the "Advancing the Impact" report, the two founders credited LRD for providing them with a wide range of comprehensive assistance, from business plans to seed capital, as well as other additional support in performing R&D activities by other related research divisions of LRD. Having been acquired by US-based 3D Systems, one of the world's largest 3D printing companies, the company has now been able to substantially expand their business operation; as of 2019, over 200 staff have been working full-time for LayerWise.

The story of reMYND also demonstrates to us the potential benefits of interdisciplinary collaboration. The company was established in 2002 by researchers from two LRD research divisions, namely Experimental Genetics Group and Functional Biology Laboratory. The two teams have been collaborating closely on transgenic mice for Alzheimer's disease (AD) modeling and in-vitro testing of novel drug compounds against the disease. The rising need for medical treatments against AD has resulted in a surge of demand for transgenic mice for drug compound trials, creating a niche area that reMYND subsequently exploited. At present, the spin-off has been collaborating with major pharmaceutical companies, notably Novo Nordisk, a Danish-based multinational corporation, through their licensing of these transgenic mice models. At present, reMYND is expanding their business into clinical trials on diabetes-related therapeutics.

The interviewee further added that at present, LRD has ownership rights over 650 patent families, by which approximately 80% of them have been – or are being – exploited in collaboration with industry through either licensing arrangements or transfer of ownership

rights, whereas the other 20% have yet to be utilized. A disproportionate majority of annual licensing contracts (which the interviewee estimated to be above 4,000 per year) are executed for large enterprises, whether from Belgium, any European country, or global multinational. Among the large enterprises, the proportion between Belgian and non-Belgian enterprises is roughly equal on a nearly 1:1 ratio, in total comprising more than 80% of all commercial licensees of KU Leuven's patents. The proportion of small and medium enterprises (SMEs) among for this category is only about 15-20%, on average, annually. Most of these SMEs are technology-intensive companies, with a particular concentration in biotechnology and ICT.

Summary and Conclusions

KU Leuven has, for decades, been a major organizational actor in Belgium's innovation system (Debackere, 2000; Debackere and Veugelers, 2005). Bulk of KU Leuven's achievements in knowledge and/or technology transfer could be attributed to the role played by Leuven Research and Development (LRD), which functions not only as the university's TTO, but also as their central hub for the coordination of research activities and agenda with various departments and faculties within the university. KU Leuven also prides itself as a 'professor-run university', as demonstrated by the dominance of faculty members in the major leadership positions within LRD.

KU Leuven's importance has been particularly significant for the regional innovation system within the city of Leuven and the broader Flemish region. As already mentioned in the beginning of the case study, the university is currently operating two science parks in Leuven, and is collaborating with other municipal governments to build three additional such zones. The university is operating several start-up incubators that are focused on university spin-offs commercializing research that originated at KU Leuven. While the university does not encourage the practice of joint patenting with industry players, KU Leuven actively partners with two major government-funded research organizations – namely IMEC and VIB – on collaborative research in emerging technologies.

The university's significant contribution on both the national and regional levels is – by and large – enabled by their unique approach in assessing the performance of their faculty members. Instead of relying on numerical weightings of assessment criteria, KU Leuven conducts their evaluation of individual academics in five dimensions (research, teaching, service to society, 'bio-sketch', and leadership capacity). Each assessed faculty member is allowed freedom to elaborate on any of up to 55 criteria comprising the five assessment dimensions; in this regard, commercialization and knowledge/technology transfer form only a part and parcel of the evaluation indicators. KU Leuven also takes into consideration faculty members' individual aspirations and expectations with respect to their research activities, their commitment to lifelong education (beyond the classroom), as well as their relationship with their fellow research team members, colleagues, students, and other participants over the matters of knowledge dissemination.

3.3.5. Tel Aviv University

Close historical linkages between the university and the city

The university's annual reports have frequently highlighted the rich partnerships between TAU and the city of Tel Aviv. Much of the collaboration could be dated back to not only 1956 – the year the university was formally established, but also to 1934, when the university's predecessors launched 'external courses' (open-space lectures) that allowed the public to participate in intellectual discussions (TAU Annual Report, 2009). Some of the pioneers of these open-space lectures had also been pivotal in helping to establish Tel Aviv in its current form back in 1909, having been dissatisfied with the perceived lack of 'intellectual space' in the city. TAU's contribution to Tel Aviv was not limited to producing high-impact, high-technology alumni and academic entrepreneurs (TAU Annual Report, 2009; TAU Annual Report, 2016). The university has closely collaborated with Tel Aviv municipal government through their contribution to legal service and public policy advocacy as well.

As an illustration, in the university's 2010 annual report, they introduced a case study by which the Faculty of Law succeeded in convincing the municipal authorities to grant exemption for multi-generational low-income families living in the city's decades-old public housing from removal and subsequent bulldozing, as well as provided legal 'clinic' service for these families on a *pro bono* basis. Some of the academics in the Faculty of Public Policy have been involved in proactive advocacy efforts to promote ethnic minorities' rights, primarily those of Israeli Arabs, Ethiopian Jews, etc. A big proportion of the justices in the Supreme Court of Israel could also trace their academic backgrounds to TAU's Faculty of Law (TAU Annual Report, 2010; TAU Annual Report, 2016). Further elaboration about the linkages between TAU and Tel Aviv in innovation and entrepreneurship development will be shown in another subsection of this write-up in the coming pages below.

Overall, the university is strongly proud of being situated in Tel Aviv. Our interviewee, a senior faculty member concurrently serving as a board member of TAU's technology transfer company, Ramot, summarized TAU's collective sentiment in the excerpt below:

> "We [TAU] take a lot of pride of being situated in Tel Aviv. This is TAU's very good selling point to students, given the everything that is happening [in Tel Aviv]. We are located close to hospitals, industries, high-tech firms.. Public relations [in TAU] takes this very seriously. We work very closely with the municipal government in promoting it. For us, this is a big plus. Israeli universities tend to be rated as not very student-friendly, but TAU is quite an exemption, as we give a lot of generous services (e.g. housing, scholarship) to the students. In terms of popularity, I'm confident to say that we are at the top… While the City of Tel Aviv is not represented in our [TAU's] administrative structure, and they don't have any formal influence [with our decision-making], when it comes to new initiatives, we always liaise with the Tel Aviv municipal government, especially in campus expansion." (Anonymous. 2021. Interview with a senior faculty member. August 11, 2021).

Strong support and resources in hiring research talents from overseas diaspora

One of TAU's strengths is also drawn from their ability to recruit scientific and research talents from Israeli and Jewish diaspora across the globe, particularly those in the United States. The university's strategy has been described as one of hiring 'global argonauts', which refers to transnational migrants that constantly move back and forth between their home and host countries (**Welch and Hao, 2016**). A major, illustrative scheme introduced by the university – in partnership with external funding sources from within Israel – is KAMEA Program (Guide for Senior Academic Faculty, September 2018 edition). KAMEA scheme is intended to channel external funding support for recently-arrived immigrant scientists in the country, specifically for those working as research fellows, researchers, or senior researchers.[102]

The university's strong sense of pride of their returnee scientists has been reflected in some of their annual reports, and in particular the 2010 edition (TAU Annual Report, 2010). The 2010 report showcased a select few of TAU's senior faculty members recruited from the world's top universities. What made TAU exemplary, in this respect, was their ability to hire these research talents despite the financial constraints they had been facing given the 2007-2008 global financial crisis and years of cuts on education budget by the Israeli government (TAU Annual Report, 2009).[103] Much of the hiring spree was made possible by 5% pay cuts that were instituted by the university's most senior leaders on their own monthly salaries, which enabled the university to save some of the money subsequently used to attract the overseas Israelis.

Beyond the 5% pay cuts, TAU, together with Israel's other major universities, also established close partnerships with the government and Israeli industry firms to create a joint fund worth 450 million shekel (equivalent to US$120 million) to attract 300 overseas Israeli talents from the world's top research universities (TAU Annual Report, 2010). The financing was divided equally among the tripartite, with the government, universities, and industry donors contributing one-third of the expected capital amount. Part of this strategy is intended to provide additional impetus for talented overseas diaspora to make the most out of the existing economic and technological opportunities back in their home countries (**Kenney et al., 2013**).

Tenure policy that accommodates university staff's diverse career tracks, but provides limited rewards on outside practice engagement

Similar to what we observed in Imperial College London, TAU's tenure policy allows a kind of flexibility that accommodates various career tracks of university staff members. From the recent Guide for Senior Academy Faculty (released in September 2018), the report specifies three different types of tenure track for university employees. The first type, the regular track, is one undertaken by faculty members in the university with both research and teaching obligation. TAU combines both American and British faculty tenure models in this track with academic ranks ranging from Lecturer, followed by Senior Lecturer, Associate Professor, and eventually a Full Professor status. In this regard, both Lecturer and Senior Lecturer positions are equivalent to an Assistant Professor role in the US academic tenure model. Early-career Lecturer and Senior Lecturer appointments are made for successful candidates for a fixed period of three years, and is renewable annually up to a maximum period of six years. The

procedure is closely similar in the case of appointments of non-tenured Associate Professor positions, with a fixed trial period of 3 years, followed by annual extensions up to a maximum of 5 years. The guideline also stated that tenure opportunities are only available for faculty members starting from Senior Lecturer position onwards. Associate Professors granted tenure will be exempt from both the fixed trial period and annual extension reviews. All faculty members who have been appointed as Full Professors are automatically granted with full tenure up to their retirement.

The second track – specifically applied to university employees at the Faculty of Medicine, also the university's largest – is quite similar to the former, and is oriented primarily for academics with professional expertise in clinical research and application. There are two approaches in this track: the regular option (with career progression starting from Lecturer, to Senior Lecturer, Associate Professor, and eventually Full Professor), and the clinical option (from Clinical Senior Lecturer to Clinical Associate Professor and Clinical Professor). The latter is particularly aimed for academic staff at the Faculty of Medicine who also work at university hospitals and/or conduct clinical work at university medical centers.

Finally, the third track – also titled 'Researchers' Track' – applies only for academic staff who strictly perform full-time or part-time research work at TAU. The career progression for a full-time researcher comprises of three stages, beginning from Research Fellow up to Researcher and Senior Researcher. Tenure opportunities are only available for those already at Senior Researcher positions. Otherwise, academic staff under this track are subject to a fixed trial period of three years, followed by annual extension of their work contracts up to a maximum of five years. Part-time researchers are ineligible for tenure reviews, but their work contracts can be extended indefinitely, normally on a per-annum basis.

In terms of faculty tenure, TAU does not establish a fixed set of percentage-based weighting on performance assessment criteria for faculty candidates. From our interview with a senior faculty member, we learned that the university actually once considered applying a fixed-percentage criteria weighting model into faculty tenure evaluation, but it faced serious opposition, and was eventually rejected, by most of the university's faculty members. The interview excerpt below provided further elaboration:

"[In TAU] we have no fixed percentage criteria. Actually several years ago I used to sit on a university committee that once considered to apply a fixed-percentage approach, but it was rejected by most university faculty members because they thought this [fixed-percentage proposal] did not respect academic freedom. Another reason was that we had to consider heterogeneities in academic fields, e.g. life sciences, humanities, social sciences, etc. In reality, promotion is very much based on 'unwritten rules'." (Anonymous. 2021. Interview with a senior faculty member, August 11, 2021).

In this paragraph, we provide further explanation about the 'unwritten rules' as highlighted by the interviewee. Faculty candidates up for tenure promotion must have a minimum number of first-authored publications in Q1 journals in their respective fields. Bonus points will be rewarded for faculty members with journal articles published in peer-reviewed academic journals in the top-90 percentiles (also in accordance with their disciplinary areas). Another

'unwritten rule' mentioned by the interviewee is that tenure and evaluation committees assign a weighting of 75% for research performance-related criteria, 20% from their research funding performance (e.g. their success rate in obtaining grants from competitive funding schemes), and the remaining percentage from "nice-to-have" criteria, such as knowledge/technology transfer activities, serving in government/public service committees, etc.[104]

Overall, it appears that TAU disproportionately favors the academics' research performance compared to other criteria. Indeed, one surprising revelation we learned from our interviewee is that the university hardly takes into consideration faculty members' achievements in knowledge/technology transfer (e.g. patenting and licensing) and entrepreneurial (e.g. spin-off formation) activities. As the senior faculty member further explained in the following excerpt below:

"Personally, I think it is very unfortunate that our university [TAU] assigns almost zero for involvement in knowledge/technology transfer and entrepreneurship… patenting, licensing, spin-offs, serving as government advisers, or working for public service committees.. these are all 'nice to have' criteria, but they are just bonuses. They [faculty members] may be asked to sit as consultants or board members in other companies/organizations, and may be financially rewarded, but they are neither academically rewarded nor promoted as much. In summary, what the [tenure] committees are looking for are mainly number of publications and funding grant amount. Translational research achievements are hardly discussed." (Anonymous. 2021. Interview with a senior faculty member, August 11, 2021).

Our interviewee told us that the same committee he sat in (which once considered a fixed-percentage weighting assessment approach) also did consider allocating some performance credits for faculty members active in patenting and other forms of commercialization of science. However, the university was not overly enthusiastic about the possibility of incorporating this new model, and the idea was eventually not adopted. The reasoning provided by the university administration, according to the interviewee, was that any research outputs that are not peer-reviewed (e.g. patents, pre-print publications) would not be properly subject to rigorous reviews by tenure committees compared to journal articles.

A caveat from our findings is that even excellent research performance by faculty members does not fully warrant their academic tenure and/or promotion, as this process is fully peer-reviewed and conducted at two stages. The first stage entails TAU tenure committees inviting fellow academics from the same disciplinary field(s) of the faculty candidates across Israel to evaluate the latter's research outputs and providing their feedback in terms of their experiences working and/or interacting with the candidates. The second – and more comprehensive – stage involves performance reviews by well-known experts in the same field(s) from outside Israel. Only candidates who have passed the two-stage review process will be granted tenure. As the interviewee said:

"We [Israel] are a small country, and we [the scientists] know each other. If someone is being discourteous [to their colleagues], even if he/she has a strong scientific potential, they [the reviewers] can write bad reviews against these faculty members." (Anonymous. 2021. Interview with a senior faculty member, August 11, 2021).

Another interesting aspect of TAU's faculty structure relates to their fixed salary scale for all faculty members, regardless of their faculties and/or departments and/or their achievements. One incentive for faculty members to 'raise' their salaries is through actively applying for a large number of research funding grants, with which they can obtain bonuses that can be topped-up with their existing salaries. As the interviewee explained in the excerpt below:

"Regardless of your scientific disciplines, salary is flat for all faculty members; [whether] you are in history, or medicine, or engineering, salary is all the same. In the US, a history professor may earn, say, US$80,000 a year, whereas for engineering [faculty], they may be earning US$250,000 a year. It's not the case in Israel, as everyone is paid the same amount. Some professors may earn more due to top-ups from their funding grants, but the difference with TAU's salary base is not very high." (Anonymous. 2021. Interview with a senior faculty member, August 11, 2021).

The interviewee further added that there have been discussions among TAU's academic circles on promoting basic pay following industry contract approach ("the better your research performance is, the higher your pay"). These options are being actively debated among faculty members at the university, but the inclination thus far points to majority of the professors at TAU viewing this proposed idea unfavorably. Their primary concern with the proposed model is that huge discrepancies may exist in pay level even among faculty members at the same department/faculty.

Permission is allowed for faculty members to engage in outside work with strict boundaries

According to the Guide for Senior Academic Staff, TAU faculty members are automatically entitled to these external services without having to secure special permission: 1) one-day-a-week consultancy practices, and; 2) part-time teaching at another higher education institution, at no more than 1/2 of the weekly hours of TAU's. In return, the university has made it clear that faculty members must not engage in full-time external employment under the 4 scenarios highlighted in the bullet points below:

- Employment at other higher education institutions (universities, colleges, etc)
- Involvement in permanent committees of non-academic organizations
- Full-time work as consultants (beyond the one-day-a-week limits)
- Organizational activities at other organizations

The university's reasoning for such restriction is that faculty members' involvement in any of the above scenarios may subsequently hinder their commitment to academia, especially to teaching and research duties. Nevertheless, such restriction does not mean faculty members are entirely barred from engaging in the above practices. Faculty members who insist on getting involved in any of these four activities will instead be required to provide a special written justification to the Rector, facilitated by the Dean of their respective faculties.

Given that engagement in outside practices is hardly considered in faculty tenure process, participation in knowledge/technology transfer and entrepreneurship becomes the primary

domain of university academics who have already secured tenure. As the interviewee elaborated in the excerpt below:

"As [an unwritten] rule, young faculty members that are not tenured yet will not become engaged in KT/TT activities, because traditional academic way of thinking dictates that they should focus on research and funding. [Tenure] committees don't look at this favorable, especially when assistant professors engage in outside practices. Only when they are tenured, [on average] when they are around 40-48 years old, they are the most actively engaged in KT/TT and entrepreneurship. At this stage, being active in these areas no longer jeopardizes their career trajectories. Indeed, many of them are among the best scientists [in TAU]. Some of the professors with fastest promotion are leading translational researchers. They are very efficient in time management… Overall, there is a clear distinction between 'pre-tenured' and 'post-tenured'. Whatever achievements that are outside academia, before tenure, they won't be looked favorably [by the committee]. But once tenured, they become active if this is what they want to. No one will tell you 'do not engage in KT/TT', because it will actually damage your career. But the fact of life is that pre-tenured scientists will focus all their work just on research." (Anonymous. 2021. Interview with a senior faculty member, August 11, 2021).

In addition, all university researchers – regardless whether they have outside engagement practices or not – are required to provide declarations in their annual reports to the university regarding their work practices beyond TAU. Faculty members on unpaid leave are generally also not permitted to engage in outside work practices, unless their outside work relates to taking up public office (government) position.[105]

A technology transfer office staffed by experienced venture capitalists, serial entrepreneurs, and commercialization-active faculty members

Ramot, TAU's subsidiary that also serves as their TTO, has been in existence since 1973. Ramot is responsible in dealing with patent filings for inventions generated by faculty members and researchers at the university, as well as providing resources and assistance on the establishment of spin-offs to commercialize the university-developed technologies. Through Ramot, TAU has been one of Israel's most prolific patenting organizations since the early 1990s (**Breznitz, 2006**). Ramot's distinctiveness, compared to other technology transfer offices we are studying, relates to the dominance of TTO professionals that are seasoned serial entrepreneurs, venture capitalists (VCs), as well as those with decades of industry experience in multiple high-technology companies. Further elaboration is provided in the paragraphs below.

At present, the chairperson of Ramot is Professor Dan Peer. Concurrently serving as Vice President of Research and Development (R&D) of the university, Professor Peer is a researcher with expertise on nanomedicine development for cancer treatment. He is also the director of Laboratory of Precision Nano-Medicine, Founding and Managing Director of SPARK Tel Aviv – Center for Translational Medicine, as well as chair of TAU Cancer Biology Research Center. Together with his research team members, they have invented technologies that resulted in 120 pending and granted patents. Professor Peer is also a scientific co-founder of 5 biotechnology spin-offs that commercialize some of these patents, and sits as a member of

scientific advisory boards (SABs) in 15 life science firms.

Ramot's board membership is also dominated by professionals with multiple firm-founding and VC experiences. Of 14 board members (which includes Professor Peer), 9 of them have at least one of the two experiences [to put in endnote maybe: 6 are serial entrepreneurs, 7 are VC partners]. Some of these professionals also served a stint in the government by advising ministries on Israel's innovation policy and development strategies. The other board members include TAU's current president, Ariel Porat, as well as a former CEO of Ramot, Head of the School of Chemistry (Professor Gil Markovich), and Vice Dean for Research of the Faculty of Life Sciences (Professor Itai Benhar). The dominance of professionals with serial entrepreneurship and VC background in Ramot's board aligns with **Avnimelech and Teubal (2006)** on how these two communities collaborated very closely in Israel's broader innovation ecosystem.

The current CEO of Ramot, Keren Primor Cohen, has been working for the company since 2007. She is an experienced technology transfer expert who has worked in other TTOs in Israel's top research institutes (notably Weizmann Institute of Science). The office's vice presidents for business development also had extensive experience in entrepreneurship and business management: 3 of the 5 vice-president positions are currently filled by serial entrepreneurs who have founded high-technology companies in the past.

Detailed policies on commercialization of university inventions and clear scope of protection of inventors' rights and duties

Similar to most other universities we have studied, Ramot – on behalf of TAU – has clearly stipulated that all inventions making use of university resources, and that are carried out by university personnel, belong to the university.[106] As specified under Inventions, Patents, and Commercialization Regulations (Tel Aviv University, 2015), scientists, whether they are senior faculty members or those primarily on the research track, have obligation to disclose details regarding their invention to the university. In turn, Ramot makes determination as to whether these inventions warrant patent protection.

Authorities on deciding the patentability (proxy for potential commercial value) of these inventions fall under Ramot's special committee, which is separate from the company's governing board. Headed directly by the Vice President of R&D (who concurrently serves as the chairperson of the board), the committee comprises of five senior academic staff. While the university's legal advisor and CEO of Ramot are invited to the committee's regular meetings, only the committee members have the voting rights in deciding matters that pertain under the circumstances listed below:

- Patentability of a university invention
- Objection raised by inventor(s) when their inventions are declared unpatentable
- Objection raised by university personnel in the case of non-inclusion in patent inventor list
- Disputes arising from proportion of contribution by university inventor(s) regarding

the disclosed invention(s)

- Proposed amendments to rules that require consent from TAU's Executive Council

The regulation also clearly stipulated that once an invention is granted a patent right that is assigned to Ramot, the company is the sole entity (on behalf of the university) that has full rights in initiating commercial negotiations, as well as signs agreements, with commercial and/or non-commercial entities (be they corporations, government institutions, charities, etc) that seek to exploit the commercial value of the patent of interest. Ramot will only hand back the IP ownership of these invention(s) to the inventor(s) once the former are no longer interested in further commercializing them. In the case Ramot receives no responses from the inventors within the stipulated period regarding the return of the ownership, the former will declare the invention as permanently 'abandoned', and inventor(s) will have no rights of future adjudication with regard to the IP concerned.

Oftentimes, there may be instances of research collaboration between TAU scientists and their counterparts from other organizations, be they universities, firms, government research institutes, hospitals, charities, etc. In this regard, the regulation also explicitly outlines the possibilities of co-patents should joint inventions occur under such circumstances. In the scenario of a formalized collaboration agreement between TAU academics and outside entities, ownership over the resulting IP to the invention(s) is granted to either some or all relevant parties involved in the agreement, with the percentage of ownership contingent on the content of the concerned agreement. In the circumstance where the collaboration is initiated on a personal basis (by the university scientists), TAU allows joint IP ownership between the university and the collaborating researchers' organizations with the proportion of ownership solely determined by TAU researchers themselves.

Nevertheless, the policy also advises strong caution on faculty members and/or researchers involved in inventive activities for which their content overlaps substantially with those of their scientific publications. In the circumstances where their publications share a high degree of overlap with their patents, TAU academics must consult directly with the Vice President of R&D on the matters of eligibility of disclosing their findings in scientific papers. In other words, these scientists can only proceed with publication efforts of their journal articles after receiving prior consent from the Vice President. The primary aim of such stopgap is to protect the novelty of these patent filings (being one of the three requirements of patent application, in addition to utility and non-obviousness, especially for USPTO-filed patents), as well as the confidentiality principle surrounding the commercialization prospects of these inventions of concern. In case the faculty members do not receive any consent from the Vice President, this automatically implies they can only publish their findings after a 60-day delay period from which the written notices regarding their inventions are submitted to Ramot.

The Regulation also provides details about the distribution of licensing income from these patents to the relevant inventor(s). In this regard, 40% of total net receipts / net income (defined as total gross receipts, or gross income, that is deducted by total expenses and an additional 5% of total gross receipts to cover Ramot's indirect and other expenses) is allocated to the respective inventor(s). Further division of the 40% net income among these scientists is

determined based on the percentage of their contribution to the invention efforts based on disclosure forms submitted to Ramot. Interestingly, the inventors can also request to Ramot to alternatively convert their 40% net receipt shares into research budget (whether for individual or team research efforts), which is administered directly by the university's Research Authority.

The remaining 60% of net income is disbursed from Ramot directly to the university. Of the 60%, one-third of them (20%) is further split into two sub-components on an equal basis. The first 10% of total net receipts is transferred to the Vice President of R&D, who is required to convert his/her shares into a special budget to support TAU's research infrastructure. The other half – also 10% of total net receipts – will be further divided among the inventors in case they are senior academic staff and/or retired scientists engaged in ongoing research efforts in the university as research budget on their own discretion. In the latter case, the President of the university – having been advised by the Vice President of R&D – makes a direct decision over the cumulative amount of funding (not exceeding US$1 million equivalent) that these senior researchers can secure. In other words, portions of any resulting surpluses (when funding amount for senior inventors surpasses US$1 million) are reallocated back to the Vice President for his/her research infrastructure development budget.

The Regulation further clarifies the circumstances where university inventors engage in outside work practices (first, through part-time employment/consulting/sabbatical in another university/research institute in Israel or abroad, and second, part-time involvement in a for-profit commercial entity). As already explained in the previous striking feature of TAU, faculty members wishing to perform outside work engagement must provide written justification to the Rector in advance. Nevertheless, in the situation where faculty members' involvement in these outside work practices potentially result in inventions worthy of IP protection, they are obligated to secure additional approval by the Vice President of R&D in advance as well.

In the situation where an employee uses his/her sabbatical through part-time employment in a non-profit institution, for which their participation may entail some degree of inventive work, the faculty member is required to provide a detailed explanation to the Vice President of R&D regarding his/her scope of duties throughout the sabbatical. As a follow up, the Vice President will contact the institution of the respective person to negotiate an IP agreement regarding the nature of their potential inventions.

The arrangement for faculty members making use of their sabbatical in for-profit enterprises, however, is more intricate. The scope for possible conflicts of interest is greater in this aspect as faculty members may tacitly disclose the content of their university research to their industrial R&D partners, or that they unwittingly assign the university IP to their corporate hosts without TAU's prior permission.[107] To minimize the scope of such conflicts, university academics wishing to be involved in part-time work with commercial firms must also secure prior approval from the Vice President of R&D. In the absence of such consent, the Vice President may request to the Ramot's special committee to hold a special hearing, with the VP having a final say over adjudication of these matters. Even when the requests are granted, the VP – from time to time – has his/her discretion to demand the transfer of information and/or data with regard to the employees' part-time work at these commercial companies, all of which are subject to terms agreed under the agreements between TAU and the respective firms.

Interestingly, faculty members whose sabbatical requests are rejected may also file an appeal directly to the university president, with which the president's decision over the dispute is final and non-negotiable.

An extraordinarily rich innovation and entrepreneurship ecosystem

Another avenue in which TAU and the city of Tel Aviv builds a rich linkage relates to their contribution to the city's innovation and entrepreneurship ecosystem. As an illustration, the university's 2016 annual report (released in celebration of TAU's 60th anniversary) showed that TAU is in Pitchbook's top-10 global university list in terms of producing VC-backed technology start-up founders, Spear's top-20 worldwide university list in producing alumni millionaires, as well as a significant number of successful exits for these technology companies, some of the examples by which (taken from 2015 Annual Report) were shown in the table below. The report also highlighted that TAU, since its inception, has generated over 2,400 inventions, 100 spin-offs, and over 550 licensed patents.

Table 3-13 Notable exits of technology start-ups involving TAU alumni and researchers

Company name	Founder(s)	Relation with TAU	Status
Waze	Uri Levine, Ehud Shabtai	Alumni	Acquired by Google for US$1 billion
Viber	Talmon Marco	Alumni	Acquired by Rakuten for US$900 million
Maker Studios	Ynon Kreiz	Alumni	Acquired by Walt Disney for US$500 million
Check	Guy Goldstein	Alumni	Acquired by Intuit for US$360 million
KAI Pharmaceuticals	Daria Mochly-Rosen	Professor of Life Sciences	Acquired by Amgen for US$315 million

Source: TAU Annual Report (2015)

The fact that many of these companies had subsequently successful exits demonstrated Israel's strong performance as a 'start-up nation' (**Senor and Singer, 2009**). Such achievement was all the more remarkable given their quick rebound after experiencing severe impacts of dot-com bubble in 2001 on Israeli economy that caused the massive wave of bankruptcies of high-technology firms in the early 2000s (**Zilber, 2007**). It was all the more remarkable given that Israel, until the last four decades, had been a less developed country. As our interviewee shared with us in the excerpt below:

“Until the end of the 1970s, Israel was considered to be young and pretty underdeveloped. The government back then invested very little in R&D compared to what they do today, especially in the academia. But beginning in the 1980s, Israel as a country made a strategic decision to be an S&T powerhouse. It was a period when TAU doubled the number of employees in a short period of time. A lot of money was poured into [Israel’s] education system. At the same time, Israeli high-tech industries began to grow a lot, partly thanks to the military. Many of those finishing the mandatory military service would immediately work in high-tech industries, especially in hardware and software industries, followed by biotechnology industries. This is a process that is fueling itself. And for most of the time, [Israeli] government did not support this in a major way. The government does not position itself as a major player in encouraging it.” (Anonymous. 2021. Interview with a senior faculty member. August 11, 2021).

An additional interesting insight from Table 3-13 is that majority of the successful exiting companies were founded by alumni, or former students, of the university. This finding indicates the important role of students and alumni in shaping the dynamics of innovation and entrepreneurship ecosystem in TAU, and Tel Aviv in general. Our interview with the senior faculty member confirmed this proposition, as summarized in the excerpt below:

“Students have been encouraged, at a very early stage, to be entrepreneurs. In TAU, we have many schemes to offer guidance, mentorship, and financial assistance to the students. We want them to be actively entrepreneurial and driving the ecosystem.” (Anonymous. 2021. Interview with a senior faculty member. August 11, 2021).

Beyond Ramot, TAU offers a rich array of resources that supports aspiring entrepreneurs to access university research and obtain funding. One of the major hubs offering such services is TAU’s Entrepreneurship Center (also known as StarTAU), which was established in 2009. The Center provides opportunities for aspiring entrepreneurs in the form of these following services: Open Doors Diversity Entrepreneurship Fund, Student Innovation Hub, Nadal Home for Technological Innovation and Entrepreneurship, as well as participation in various hackathons and competitions, whether organized by the university or externally.

While StarTAU is based in the university, it is a largely independent entity (not a subsidiary unit of Ramot) and does not report directly to TAU. Individuals running the organization – primarily students from computer science and engineering fields – make their own decisions, but are always transparent to the university. This is evident, as illustrated by the interviewee, from the close coordination between StarTAU and Ramot. On average, in every three months, there are constant meetings and regular reporting between representatives of the two organizations. Simultaneously, Ramot does not make any decisions or orders on StarTAU, as the latter is an independent entity.

In addition to StarTAU, some of TAU’s faculties also offer their own specific innovation and entrepreneurship programs, with the scope of support ranging from courses, discussion sessions with stakeholders regarding existing problems to be solved, business pitch competitions, business plan consultancies, networking support with leading technology entrepreneurs / firms / government agencies, etc. Table 3-14 below summarizes some of the existing entrepreneurship-related units and initiatives.

Similar to StarTAU, these faculty-specific programs are run largely independently, and are not subordinate to Ramot. In other words, there is no organized coordination mechanism between Ramot, StarTAU, and these faculty/department-specific entrepreneurship initiatives (except on matters pertaining to IP resulting from university research and commercialization procedures). Nevertheless, every activity in these programs is always reported directly to the university, particularly to the president, TAU's governing board, and the deans. As a whole, TAU does not influence the decision-making processes taking place at these programs.

Nevertheless, recently the university has inaugurated a new center of entrepreneurship ("Center for Entrepreneurship and Innovation") that is directly run by the university administration. This new center was established to enable TAU to initiate large-scale collaboration scientists and industry firms. This is a university initiative that directly reports to the university leadership.

Table 3-14 Other major innovation and entrepreneurship initiatives at TAU

Name	Initiator	Function
Brainboost	Sagol School of Neuroscience of TAU	A program offered by the school to accelerate the development of therapeutics and other novel solutions in addressing brain and other neurological-related diseases through the formation of spin-offs. In addition, Brainboost also offers internship and job-seeking support for soon-to-graduate schools at the school.
Capsula (formerly Center for Innovation in Transportation)	Porter School of the Environment and Earth Sciences of TAU, Smart Mobility Initiative Unit of the Prime Minister's Office	A special initiative jointly launched by the university and the Prime Minister's Office that acts as an intermediary organization between smart mobility researchers TAU, high-technology companies developing smart city solutions, as well as relevant government agencies. It also serves as an incubator for early-stage companies developing smart mobility solutions.
BioMedTech (Biomedical Technology Innovation Program)	Faculty of Medicine of TAU, Sheba Medical Center, Tel Aviv Sourasky Medical Center, Rabin Medical Center	A unit under the Faculty of Medicine (and jointly in coordination with TAU-affiliated medical centers) that provides courses on entrepreneurship and existing medical challenges yet to be addressed. It provides opportunities for medical students and researchers to interact with scientists at TAU and the

		medical centers regarding these unmet challenges. It also offers seed funding and business planning support for early-stage companies seeking to solve these challenges, e.g. prototyping, proof-of-concept, etc.
Collier Institute of Venture	Collier School of Management of TAU	A research institute under the school of management that conducts research on topics related to management sciences, innovation studies, and entrepreneurship. It also provides consultancy services for start-ups and organizes competitions for these early-stage companies.
TAU Momentum Fund	Ramot, Tata Group (India), Temasek Holdings (Singapore)	A new funding opportunity initiated by Ramot to support early-stage companies seeking to commercialize TAU's technologies, especially those at the leading edge, e.g. lithium-ion batteries, cancer immunotherapy, metamaterials, etc.
i3 Equity Partners	TAU, GE Ventures (United States), Qualcomm Ventures (United States), Tata Group (India), Pitango Venture Capital (Israel)	A joint venture capital fund that invests in emerging-technology companies involved in various sectors, e.g. Intenet of Things (IoT), smart city solutions, nanomaterials, etc.
Center for Entrepreneurship and Innovation	The university's leadership board	A very recent initiative announced by the university leaders in November 2018 to encourage large-scale collaboration between TAU scientists and industry partners. Beyond U-I collaboration, the center also seeks to promote social entrepreneurship, expand start-up formation beyond technology-oriented focus, as well as broaden the engagement of ethnic minorities in entrepreneurial activities.

Knowledge and technology transfer performance at TAU: undisclosed statistics

At present, neither of the annual reports we collected nor any materials from Ramot website contained information about the university's financial performance in terms of knowledge and technology transfer activities (e.g. IP and patent licensing; income from collaborative research, contract research, and consultancy; funding for TAU start-ups, whether founded by students, alumni, researchers, and/or faculty members). We asked the interviewee – who at present is a full-time board member of Ramot – about information regarding the figures. Unfortunately, the interviewee is not allowed to disclose the figures to outside parties. As the interviewee explained in the excerpt below:

> "I sit on the board of Ramot. I know these figures, but they are confidential. We report [these figures] to the university leadership and the president, but mainly the lump sum. This information is not publicly available, and we cannot disclose [these figures] to other parties. Even scientists and faculty members [beyond Ramot's board and senior leadership] have no full knowledge of TAU's revenues from knowledge/technology transfer. Even Ramot does not have a full knowledge of how many spin-offs or start-ups, or funding amount, that exist out there beyond what are reported to us." (Anonymous. 2021. Interview with a senior faculty member. August 11, 2021).

Summary and Conclusions

Tel Aviv University has been playing an influential role in promoting knowledge/technology transfer and innovative entrepreneurship in Israel in general, and the city of Tel Aviv in particular. This is evident from the proliferation of entrepreneurship-related initiatives and/or programs at the school and faculty levels, both within and outside the purview of the university's technology transfer unit, Ramot. Such phenomenon is unseen-of in comparison with other university case studies we covered in the report.

Even more surprisingly, TAU's vibrant innovation and entrepreneurial ecosystem has barely to do with their policies on faculty incentives on outside practices; indeed, the university's faculty assessment policy has been somewhat restrictive compared to other policies we studied in other universities. Evaluation of faculty members' performance has been almost entirely driven by research alone, with such approach becoming disincentives for pre-tenured faculty members (especially assistant professors). Nevertheless, such policies do not hinder TAU's broad contribution to the city's – and the country's – innovation system. Instead, some of the university's most renown professors also happen to be academic entrepreneurs (at the position of associate professor and above).

The organizational structure of TAU's technology transfer subsidiary, Ramot, is also one of particular interest worth mentioning. Structured as a company, Ramot is led by a board of members that encompass serial entrepreneurs, venture capitalists (VCs), academics, former government policymakers, as well as individuals having a combination of these roles and experiences. Furthermore, Ramot is jointly led by a CEO (who runs the organization's overall activities) and the board chairperson (who evaluates Ramot's organizational activities and

performance). Interestingly, the role of board chairperson is directly undertaken by the university's Vice President of R&D, and in this regard, the Vice President has enormous powers in managing the boundaries between academic and knowledge/technology transfer practices – ranging from settling on disputes over patent inventorships, deciding the patentability of university inventions, to determining matters of researchers' publication delay arising from overlaps with the content of patent applications. However, Ramot is also different from other university TTOs in terms of their non-disclosure of figures and revenues relating to KT/TT indicators.

3.3.6. University of Tokyo

Introduction

Established in 1877, the University of Tokyo enjoys a long history and its development process of Todai is nicely put into flow chat on the official website. From which the predecessor of Tokyo University can be learned that it was a combination of Tokyo Kaisei school and Tokyo Medical School. Both schools are closely related to the development of the city of Tokyo. In order to cope with the popularization of western advanced science and technology and adopt the cutting-edge academic knowledge in Japan at that time, the Institute for western studies was established in Kaisei school. On the other hand, Otamagaike vaccination clinic was a clinic established in Edo era for the purpose of preventing smallpox and vaccinating cowpox (Webpage of University of Tokyo, 2014). Both of these two institutes made a great contribution to the wellbeing of Japanese people in 19th century and finally attracted more academic streams to merge into one to contribute to a better academic performance.

At the beginning of its establishment, the University of Tokyo was composed of only four departments: Law Department, science department, literature department and medicine department. Subsequently, a series of scientific research institutions were established in the mid-1990s, such as the Institute for infectious diseases, Aeronautical Research Institute, Tokyo Aerospace Observatory, marine biological station, Institute for nuclear study and so on (Webpage of University of Tokyo, 2020). These scientific research institutions have played a key role in the historical development of Japan and promoted the continuous progress of Japanese science and technology.

After entering the 21st century, the global environmental and energy problems and Japan's aging population have gradually become prominent. In order to solve these problems, the University of Tokyo actively promotes university-society-industry contact and cooperation. University of Tokyo also helps society and industry to observe problems, share information and offer solutions(Webpage of University of Tokyo，2012). The excellence of the University of Tokyo is also reflected in its academic achievements. In 2015 and 2016, two professors (Takaaki Kajita and Yoshinori Ohsumi) of the University of Tokyo won the Nobel Prize in physics and the Nobel Prize in medicine respectively (Webpage of University of Tokyo, 2020). While gathering cutting-edge knowledge, the University of Tokyo carries out extensive social cooperation. In addition to public lectures, there are many opportunities for enterprises and citizens to discuss and share their own policy suggestions.

The University of Tokyo won the 24th place of QS ranking in 2021 owing to its international reputation and academic attainments. It has attracted many foreign students to study. As of last year, the University of Tokyo has received 4249 foreign students, and the number of local students has reached 24557, a total of 28806 (Webpage of University of Tokyo, 2021). The University of Tokyo is also equipped with rich educational resources, with 3225 faculty members and 8131

academic staff.

The University of Tokyo has well-structured industry-university cooperation system(as shown in Figure 3-10) to help the University of Tokyo efficiently transfer their scientific research achievements to the real industry. The system is called “The Division of University Corporate Relations. The DUCR of the University of Tokyo is an independent institution established for the scientific and technological innovation of the University of Tokyo, which provides a series of system support such as start-up business incubation, entrepreneurship education and commercialization of scientific and technological achievements. In addition to these four divisions, there are many innovative subsidiaries and external organizations supporting the scientific and technological innovation of the University of Tokyo, such as: Tokyo Technology Licensing Office (Todai TLO, Ltd), IP and capital fund at the University of Tokyo, UTokyo innovation platform Co, Ltd, and the University of Tokyo edge Capital Partners Co, Ltd (UTEC) (University of Tokyo, 2021).

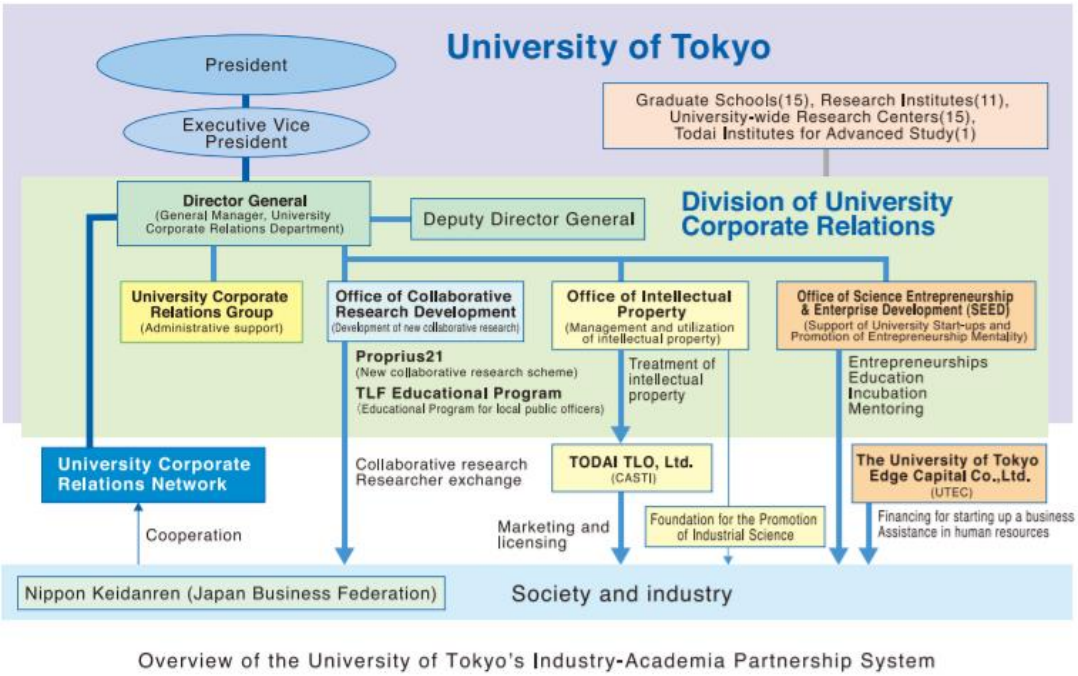


Figure 3-10 The system of industry-university cooperation and social cooperation provided by The University of Tokyo[108]

UTokyo’s IP policies

Purpose: In order to make inventions and others assigned to the University of Tokyo (hereinafter, the “University”) be utilized widely in society, the University hereby indicate clearly the basic concepts regarding licensing activities conducted by the University for promoting appropriate and smooth technology transfer to industry, based on the basic policy stated in the University of Tokyo Intellectual Property Policy (revised on September 30, 2004).

Basic concepts: Regarding licensing activities. For clearly indicating the basic concepts regarding licensing activities conducted by the University, the main policies are established as follows (DUCR of University of Tokyo, 2009):

1. Promote licensing activities in collaboration with joint applicants, TLO, etc., so that inventions and others assigned to the University would be utilized in ways that maximize their social effects.
2. With respect to the licensing technologies, focus on the potentials for application and business development in society together with the prompt feasibility thereof.
3. Pay attention not to be utilized for purposes violating public order and morals.
4. Pay attention not to produce any third party who is inflicted inappropriate damage due to the license activities. (Pay attention not to take part in the acts of so-called "patent troll".)
5. Take into account of the licensees' social credibility and compliance situations.
6. Pay attention not to hinder research activities due to the licensing activities. For this purpose, respect the concepts stated in the University of Tokyo Research License Treatment Guideline (established on August 5, 2008) and the University of Tokyo Research Tool Patents Treatment Guideline (established on February 8, 2008).

UTokyo's Rules for the Treatment of Inventions

The University established the Office of Intellectual Property as a university-wide

organization to conduct affairs under these Rules. The Office of Intellectual Property shall determine whether or not it is necessary for the University to succeed to the right to obtain a Patent for of an Invention made by a Faculty Member (DUCR of University of Tokyo, 2004).

Principle of Organizational Ownership

1. The University may succeed to the right to obtain a Patent of an Employment-related Invention made by a Faculty Member.
2. If an Employment-related Invention has two or more Inventors, the University may succeed to the Faculty Member's share of the right to obtain a Patent.
3. If the University decides that it is not necessary to succeed to the right to obtain a Patent of an Employment-related Invention, the right may belong to the Faculty Member concerned.
4. A Faculty Member who has made an Invention shall not dispose of the right to obtain a Patent of the Invention by way of assignment or otherwise unless the University has decided not to succeed to such right.

5. If deemed necessary by the University, the University may succeed to the right to obtain a Patent of Other Invention by obtaining the agreement of the Faculty Member concerned.
6. The right to obtain Patents of Other Invention that the University does not succeed to shall belong to the Faculty Member concerned.
7. This rule shall not apply to research results with respect to which it is considered that the exercise of the right to obtain a Patent would not be an appropriate contribution to society.

Tasks Relating to Technology Transfer

1. The Office of Intellectual Property shall promote the practical use of the rights to obtain Patents, or the Patent Rights that the University owns, and may transfer technology with respect to such rights to corporations and other parties when the Office of Intellectual Property considers it necessary to do so (DUCR of University of Tokyo, 2004).
2. The Office of Intellectual Property shall select a method of technology transfer that it considers will give society the greatest benefit from the Invention, whether a grant of an exclusive license, a grant of a nonexclusive license, or an assignment of rights.
3. The Office of Intellectual Property may delegate all or a part of the tasks provided in Article 1 to a third party, such as a technology licensing organization.

Receipt of Patent Rights and Rights to Obtain Patents

1. When Faculty Members or Other Researchers offer to the University to assign a Patent Right or a right to obtain a Patent with respect to which the Application has already been made, the University may, where considered necessary by the Office of Intellectual Property of the University as set forth in Article 8, receive those rights with the approval of the Faculty Members or Other Researchers.
2. In order to promote the technology transfer of Inventions of the University, the University may, where considered necessary by the Office of Intellectual Property receive a Patent Right or a right to obtain a Patent from any persons other than Faculty Members and Other Researchers, and any organizations other than the University.

UTokyo's Technology transfer offices: UTokyo DUCR

The DUCR of UTokyo has established in April 2004. In order to ensure the efficient operation of industry university cooperation, DUCR and all its internal subsidiaries are arranged in the same building of the University of Tokyo. DUCR is currently composed of four sub departments which are: Office of Start-up and entrepreneurship education, Institute for open innovation, office of strategic research alliance and office of intellectual property management (University of Tokyo,

2021).

Office of Start-up and entrepreneurship Education

The Office of Innovation and Entrepreneurship is working for the promotion program of the research and the business creation. It also aims to build a large start-up company, which is internally supported by two pillar cores. The first is the one to support the business incubation facilities for start-ups and legal management affairs (University of Tokyo, 2021). Secondly, the Department has various forms of human resources development plans, such as entrepreneur Dojo, EDGE-NEXT and other education plans (University of Tokyo, 2021). These talent training programs is back-up by UTEC, TOL and other capitals, so that the talent training and start-up incubation of the University of Tokyo can be fully guaranteed.

By assisting start-ups, the Office of Innovation and Entrepreneurship encourages innovation. Incubation facilities are provided, as well as assistance with business models for emerging enterprises. "The University of Tokyo Entrepreneur DOJO" is established to assist innovators and entrepreneurs with their start-ups. Other action-based entrepreneurship education activities are also available to students through the office. Data in Table 3-15 is provided in the Annual report 2011 by DUCR of The University of Tokyo to give an overview on the Profile of students who participated in the university of Tokyo Entrepreneur DOJO in the last year.

Table 3-15 Profile of students who participated in the university of Tokyo Entrepreneur DOJO in 2011[109]

	College of Arts and Sciences Junior Division	Undergraduate major course	Graduate and postdoctoral	Total
Science	34	193	511 (49.6%)	738 (71.6%)
Humanities	42	148	103	293 (28.4%)
Total	76 (7.4%)	341 (33.1%)	614 (59.6%)	1031 (100.0%)

The institution employs a variety of tools for commercialization, depending on the circumstances. Licensing or selling intellectual property rights to firms, as well as founding new enterprises, are examples of these. Researchers are allowed to spend some time on start-up-related activities when beginning a new firm, and they can possess up to 50% of the shares in start-ups. They should not, however, be the company's CEO in order to avoid any potential conflicts of interest.

Institute for Open Innovation

IOI is a cross departmental organization directly led by the president of the University of Tokyo. This organization is independent of the organizational system of the University of Tokyo which helps enterprises solve social problems and obtain the double benefits of profit growth through its science and technology and high-level talent management level (Institute for Open Innovation, 2021). Combining with the advanced research results of university and potential social demands of the society, IOI can not only help enterprises to make progress, but also able to realize knowledge co creation and help IOI improve itself in academic and management. As shown in the Figure 3-11, the working mechanism of IOI is an cooperation of IOI and institutions.

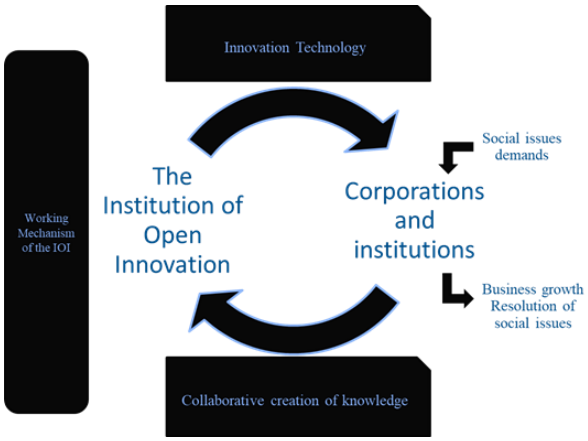


Figure 3-11 The Working mechanism of IOI[110]

From the system level of operation, the IOI is divided into two operation modules. The first is the Management sector, which is responsible for cooperation with enterprises and docking research in universities with enterprises in demand. It recruits project managers and project coordinators to ensure the efficient operation of technology transfer projects. At the same time, it is also responsible for helping enterprises carry out relevant consulting work. Through the coordinator's continuous exploration of potential demands with enterprises, gradually clarify the research direction and objectives, and bring the common research results into the industry (Institute for Open Innovation, 2021). The second module is the project sector. In this operation module, cooperative projects are subdivided into various fields to form a professional research team by accurately mobilizing relevant researchers in the university research field.

Office of strategic research alliance

The University of Tokyo builds a mutually beneficial network by making use of its strategic cooperative relationship with well-known overseas universities to carry out academic exchanges and the commercialization and practical application of scientific and technological innovation. This organization aims to design the innovation ecosystem model of start-ups from a macro perspective and help enterprises plan various entrepreneurial routes. The Institute will also promote and disseminate the concept of industry university cooperation in the school, and actively

promote the matching and docking between the school research team and social enterprises. The agency also provides two subsidy schemes to help enterprises commercialize in the early stage, which is “the University of Tokyo GAP Fund” and “The university of Tokyo New coronavirus infectious Disease countermandment Practical Use Promotion Subsidy Program.”

Office of Intellectual Property Management

The office is responsible for the intellectual property management of research results in the University, reviewing and approving the commercialization license of intellectual property and patents in the University. Through cooperation with the judiciary, The Office protects the intellectual property rights of the original scientific research achievements of the University of Tokyo, and manages the profits and investments generated by these intellectual property rights and patents (DUCR of University of Tokyo, 2004). These funds are often used for a new round of research activities to form a good sustainable research ecological cycle. TLO and FRIPS participate in ensuring the operation and commercial profitability of scientific research funds.

UTokyo’s programs to promote culture of innovation and entrepreneurship

The University of Tokyo Edge Capital Partners Co., Ltd. (UTEC）

The University of Tokyo Edge Capital Partners Co., Ltd. (UTEC) primarily provides venture capital fund management services by investing in venture companies that make use of university and research institution technology and human resources, such as the University of Tokyo.

UTEC has collaborated with academia in Japan and overseas, including the University of Tokyo, since its foundation in 2004(UTEC, 2021). By bringing together capital, talent, and knowledge around science and technology, UTEC has sponsored innovative businesses that are pioneering boundaries to solve global concerns of humanity.

Tomotaka Goji is the Co-Founder and Managing Partner of The University of Tokyo Edge Capital Partners Co. Ltd. (referred to as "UTEC"), as well as the Managing Director of the Japan Venture Capital Association. He has raised and managed five funds totaling roughly JPY 85 billion since the foundation of The University of Tokyo Edge Capital Co. Ltd. (formerly known as UTEC), created the investment team, and supervised UTEC's investments into seed/early-stage firms. UTEC's portfolio firms have been bought 12 times, and 13 have gone public(UTEC, 2021). The funds are based on a Japanese law known as "The Limited Partnership Act for Investment," which he helped to enact in 1998 at the then Ministry of International Trade and Industry (now known as METI: the Ministry of Economy, Trade, and Industry) and which has since become the foundation for Japanese venture capital funds.

The University of Tokyo's start-up establishment process is divided into nine steps following the investment flow of UTEC(UTEC, 2021). The first step is the research stage, which is mainly completed within the University of Tokyo. The problem to be solved is mainly to think about how

to turn research into business, which often requires the creativity and innovative R&D skills of researchers at the University of Tokyo. The second step is the decision to establish a start-up. This step requires the participation of UTEC. UTEC and the University of Tokyo share ideas, discuss business ideas and establish a preliminary business model. The third step is proof of concept, which needs the cooperation of researchers from UTEC and the University of Tokyo. The main purpose is to test the goods and find the target market. The fourth step is the business plan. In this step, UTEC mainly needs to find the project competitive advantages are and to discuss with the University of Tokyo on the detailed business plan and ownership structure table. In the fifth step, UTEC is required to network and help the project team build, so as to set up a corporate entity in the sixth step. The last three steps are the first, middle and later stages of IPO / M&A.

Table 3-16 The funds from UTEC

UTEC 5 Limited Partnership Establishment : May 7, 2021 General Partners: UTEC Partners Limited Liability Partnership Fund size: About 30.4 billion yen Number of Investments 16	**UTEC 4 Limited Partnership** Establishment : January 17, 2018 General Partners: UTEC Partners Limited Liability Partnership Fund size About 24.3 billion yen Number of Investments 36
UTEC 3 Limited Partnership Establishment: October 15, 2013 General Partners: UTEC 3Partners Limited Liability Partnership Fund size About 14.5 billion yen Number of Investments 31	**UTEC 2 Limited Partnership** Establishment : July 31, 2009 General Partners: The University of Tokyo Edge Capital Partners Co., Ltd. UTEC Venture Partners, Inc. Fund size: About 7.1 billion yen Number of Investments 13
UTEC 1 Limited Partnership Exit Establishment : July 1, 2004 General Partners: The University of Tokyo Edge Capital Co., Ltd. Fund size: About 8.3 billion yen Number of Investments 34	

UTEC has managed five funds totalling about JPY 90 billion (Details are shown in Table 3-16), the most recent being UTEC 5 Limited Partnership, which was created in 2021 with a commitment of over JPY 30 billion (UTEC, 2021). They've invested in over 110 start-ups over the last four funds, 13 of which have gone public and 12 of which have had other significant exits, mostly through mergers and acquisitions.

TODAI TLO, Ltd

TODAI TLO, Ltd is a firm that represents the university's researchers. TLO, as a subsidiary of the

University of Tokyo, is involved in a number of initiatives aimed at transferring the University of Tokyo's inventions, technology, and intellectual property to society via industry circles to spreading useful knowledge and skills to the society. Todai TLO specializes in intellectual property licensing, consulting, and technological counselling, as well as knowledge transfer agreements, software licenses, and other IP-related concerns in the business (DUCR (2011). They also handle collaborations, contract research agreements, responses to industry inquiries, information sharing, and other industry copy rights. When the society needs a certain science and technology, the research team of the University of Tokyo often senses this demand and carries out basic research and innovative technology research. When the research results come out, the University of Tokyo needs to use start-ups to commercialize them and enter the industrial world. This often requires the help of TODAI TLO of licensing. Until present, the TLO has handled multiple licensing agreements and technological transfers for the University of Tokyo. According to the chart, it can be concluded that cooperative investment accounts for the vast majority of Todai TLO contracts in recent years. And among the technology transformation income projects, most are single investment of the University.

As for the licensing process for innovations, the first step is often for researchers to disclose the research results to UCR and Todai TLO, preliminarily determine the patentability and marketability of the research results through analysis and negotiation of both parties, and feed back to researchers. Today TLO will focus on questionnaire survey and data statistics on Patentability and marketability, recommend appropriate research results to UCR and apply for patents. Finally, after licensing by today TLO, the scientific research results will be sent to industry.

As shown in Figure 3-12, while making full use of TLO's experience and achievements, the Office of Intellectual Property Management focuses more on administrative work, and TLO focuses on operation work, as a result, the unified management is achieved.

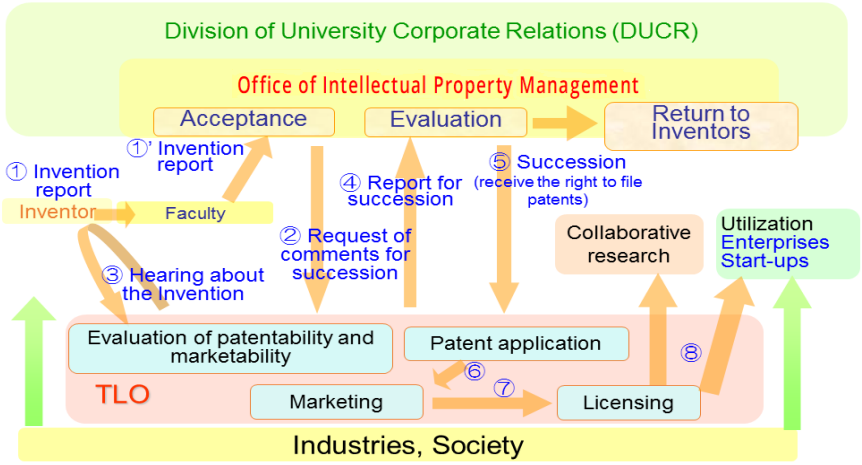


Figure 3-12 Invention management in UTokyo[111]

In the finical years of 2021, the total number of patents at the University of Tokyo reached 79 and completed a new record. Among them, Todai TLO has won four technology transformation projects with an income of more than 10 million yen (three are engineering projects) (DUCR (2011). Table 3-17 shows its specific sales results.

Table 3-17 Outcome of patent from University of Tokyo (FY2000)[112]

		Number of patents permitted for implementation	Number of patents that generated revenue	Revenue (￥1.000)
Patents belonging to the University of Tokyo	Patents based on inventions created before the University of Tokyo become a national University corporation	0	0	0
	Patents based on inventions created after the University of Tokyo become a national University corporation	290	112	139,756
	Subtotal	290	112	139,756
Patents belonging to individuals	Individual patents handled by TODAI TLO	1	1	139,756
Total		291	113	153,348

From Table 3-18 which cited from the official webpage of Todai TLO below (2021), its earnings from technology transfers have been steadily expanding in recent 10 years. The revenues are divided as a percentage according to the following model:

Table 3-18 Technology transfers earnings from TLO[113]

28 % to the inventors
21 % to the inventors' university department
21 % to the university itself
30 % to Todai TLO

This fund is intended to provide incentives to inventors, the department responsible for promoting such activities, the university, and the funding of Todai TLO's operations. The funds can be used for a variety of purposes at the university, including wages, operational costs, and equipment, but not for venture or equity capital.

UTokyo's facilities and equipment

The University of Tokyo is mainly equipped with 4 Incubation facility. Entrepreneur Plaza, DUCR Incubation Room, Incubation Rooms on Komaba Campus, Entrepreneur Plaza Shared Incubation Room. Details are listed in Table 3-19.

The University of Tokyo Entrepreneur Plaza: The Entrepreneur Plaza is the largest facility among the four facilities and was opened on Hongo Campus in 2007 housing a total of 29 rooms with roughly 58m² of space each (DUCR, 2011). 20 of these rooms that are located on the 4th - 7th floors can be used as an office but can also be used as a wet laboratory capable of conducting P2 level biotechnology experiments.

Incubation Rooms on Komaba Campus: Starting in 2009, having offices of around 27m² as well as around 68m² in the Collaborative Research Building located on the Komaba II Campus as incubation rooms for startup companies and entrepreneurs (DUCR, 2011).

The University of Tokyo Entrepreneur Plaza Shared Incubation Room: Since 2012, a room was operated in the University of Tokyo Entrepreneur Plaza as a shared office where entrepreneurs and startup companies can start a business by using a desk in the shared office.

DUCR Incubation Room: The Office of Innovation and Entrepreneurship of the Division of University Corporate Relations seeks to achieve creative university-industry collaborations in order to implement the University's research outcomes into society and attain high-impact innovation.

Table 3-19 Four Incubation facilities in Todai[114]

Name of facility	The University of Tokyo Entrepreneur Plaza	DUCR Incubation Room	Incubation Room on Komaba Campus	Entrepreneur Plaza Shared Incubation Room
Location	Hongo Campus	UCR Plaza in Hongo campus	In Komaba II Campus Collaborative Research Building	University of Tokyo Entrepreneur Plaza
Room size	Approximately 58m²	Approximately 50m²	Approximately 27m² or 68m²	Desk
Number of rooms	29 rooms	Several rooms	Several rooms	16 desks
Usage	20 rooms available for use as a wet laboratory	Office use only	Office use only	Desk use
Length of Term	1 to 3 years (Possible to renew contract up to 2 times)	1 year (Extension possible)	1 year (Extension possible)	1 year (Extension possible up to 2 years)
Contract form	Lease agreement with outside contractors and a MOU with University of Tokyo	Lease agreement with the University of Tokyo	Lease agreement with the University of Tokyo	Contract with outside contractors and a MOU with the University of Tokyo

Research Center for Advanced Science and Technology of University of Tokyo

Since its founding in 1987, the Research Center for Advanced Science and Technology, the University of Tokyo's newest institute, has aimed to contribute to the advancement of science and technology by quickly addressing new challenges arising from advances in science and concurrent changes in society, as well as by exploring new areas of advanced science and technology for the benefit of humanity and society. More than 40 eponymous labs across a wide range of specialist subjects are conducting innovative research in science and technology, social sciences, and barrier-free research (RCAST, 2021). These study areas at UTokyo span a wide range, from basic and applied studies to the social system. Their mottos are Interdisciplinary Approach, Mobility, International Perspective, and Openness.

The basic research at RCAST is exposed to significant discoveries that can provide not only an important word of caution, but also contribute to more successful investments of time and resources by working together with researchers from different departments and fields (RCAST, 2021). Similarly, interacting with experts from the natural sciences, social sciences, and humanities can help to create a more dynamic and engaging academic environment, as well as open doors to new options that a lone researcher might not have considered otherwise.

Summary and conclusions

As the oldest and largest public university in Japan, the University of Tokyo is famous for its outstanding scientific research achievements. The University of Tokyo intends to establish a strong network with academic institutions and industries with common goals at domestic and abroad to work together and promote initiatives to connect academia and society. In The University of Tokyo: Vision 2020, it will further strengthen the awareness of the synergy between excellence and diversity in research and aiming for a clearer understanding of humanity and the world. The University of Tokyo will establish a strong network with academic institutions and industries with common goals at home and abroad and work together to promote initiatives to reconnect academic learning with society.

To be specific, while transmitting outstanding academic results from both the humanities and the sciences to Japan and the rest of the world more than ever, UTokyo will also attract more talented people irrespective of nationality, gender or age to the University of Tokyo by creating an environment in which everyone can have the peace of mind to focus on their research. In addition, by providing opportunities for the people brought together at the University to transcend the frameworks of their organizations or their areas of study and collaborate with one another, UTkyo will make further advancements in learning at the University and promote interdisciplinary research, thereby bringing about the creation of new value. With this kind of "synergy between excellence and diversity," both qualities will work in a closely interdependent fashion to elevate

each other dynamically. To put it in other words, one could compare this process to an upward "spiral motion."

As to the visions of research area, it been summarized into 5 aspects

1. Expansion and Establishment of Internationally renowned Bases for Research

Establish and expand upon internationally-renowned bases for research at the University of Tokyo by carrying out such initiatives as advancing the development of both the University's strongest fields in which it is leading the world and unique areas of original research which should unwaveringly continue to be studied, promoting joint research and international collaboration that goes beyond the framework of the University of Tokyo, and creating new, interdisciplinary knowledge that is the first of its kind in the world.

2. Further Revitalization of the Humanities and the Social Sciences

Further revitalize the humanities and social sciences through active support of outstanding research in those fields. Increase the University of Tokyo's international presence in those areas.

3. Fortification of Infrastructure Supporting Academic Diversity

Fortify the infrastructure supporting academic diversity by constructing an archive containing the University of Tokyo's academic assets and facilitating its opening to the public while promoting its active use.

4. Ensuring of Time for Research and the Improvement of the Quality of Educational and Research Activities

Conduct proper staff evaluations and, through initiatives such as enhancements to the research support system and operational optimization, ensure that academic staff members have time to devote themselves to their research. These actions will be carried out with the aim of further improving the quality of the educational and research activities of academic staff members.

5. Reform of the Researcher Employment System

Raise the appeal of a life dedicated to research and attract a diverse array of outstanding and talented people from both Japan and overseas by promoting the reform of the researcher employment system.

To realize the mentions visions and missions above, University of Tokyo's promote a combination of top-level innovation research. It also focuses on solutions to societal challenges, collaborative measures, and a support system that simplifies the commercialization process for innovators and entrepreneurs. Together with the freedom universities have for using the revenues, the model for distributing profit to the innovator, research department and university, serves as a balanced model for incentives for commercialization. The University of Tokyo Edge Capital Partners Co., Ltd. (UTEC） and TODAI TLO, Ltd are also utilized to invest and cultivate start-ups for Utokyo.

3.3.7. Seoul National University

Seoul National University (SNU) was the first comprehensive university of South Korea (hereafter Korea) in 1946 with its main aim to produce intellectual elites who would lead the newly liberated country. SNU opened with 9 Colleges and 1 Graduate School: Colleges of Agriculture and Forestry, Commerce, Dentistry, Education, Engineering, Fine Arts, Law, Liberal Arts and Sciences, Medicine and the Graduate School. After the Korean War, the university made a rapid recovery with aid from countries all over the world, propelled by the Korean people's collective desires to provide education for the young generation. Examples of aid projects included Minnesota Project for reconstruction and development of SNU during 1954-1962 period with 9,791,000 USD of foreign financial aid, and 218 SNU professors sent to universities in the US. In regards of transforming the nation, SNU community members spearheaded the democratic movements, while graduates also played a central role in the economic development of the country from 1960 to 1975. In addition, SNU had established and expanded newly professional graduate schools: Graduate Schools of Public Administration and Health (1961-Present), Graduate School of Judicial Research & Training (1962-1970), Graduate School of Education (1963-1975), Graduate School of Business (1965-1975), Graduate School of Mass Communication (1967-1975), Graduate School of Environmental Studies (1973-Present).

In 1975, SNU merged its multiple campuses into three main locations: Gwanak main campus, Yeongeon medical campus, and Suwon agricultural campus. After a long struggle for pro-democracy protest from 1980 to 1995, the university became normalized in terms of the achievement of democracy, and there was a great increase in the number of students and faculty members. With the aim to become a world-class research university, SNU put various plans in motion, and many research institutions were established from 1995 to 2011. The government announced Plan for Education Reform in Preparation of Globalization and Digitalization Age in 1995. Since Ministry of Education (MOE) and National Research Foundation launched Brain Korea 21 (BK21) project, a 140 billion KRW plan to enhance global competitiveness of Korean research universities in 1999, with thirty SNU research teams selected for the project.

In terms of its rise to global prominence, SNU was ranked 20th in the world in SCI paper publications on April 2010. SNU community members had long been seeking autonomous governmence. In 2011, SNU finally changed its legal status from a government institution to an incorporated entity. At the same time, SNU was ranked 31st among world universities according to QS World University Rankings in 2014, opened the Graduate School of Data Science and completed 1st stage of the Siheung Campus (University Branch Campus) in 2020. Following the global academic trend toward providing data-based education, the Data Science Graduate School offers a new educational model and aims to be the hub of interdisciplinary research that preemptively responds to global issues. Furthermore, for establishing a system for university

innovation, the University Innovation Center will act as a think-tank to pioneer the higher education of the future by sponsoring mid- to long-term research projects through extensive data analysis.

Korea's first national institution for higher education, SNU

SNU defines its position and vision as "a community of knowledge, leading the future." It highlights its objectives into four categories in: (1) Foster global convergence talent, (2) Build an innovative knowledge ecosystem, (3) Create knowledge-based social values, (4) Establish a foundation for sustainable university development. SNU constitutes 3 types of educational organizations: 15 Colleges, 1 Graduate School, and 12 Professional Graduate Schools.

One of the visions of SNU is to establish a system for university innovation center. The following figures are academic performance of SNU full-time faculty: research project funding (Figure 3-13), assignments based on university information Public disclosure (Figure 3-14), and thesis (Figure 3-15) from 2013 to 2017.

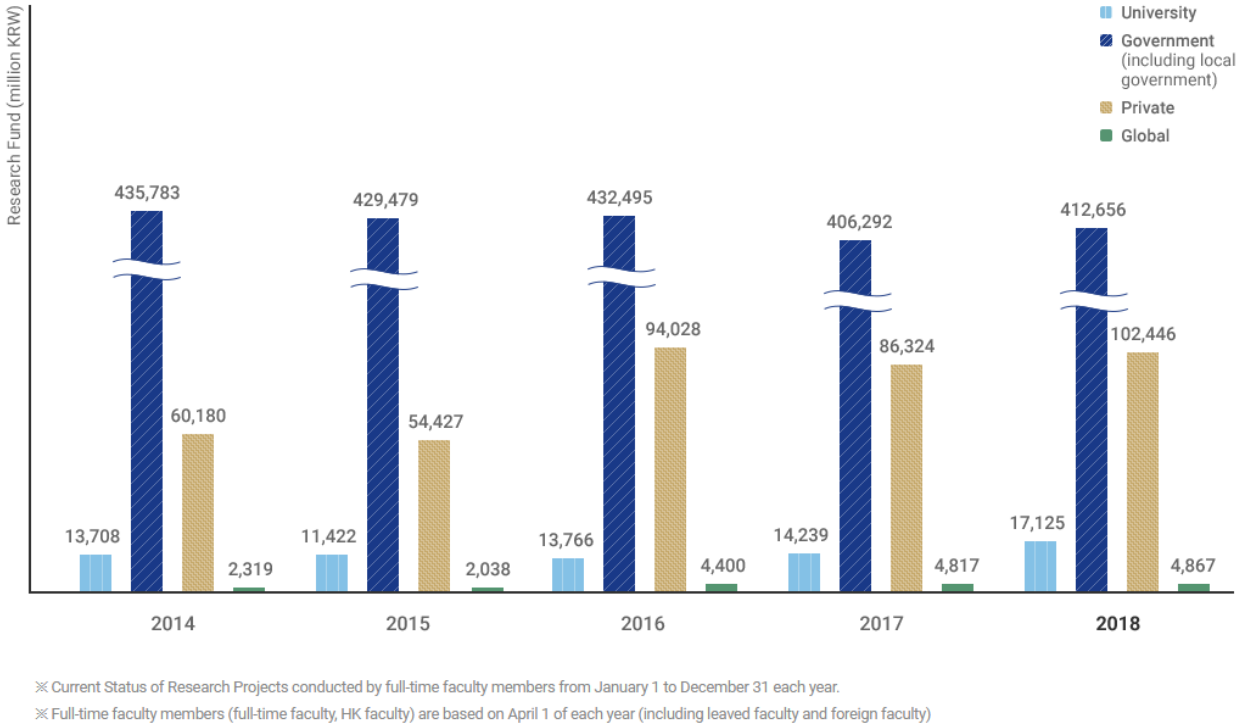


Figure 3-13 Full-time faculty research projects funding [115]

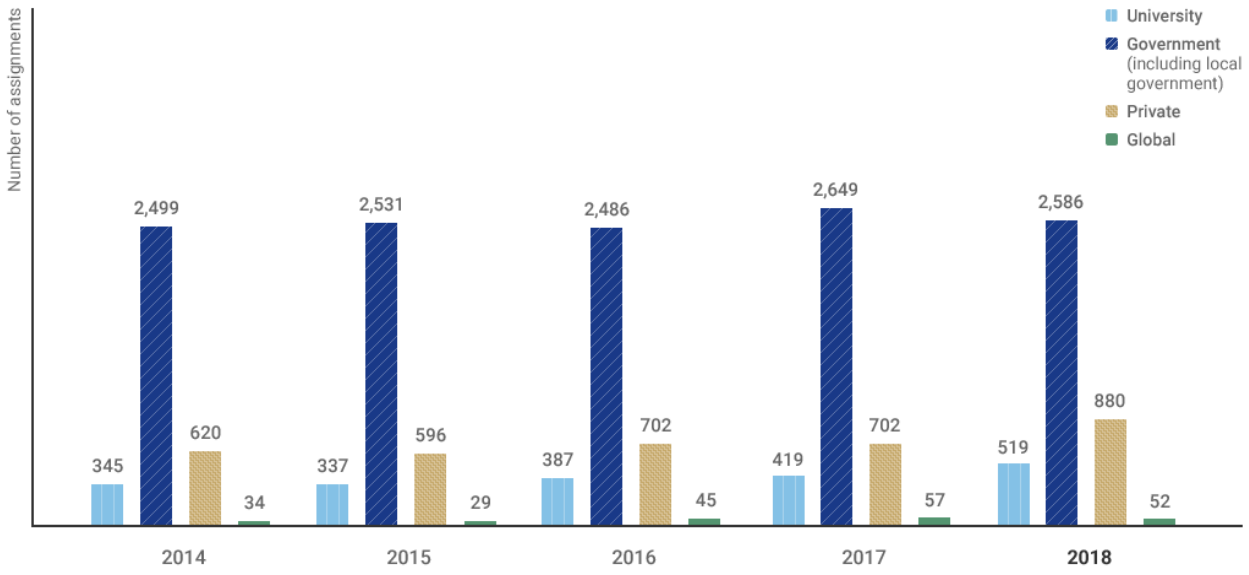


Figure 3-14 Full-time faculty assignments [116]

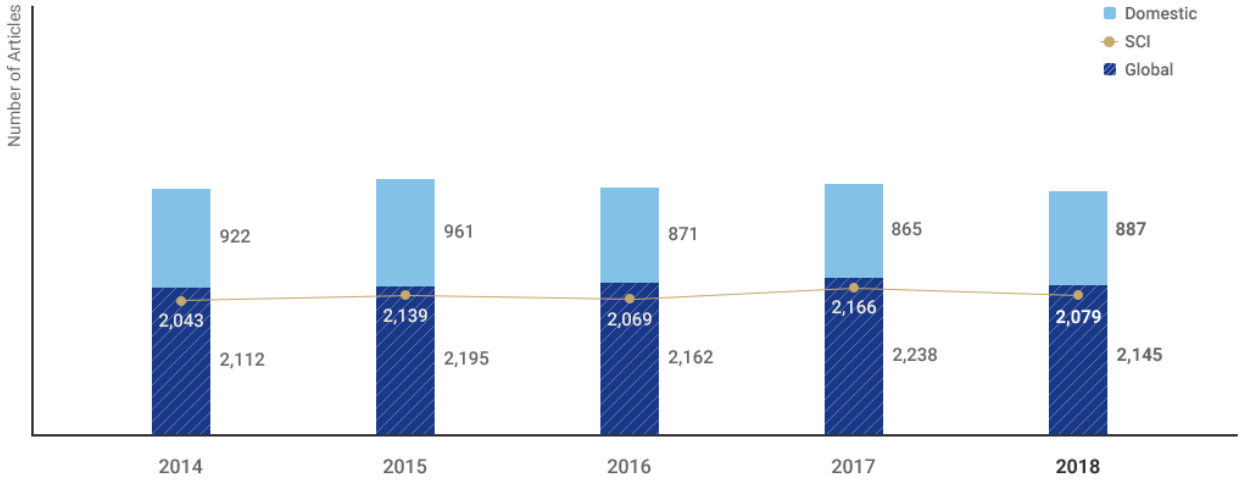


Figure 3-15 Full-time faculty thesis [117]

Teaching and research given equal weighting in faculty assessment

SNU indicates the performance evaluation rules for faculties reflecting 40% education, 40% research, 10% volunteer work, and 10% evaluation by the head of the institution. However, depending on the characteristics of each college, it is possible to change the weighting ratio through the regulations.

From September 2017, SNU Graduate School of Engineering Practice (GSEP) has decided to significantly reflect the results of volunteer work and UIC activities in the evaluation of faculty achievements, which used education and research performances as its main indicators. GSEP was

established in 2016 with the goal of nurturing technical talents for industrial fields. GSEP recruits those with more than 3 years of work experience, and upon completing of the project, a master's degree in engineering is awarded without writing a thesis. According to the new bylaws, GESP reflects 25% volunteer work and 20% UIC performance in the faculty evaluation with 30% allocated for education and 25% for research. It plans to evaluate the UIC performance by comprehensively considering technology transfer, patent application, and research projects from industry. The plan makes the evaluation of volunteer activities more practical through qualitative evaluation beyond the formal level.

Regarding incentives for promoting UIC, SNU UIC Award was enacted in 2020 to increase the motivation of its members for UIC by rewarding faculties who have contributed to the technology transfers to the industry and commercialization to strengthen the competitiveness. Three professors with outstanding achievements were selected as winners of the 1st SNU UIC awards.

Establishment of SNU's innovation ecosystem through technology licensing offices

In line with the MOE's requirement of setting up a TLO under TTPA, SNU R&DB Research Foundation (SNU R&DB Foundation) was established, in 2003, to manage research funds and to facilitate the collaboration between SNU and industries. The offices under SNU R&DB Research Foundation is structured in terms of functions and areas of responsibility or relevant units and offices, including both technology transfer and R&D. Moreover, SNU has various kinds of university incubators: SNU Engineering Consulting Center, SNU Entrepreneurship Center, and SNU Technology Holdings, Inc. Under SNU Entrepreneurship Center, Startup Incubation Center (operated with "SNU Foundation"), Golden Helix, New Technology Startup Network (mostly inhabited by student startups) and Biotechnology Incubating Center are located in the main campus, and College of Medicine Startup Incubator Center and College of Dentistry Startup Incubator (New Dental Technology Business Incubator) in Yeongeon Campus and College of Agriculture and Life Sciences Startup Incubation (CALS Bio-Venture Valley) are based in Suwon Campus (original College of Agriculture and Life Sciences).

SNU R&DB foundation is composed of four functional departments: (1) The research fund central management, which manages and supervises the overall fund and planning for research and research person in charge [118], (2) IP management, including the intellectual property rights (IPR) and Trademark. The management set clear description and procedure for IP application and management [119], (3) Conducting the management for technology licensing and commercialization, including the technology consultation activities, joint research (also known as "Academic—industrial cooperation research"), and technology (patent) transfer. Technology transfer is transferring the ownership of a patent from university to a corporation, which requires signed agreement [120], (4) Achievement of medium-and-long-term development strategy R&D Education Center. R&D Education Center is established to provide systematic and comprehensive education for researchers and research administration personnel[121]. In regards of performance related research funds, SNU R&DB foundation provides information as shown in

Table 3-20.

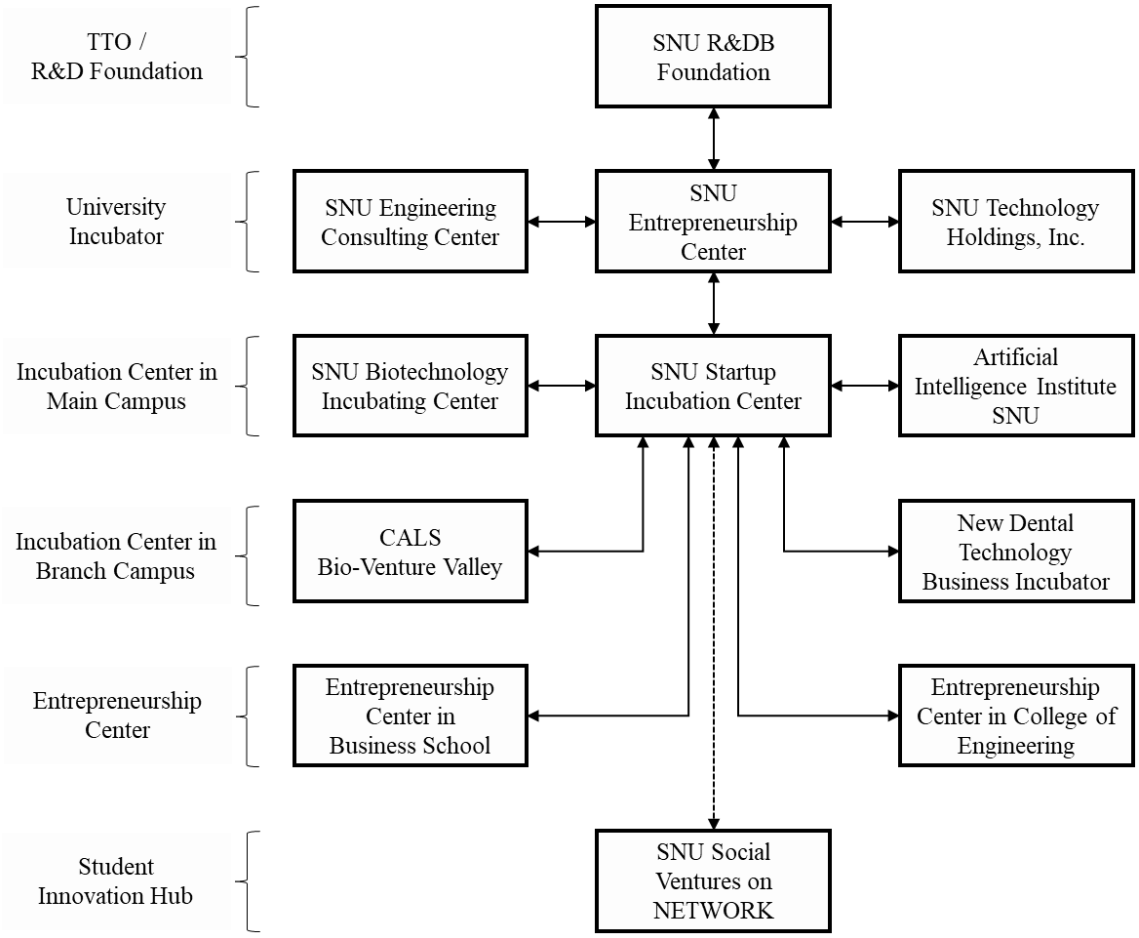


Figure 3-16 Organizational structure of SNU (Authors drawing)

Table 3-20 Research funds through SNU R&DB Foundation (unit: 1,000 KRW) [122]

Year	Total		From SNU		Outside of SNU					
					Government		Private		International	
	No. Projec	Funding Performance	No. Project	Funding Performance	No. Projec	Funding Performance	No. Project	Funding Performance	No. Project	Funding Performance
2015	3,493	497,368,864	337	11,422,674	2,531	429,479,935	596	54,427,621	29	2,038,634
2016	3,620	544,691,490	387	13,766,380	2,486	432,495,630	702	94,028,777	45	4,400,703
2017	3,876	511,673,290	419	14,239,104	2,649	406,292,164	702	86,324,024	57	4,817,998
2018	4,037	537,094,558	519	17,125,359	2,586	412,656,415	880	102,446,071	52	4,866,713
2019	4,006	534,509,286	595	19,829,708	2,518	406,985,887	857	103,040,073	36	4,653,618

Incentivizing faculty engagement in knowledge transfer – policies on technology licensing, royalty sharing, incentives, and partial relief for concurrent positions

To motivate researcher's innovation capacity and follow-up commercialization of the research, SNU R&DB Foundation encourages technology licensing procedures including technology consultation, and joint research. Technology licensing is defined as "the act of providing full execution rights to or acceding all rights due to the request of the inventor of the technology (intangible products such as patent rights, program, know-how etc.), request of a corporation with demand for the technology, or TLO marketing". In addition, SNU R&DB Foundation classified types of technology licensing into patent rights, implementation rights, and sub-licensing as shown in Figure 3-17.

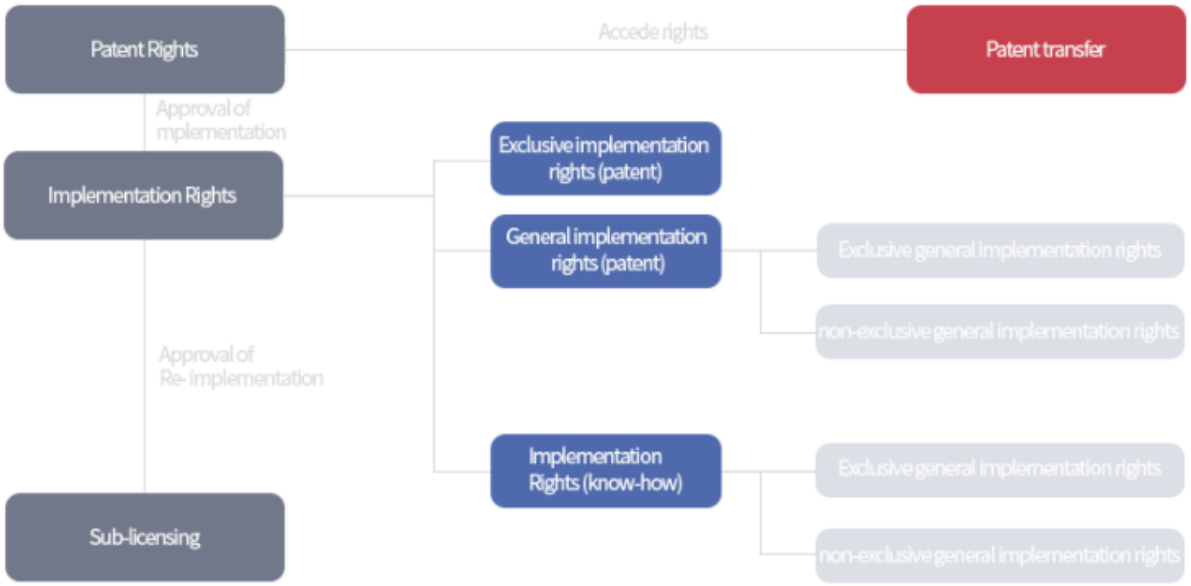


Figure 3-17 Types of Technology Licensing

The patent right is transferring the ownership rights of a technology to a corporation. However, the technology transfer is implemented only in special cases because argument may arise in case future research is necessary. While general implementation rights authorize several corporations use the technology (or patent) exclusive implementation rights authorize only a certain corporation to use the technology (or patent), which more than half of all technology transfer contracts include the exclusive implementation right. It also mentioned like the following:

"Although companies prefer to have exclusive implementation rights which enables exclusive use of the technology, universities are careful to prevent cases where the corporation does not make actual use of technology rights, in which case there are no tangible benefits, though adjusting the payment method for technology or other agreement clauses".

SNU royalty distribution guideline covers the requirement for getting royalty reward through technology transfer and corresponding compensation amount.

The distribution of royalty revenue is allocated to inventor according to the implementation of results of government project (patent, know-how etc.) [123]. Government ministries provide regulations for terms of technology transfer, royalty allocation etc. for each project, and although the exact amount differs. In general, more than 50% of the total amount (with the exception of cases where royalty revenues exceed 500 million KRW) must be allocated to the inventor, and the rest of the amount is to be allocated by the university as technology transfer fees (incentives) or for university funds, and in some cases part of the amount is to be re-invested in research activities (see Table 3-21). For example, in case of a project by the Ministry of Knowledge Economy, in case the recently revised regulations are applied, 50% is for the inventor, 10% is for incentives for technology transfer, 28% is for research expenses, 12% is allocated to the university. In case of a project in which the allocation ratio has not been specified, 50% will be allocated to the inventor first, and the patent application fees and technology transfer incentives funded by the university will be deducted from the remaining amount, of which 2/5 will be additional allocated to the inventor (for use as research funds), and 3/5 will be allocated to the university, in accordance with the "SNU Intellectual Property Management Regulations" and guidelines.

Table 3-21 Distribution method of royalty revenue

	20 million KRW (136 thousand HKD)		20 million ~ 100 million KRW (136 thousand ~ 684 thousand HKD)		100 million ~ 500 million KRW (684 thousand ~ 3.42 million HKD)		500 million KRW (3.42 million HKD ~)	
	Inventor	University (SNU R&DB Foundation)	Inventor	University (SNU R&DB Foundation)	Inventor	University (SNU R&DB Foundation)	Inventor	University (SNU R&DB Foundation)
Patent rights	100%	0%	80%	20%	70%	30%	50%	50%
Know how	90%	10%	85%	15%	75%	25%	55%	45%

Knowhow: confidentially held, or better, closely held information in the form of unpatented technical information, inventions, formulas, designs and processes, secrets, experiences, and sales strategies.

Based on the SNU royalty allocation guidelines in Table 3-21, SNU royalty distribution guidelines explained more detailed regulations. Under the Article 3, the distribution of royalty happens

"Where royalties occur through technology transfer, from the net royalty revenue obtained by deducting in advance the expenses for securing rights to intellectual property and the Technology Transfer-Related Expenses from the royalty amount (hereinafter referred to as "Net Revenue"), compensation for the inventor shall be paid, with the remaining amount distributed to the R&DB Foundation." The amount should include advance payment and running royalties and shall exclude the patent fee [124]. Under the Article 4, the calculation of compensation for inventors is explained in detail. The amount is based on the net revenue gained. In addition, under the Article 5, the term "Technology Transfer-Related Expenses" refers to the amount distributed to the technology transferor in accordance with the relevant Acts such as the TTCP Act. Bonus to be paid to a person in charge of technology transfer shall be determined to be the amount obtained by multiplying the Contribution Dividend for the TTO by the distribution percentage in the table below [125]. As the interviewee explained in the excerpt below:

"Faculty members may participate in external practices, but the procedure is very strict. Outside activities are not encouraged by the faculty with tenure track and their focus on teaching and research. Although the promotion/tenure policies are different for each department, SNU as a national university considers three main categories of importance: teaching, research, and social contribution. Regarding technology transfer/knowledge transfer activities, there are incentives and support for corporate joint research, license, and startups. However, since these are for the individual faculty to benefit, SNU is not forcing it with the university policy. In the case of the current distribution of license income, 40% of the net profit is obtained by the licensor and the reminting 60% by the SNU." (Anonymous. 2021. Interview with an official of SNU research policy. September 3, 2021)

Table 3-22 Bonus for person in charge in SNU Royalty Distribution Guidelines

Division	Distribution percentage
An enterprise participating in government projects; an inventor decides on an enterprise to be the subject of technology transfer; technology transfer of a co-owned patent regarding an industry-academic cooperation project	20%
A person in charge of technology transfer decides on an enterprise to be the subject of technology transfer or an intra-university technology	30%
Where the enterprise to be the subject of technology transfer is a foreign corporation	35%
Where the royalty in 1, 2, and 3 above exceeds 500,000,000 KRW	10% of the amount exceeding 500,000,000 KRW

Regarding the 'one day per week' consultancy activities [126], SNU revised the 'Regulations on Permission for Concurrent Positions, such as outside directors for full-time faculty members at SNU in December 2020. As a result, external activities of full-time faculty members can exceed one-fifth of the total working hours (8 hours). Previously, it was virtually impossible for a professor at SNU to work for a private company because external activities were limited to less than 8 hours per week. Since the revision, faculty members have been permitted to engage in outside practices for more than 8 hours a week. As an example, SNU appointed Dr. Junseok Lee, who is concurrently working as a research engineer at Google, as a professor at the Graduate School of Data Science in March 2021. In other words, for securing the latest cutting-edge technology and talents, SNU invites developers, software engineers, and researchers from Big Tech as faculties, or alternatively as Adjunct Professor.

Startup ecosystem focusing on startup incubation center and entrepreneurship center

SNU entrepreneurship center is established to create new values based on innovation and creativity, separating from industry-oriented innovation strategies. The center is regarded as a business start-up support group/supportive infrastructure to achieve a self-evolving startup ecosystem as shown in Table 3-23. The SNU entrepreneurship center defines its objective as leading global startups and regional special zones to create a collective information sharing platform. Along with the intelligent talents, specialized skills and innovative ideas, the program could strengthen SNU innovative capacity and lead university for startups on a global scale [127].

Professors with tenure-track must obtain approval from the in-house startup support committee when he or she wants to start a business. During the deliberation of the startup support committee, the SNU R&DB Foundation, and SNU Technology Holdings, Inc review the technology and business feasibility of the startup companies. In this process, the lack of entrepreneurs is supplemented with programs to support business activities and intellectual property rights. The SNU entrepreneurship center is supporting the technological commercialization by supporting several essential courses such as commercialization process planning, business model design, IR material production, and management consulting (entrepreneurship official, 2021). As our interviewee shared with us in the excerpt below:

"SNU intents to use the profits generated from the sale of the donated stock to be used as a virtuous cycle fund for creating a startup ecosystem by distributing the profits to the departments to which the founder of the faculty of department belongs. We provide consulting and mentoring in various fields necessary for business activities by startups using external pools as well as university staffs, patent attorneys in the SNU R&DB Foundation, and investment experts in the SNU Technology Holdings, Inc. In addition, for practical support in the fields of law, tax, and labor required during the process of establishment and operation of the company, SNU has signed a contract with a specialized company to support the connection between startup and the company." (Anonymous. 2021. Interview with official A of SNU entrepreneurship center. September 3, 2021)

Table 3-23 University entities for startup ecosystem

Division	Center	Summary	Number of Staff	Targeted clients
Startup Incubation Center	SNU Startup Incubation Center (startup.snu.ac.kr)	Startup Incubation Center is to inspire entrepreneurs and those who want to start a business, and nurture global creative talents by systematically supporting technological innovation. The Center serves as a mediator managing and connecting other startup incubation and entrepreneurship organizations	13 staff	• For businesses • For academic staff • For students
	CALS (College of Agriculture and Life Sciences) Bio-Venture Valley (agbio.snu.ac.kr)	Bio-Venture Valley located in Suwon Campus (Branch Campus) provides technical support and advisory services to resident companies that fit the infrastructure necessary for startups and form a network connected with all laboratories within CALS to revitalize startups in the field of agricultural life science	-	• For businesses • For academic staff
	New Dental Technology Business Incubator (dentistry.snu.ac.kr/en/research/ac)	New Dental Technology Business Incubator aims to vitalize support for establishment of dental enterprise by the Small and Medium Business Administration	14 enterprises	• For businesses • For academic staff
	SNU Biotechnology Incubating Center (Golden Helix) (imbgbi.snu.ac.kr/en)	Biotechnology Incubating Center provides support for prospective startups and venture companies related to life science, promote the technology intensives SMEs, and establish a holistic and organic cooperative system between triple helix	7 enterprises 3 staff	• For businesses
	Artificial Intelligence Institute Center for Industry Collaboration (CIC) (aiis.snu.ac.kr)	AI Institute has been operating the CIC since January 2021 to promote efficient and valuable UIC. When a company proposes a problem, CIC selected 3 to 5 researchers from among 300 AIIS professors and researchers, and solving problems. The CIC supports funding scheme for researchers, scholarship for	14 staff	• For businesses • For academic staff • For students

		postgraduates students, and internship for undergraduates students		
	SNU Engineering Consulting Center (snuecc.snu.ac.kr)	Engineering Consulting Center is an organization that systematically operates various entrepreneurship education and support programs in the College of Engineering so that students and professors can start a technology-based startups	11 staff	• For academic staff • For students
	SNU Technology Holdings, Inc. (snuholdings.com/en)	SNU Technology Holdings encourages the founding of business ventures by faculty and students of SNU and to facilitate the commercialization of the school's excellent technology resources	-	• For businesses • For academic staff • For students
Entrepreneurship Center	SNU Entrepreneurship Center (in Business School) (ect.snu.ac.kr)	Entrepreneurship Center aims to spread entrepreneurship and revitalize start-ups through entrepreneurship education. In addition, it supports education for nurturing practical leaders with entrepreneurial spirit, conducts research to create leading academic values, and supports the commercialization of technology startups to discover and nurture entrepreneurs.	4 staff	• For students
	SNU Entrepreneurship Center (in College of Engineering) (k-startup.go.kr/univ/snu/index.do)	Entrepreneurship Center discovers the technology-based start-up competency of prospective entrepreneurs through education/seminar, provides mentoring and consulting to promote commercialization, inspires entrepreneurship and creates a production environment where ideas can be experimented, and operate programs to strengthen regional-based occupancy capabilities through investment mediation	-	• For academic staff • For students
Student Innovation Hub	SNU Social Ventures on NETWORK (snusv.net)	SNUSV.NET provides an opportunity to find reliable partners with passion for starting a business. Based on the wide range of knowledge for starting a business such as entrepreneurship, organizational structure, marketing, development, design, writing a business plan, and how to	-	• For students

		attract investment, each team conducts a practical startup project.		

SNU provides infrastructure, funding schemes, and programs for creating innovative ideas

SNU Engineering Consulting Center [128] was established to support the areas of technical advice, technology appraisal, technology education, and technology commercialization in response to the demand for an industry-academic cooperation model that solves technical problems and creates practical economic effects that large, mid-sized, and SMEs need. The Center serves as a strategic hub that systematically connects industries – especially local firms – with the university's School of Engineering. The Center provides an innovation space called 'SNU HAEDONG Idea Factory' [129] in order for students to exchange opinions and realize their ideas. Idea Factory support equipment such as 3D printers, 3D scanners, laser cutters, and CNC machines, electronic parts, and materials as well as, home base space and production space. Another space for supporting students' startup is 'GongZone34' [130] which support technology-based startups and ecosystem by providing space to cultivate talents. In addition, GongZone34 provides startup customized programs such as mentoring and club activities. The SNU Engineering Consulting Center operates 'SISP Entrepreneurship Center[131]. In System on a Chip (SoC) field, SISP Entrepreneurship Center aims at incubating the advanced 50 SMEs. Providing free IP in design stage in cooperation with ARM (Advanced RISC Machines) in the three field: system semiconductor, bio-health, and future vehicle. The center provides mentoring from design to prototype development, and from patent strategy to business model establishment and IR strategy. In addition, the center provides various kinds of networking using the resources of SNU: IR networking (VC, AC), C-Level networking (related to system semiconductor), Chain networking (whole industries), Smartcity networking, Alumni networking, and MatchPoint networking.

SNU Technology Holdings was established in October 2008 to encourage the founding of business ventures by faculty and students of SNU and to facilitate the commercialization of the school's excellent technology resources. Its main functions are (1) provide consultation to faculty and students wishing to found a business venture regarding the potential for commercialization and the commercialization process, (2) discuss important matters regarding founding a business venture on behalf of the university, (3) establish a subsidiary where the school (SNU Technology Holdings) holds a partial share through case or investment upon based on discussion with the founder, and (4) provide support such as commercialization funds, additional development funds, venture funds to the subsidiary in connection with outside investment institutions, Korean Intellectual Property Office, Small and Medium Business Administration etc. In the case of a company that uses technology owned by SNU and where SNU Technology Holdings, the SNU Technology Holdings holds shares of over 20%.

Center for Industry Collaboration (CIC) - Artificial Intelligence Institute SNU (AIIS) [132] aims to promote efficient and valuable UIC between AI researchers and companies at SNU since January 2021, the CIC has been established and operated. Although active exchanges and cooperation between companies and universities are essential elements for the development of high-tech industries, there have been many cases of UIC in Korea being operated based on personal connections without systematic processes and management. AI researchers are promoting systematic cooperation with companies that want to work with SNU's AI researchers through CIC.

- A company that wants to respond to the future with AI-based digital transformation
- A company that wants to expand into new business and secure competitiveness with AI technology
- A startup that wants to confirm the commercialization potential and jump to a unicorn with AI technology
- Integrated AI manpower across 60 departments of SNU (300 professors and 2000 researchers)
- AIIM Members: HYPERCONNECT, NAVER, LG AI Research

Summary and Conclusions

SNU has significantly contributed to the Korea's scientific and technological knowledge accumulations as well as Korea's economic growth and innovation development. SNU as the 1st ranked university in Korea has been leading the changes in the history and the system of higher education by experimenting and realizing them with the development of science and technology in Korea. With to the introduction of TTCP, IARC, and LINC, SNU has embodied various policies to encourage UIC, to foster creative leaders, and to support and nurture start-ups. As the interviewee explained in the excerpt below:

"Comparing with global innovative universities, universities in Korea used the name of UIC foundation instead of TTO/KTO. In the case of SNU, the SNU R&DB Foundation was established as an independent corporation with the purpose of integrated management of research projects and funds transparently. In particular, the UIC foundation was formed because research projects at universities depend heavily on government support and industry collaboration and managing research expenses is important. In the past 5 years, as interest in university spinoffs and startups has increased, SNU entrepreneurship center was emerged, which is managed under the umbrella of the president." (Anonymous. 2021. Interview with an official of SNU R&DB Foundation. September 3, 2021)

This suggests that the technology transfer/knowledge transfer activities of SNU depend a lot on government support and UIC activities, and that performance such as licensing, spinoff, and startup requires a long-term. In addition, SNU R&DB Foundation is a centralized organizational structure and an efficient and effective management structure with sub-organizations under it. The SNU R&DB Foundation is formed by a large group of 162 members including laywers, patent attorneys, and tax accountants. The performance of these activities is increasing every year and showing rapid growth with the achievement of 5,217 million KRW in 2020. In the startup incubation, there are independent centers that support startups for each college, and there is an entrepreneurship center under the direct control of the president who integrate and manage them.

There are two interesting practices of SNU. The Korean universities have their own unique practice of recruitment to hire industry experts with 10 years of working experience in faculty

positions. In this system, the faculties can concentrate only on the UIC activities using their own formal/informal networks and connections and bring many opportunities of UIC to SNU. The other practice is a flexible policy experiment of 'one day per week'. SNU tries to bring global scholars and experts to SNU using faculty positions concurrently.

3.3.8. Korea Advanced Institute of Science and Technology

Founding background: Science and technology park

Daedeok Science and Technology Park (DSTP) is the representative public research and development (R&D) hub in South Korea (Korea). DSTP is in Daejeon, an hour away by high-speed train from Seoul, the capital of Korea. DSTP was planned and built by the Korean government in the early 1970s to strategically foster the chemical industry and heavy industry. DSTP as a planned park played an important role in Korea's top-down science and technology (S&T) policy at the national level and led Korea's technological development as a "national" R&D hub, particularly in the early stages of Korea's industrialization. The country which depended on imported technologies from advanced countries has established several government research institutes (GRIs) specializing in various kinds of technologies to promote R&D activities for the independent development of production and manufacturing technologies. When Korea coped with the economic crisis, a wide range of venture firms in DSTP were emerged as spin-offs from GRIs with industrial and production activities. In 2000, the government proclaimed DSTP as "Daedeok Valley" for turning it into a regional innovation cluster like Silicon Valley. In addition, for reinforcing the commercialization of DSTP's R&D performances, the government designated DSTP as a "Special Zone for National R&D" to accelerate innovation and technology hub in 2005.

In 1971, the Korean government established its predecessor, Korea Advanced Institute of Science (KAIS), aiming to "educate and train highly qualified scientists and engineers equipped with theoretical and practical expertise". Ten years later, the government merged it with the Korean Institute of Science and Technology (KIST), thus forming KAIST. The Korean government decided to redesignate Daedeok Science Town as a "Technopolis" in 1984. More than simply a national research center, it would combine research with development and provide a medium-sized city with ample housing, recreational and cultural sophistication. To Korean policymakers, KAIST was an ideal centerpiece for new Technopolis. KAIST administrators initially resisted because stakeholders including faculties, business partners, and students did not believe that KAIST would provide sufficient incentives for companies to set up a research institutes in Daejeon. In 1989, KIST decided to be separate from KAIST. To secure sufficient space and sustainable financial and political supports from the government, KAIST had no choice but to move to a new campus in the DSTP by merging with Korea Institute of Technology (KIT) in 1990. Despite two mergers, KAIST has always been a research-oriented science and technology school. It has a close relationship with the Korean

government and has undertaken various national research and technology transfer work.

A brief introduction to KAIST and the composition of the department and main research areas
As the first technical university in Korea, it is also the top technical university in Korea. Founded in 1971, KAIST is a public research university located in Daejeon Metropolitan City, South Korea. It is ranked by QS as one of the top 50 universities globally, with high ratings and industry recognition in South Korea.

KAIST was established in 1971 as the Korea Advanced Institute of Science (KAIS) with a $6 million loan ($38 million in 2019) from the United States Agency for International Development (USAID) and the support of President Park Chung-hee. The institute's academic program was designed primarily by then Stanford University Vice President Frederick E. Terman and Chung Geum-mo, a professor at the Polytechnic Institute of Brooklyn. The two main functions of the institute were to train senior scientists and engineers and develop a structure for graduate education in the country.

In 1981, the government merged the Korea Advanced Institute of Science and the Korea Institute of Science and Technology (KIST) to form the Korea Advanced Institute of Science and Technology or KAIST. Due to differences in research philosophy, KIST and KAIST separated in 1989. In the same year, KAIST merged with Korea Institute of Science and Technology (KIT) and moved from Seoul to Daedeok Science City in Daejeon. in July 2006, President Seo's first order of business after assuming office was to develop a KAIST development plan. On February 5, 2007, the "KAIST Development Five-Year Plan" was finalized by the KAIST Steering Committee. in January 2008, the university dropped its full name, "Korea Advanced Institute of Science and Technology", and changed its official name to just KAIST.

KAIST is a research-oriented science and engineering institution. It is also considered one of the nation's most prestigious universities, is internationally recognized for its business education, and hosts the secretariat of the AAPBS.KAIST has 10,504 full-time students and 1,342 faculty researchers (as of the fall 2019 semester) and a total budget of $765 million in 2013, of which $459 million came from research contracts. With its education, R&D facilities of international standard, its system of consecutive bachelor's, master's, and doctoral degrees, and it is the human resources training system that combines teaching and research; it has produced a large number of senior personnel with high theoretical knowledge and practical application skills, making a significant contribution to the technological and economic development of Korea. KAIST has nine research institutes, 34 research centres (9 nationally designated research centres), and 62 research laboratories in various fields, including the Institute of Advanced Science, the Institute of Scientific Excellence, the Institute of Mathematics, the Institute of Nanotechnology, the Institute of Mechanical Technology, the Center for Artificial Satellite Research, the Brain Science Research Center, and the Semiconductor Design Education Research Center, making it the cradle of basic and high-tech research in Korea. In 2003, the institute spent 115.1 billion won (about $100 million) on research, with 973 research projects and 247 million won per professor. As of 2003, 33,114

papers were published in reputable domestic and foreign journals, including 22,077 in foreign journals; 1,577 papers were published in SCI in 2003, 4 per professor. Two hundred sixty-one patents were registered in 2003, including 181 domestic and 80 foreign. The institute has built a technology innovation centre and a new technology business support group. A professional incubator and graduates have successfully started more than 580 high-tech venture companies to date.

KAIST researches national subjects as well as development commissioned by companies and has established industry-academia partnerships with many famous companies such as Samsung Electronics, Hyundai Electronics, LG Semiconductor, and SK Communications, engaging in joint research on subjects and directed human resources training according to the needs of companies, with the required funding provided by the relevant companies. Although KAIST has a short history, its graduates are active in many major companies in Korea, such as Samsung Electronics, LG Electronics, Hyundai Motor, and Telecom.

Vision for 2031 and plans to promote a culture of innovation and entrepreneurship
Under Vision 2031, KAIST seeks to contribute to the happiness and prosperity of humanity through innovation in science and technology. Vision 2031 entails KAIST's innovation initiatives in the five areas of education, research, technology, commercialization, and globalization, and future strategy. Vision 2031 reflects the three keywords of humanity, happiness, and prosperity.

First, the mission of KAIST when it was founded in 1971 was the development of science and technology and industry. Today, KAIST should exert efforts to achieve universal values that extend beyond Korea to benefit humanity. The happiness we pursue is a concept that covers social value and encompasses sustainability, dignified living, and qualitative satisfaction. Social entrepreneurship and the launching of social enterprises are also included. Prosperity is the enjoyment of life, surpassing basic needs in terms of psychological, economic, and material fulfilment.
KAIST will provide education to foster creative leaders who enhance the social value of science and technology, conduct research and development to overcome challenges for humanity, emerge as an entrepreneurial university that creates value through technology commercialization, and play the role of 'World Bridge KAIST' through globalization. The core of these four key innovation strategies lies in the goal of becoming a university that pursues 'what' as well as 'how.' KAIST's entrepreneurship education assessment system is results-oriented, with relatively comprehensive evaluation indicators, usually in a systematic way, and a strong focus on openness and sharing at the level of results translation.

According to KAIST International Office, there are three major research programs, the HRHR (high-risk, high return) Program, Undergraduate Research Participation (URP) Program, and EEWS (energy, environment, water, and sustainability) Program.
The HRHR Program provides funding for researchers who have creative ideas and can put them into practice. When searching “HRHR Program” online, we could find many papers published by researchers and scholars supported by this program.

The URP Program, as the name suggests, is targeted at undergraduate students, aiming to encourage them to take part in research projects related to science and engineering to enhance their research capabilities.

The EEWS Program is a graduate school that was established in 2009. It cooperates with other research facilities and companies around the world to conduct inter-disciplinary research and develop technologies. KAIST-IP CCE is an institution run by KAIST for cultivating talents in terms of intellectual property and entrepreneurship. Every year, this institution admits 80 middle school students and provides them with a two-year training, after which these students can choose to receive more professional training.

Purpose and educational model for the establishment of K-Schools and Entrepreneurial Villages

Engineers must exercise creativity and embrace challenges to solve challenges faced by humanity in the 21st century. If driven by creativity and a love for challenge, engineering technology produces innovative solutions that contribute to advancements for humanity. It is entrepreneurship that makes such innovations possible.



K-School was established in 2016, with funding of 3.8 billion won from the Ministry of Science, ICT and Future Planning to integrate entrepreneurship in KAIST's specialized engineering curriculum.

K-School provides undergraduates with theoretical education on entrepreneurship and business under a minor in science-based entrepreneurship. To instil entrepreneurship in all students of KAIST, it offers educational programs and seminars through mandatory general courses and activity units.

K-School is home to the Start-up Village, an entrepreneurial platform that supports all stages from idea development to the launch of startups. More specifically, the five stages are: step one: idea enhancement; step two: ideation; step three: prototype development and R&D; step four: incubation; and finally: startup launch.



Figure 3-18 The stages of launching a startup at K-School

Leading roles mainly include 4 parts:
For Masters students, the Master in Entrepreneurship and Innovation has 21 participating departments. The practical courses are aimed at problem-solving and include capstone design and internships. For undergraduates, a minor in the science of entrepreneurship is very important. In addition, undergraduates need to focus on the theory and practice of entrepreneurship and start-ups. Knowledge of entrepreneurship theory helps undergraduates to quickly understand the structure and core ideas of a start-up business. At the same time, KAIST helps students to practice and quickly enter the world of practical work. For all students, KAIST expects everyone to join courses and seminars on entrepreneurship and business. Business courses and high-level industry seminars are considered the fastest way to help students talk to entrepreneurs. Some of the courses in collaboration with KAIST's Institute for Startups (ISK) are supported by ISK, and the Startup Village is primarily used to build a platform for entrepreneurship and support startups at all stages from conception to launch. It focuses on the synergy of team and community activities.

Profile, mission and strategy of the three institutes under KAIST
The HR Program is mentioned in "Programs to promote a culture of innovation and entrepreneurship". KAIST Team Grant Program. KAIST Team is a special fund dedicated to KAIST's high-priority projects for fostering multidisciplinary global talents, inviting/researching leading international scholars, expanding educational and research infrastructure, etc. The program when "regular monthly donations of 10,000 KRW to support KAIST". Departmental and laboratory development funds are required for specific funding. The majority of these funds flow to the development of colleges, departments and laboratories. (You may also donate to colleges/departments other than those listed below.) If you want to support research in a specific area you need to give to a specialized research group." Please support research in a specific area by donating to a department or lab."

The KAIST Institute (KI), established in 2006, plays an essential role in "open innovation and inter-and multidisciplinary research." It has six research institutes for BioCentury, Information Technology Convergence, Robotics, NanoCentury, Health Science and Technology and Artificial Intelligence, and three research centres. KI comprises six research institutes in the fields of BioCentury, IT Convergence, Robotics, NanoCentury, Health Science and Technology and AI. There are also three additional research centres: I-Space, the Saudi Aramco-KAIST CO2 Management Center, and the Fourth Industrial Revolution Intelligence Center (FIRIC)), which performs trends analysis and predictions concerning significant policies, governance, and technology in the era of the Fourth Industrial Revolution. KI's mission is to promote and facilitate interdisciplinary excellence in research , and interdisciplinary development can bring different disciplines closer together to generate more innovative ideas. To develop strategic research programs that address critical issues for the future of humanity, provide new growth drivers for the Korean economy, and bring new impetus and change to Korea's national industry in areas such as science and technology. To enhance KAIST's reputation by producing world-class R&D results. KI's strategy is to operate independently of academic units and to focus on future or practical topics with significant impact, linking knowledge to real life. Identify new topics through a faculty and administration-

led process. Incubate new themes by providing seed funding and organizational support until they become mature, leading to the establishment of a regular research center at KI. Enhance open innovation through a network of national and international partners in academia and industry. Implement and maintain large-scale testbeds for resilience-based interdisciplinary and convergent research.

We research and develop source technology for security applications while training security technology professionals for the future. The Institute of Security Convergence (ISC) has been established in response to the complex internal and external security landscape and intensifying threats surrounding our nation, under the goal of applying advanced technology developed at KAIST to the field of security and national defence, to create one of the world's leading security technology institutions. The Institute of Security Convergence consists of the SC-Strategy Institute, which conducts mid to long-term projects under the eight research groups of cyber security and space systems. Defence technology, unmanned systems, energy, materials, sensors and quantum, the SC-Theatre Defense Research Center, Poongsan-KAIST Future Technology Research Center, Hanhwa Systems-KAIST Research Center for the Convergence of National Defense and Artificial Intelligence, LIG Nex1-KAIST Smart National Defense 4.0 Research Center, Security Technology Research Center, and the Next Generation National Defense AI Research Center.

KAIST pairs senior and junior faculty members who will continue the senior scholar's academic legacy and achievements even after the senior researcher retires. The labs will be funded for five years, and the funding will be extended if necessary. Six labs have been selected for this research drive introduced in 2018 under the Vision 2031 Innovation Initiatives.

State-of-the-art facilities at KARA provide accurate data and experiment analysis for helping research create meaningful results. The centre is open to other universities, research institutes, start-ups, and SMEs. Their key responsibilities are divided into 3 parts:
The first step is to procure shared equipment and build infrastructure to continue expanding the inventory of advanced research equipment in accordance with the medium-term plan. At the same time, train professional staff and expand facilities. Involve more people. Finally, build and manage the joint utilization system at KAIST. Through the system, data collection and management is performed.
The second is advanced research support. Provide support services that lead research by developing new analytical methods and providing accurate analysis. Accumulation of know-how and development services through the introduction of a large number of overseas human resources and advanced technologies. Support for research at universities, research institutes and companies through the shared use of equipment.
The third is education and management. Education and management are very important for KAIST. Building an open system to educate students on the use of the equipment. Hold application analysis workshops to fully expose teachers and students to more new ideas and stimulate a sense of innovation and self-learning. Build a radiological safety system and educate users.

KAIST's Faculty Promotion and Tenure Policy

Since the level of professors and the mobility of faculty members have a direct or indirect impact on the level and reputation of the university. Therefore, it is important to understand KAIST's tenure rules. According to KAIST's tenure policy, faculty members who wish to apply for or be appointed to tenure must be in good standing in teaching and have made significant contributions to scientific research and industry-academia collaboration. Below are the rules that govern tenure-track faculty appointments.

Article 1 (Purpose) The purpose of these Rules is to establish matters necessary for the appointment of tenure track faculty to secure outstanding faculty and guarantee their status, under Article 21 of the Regulations of the Korea Advanced Institute of Science and Technology (in the future "KAIST") and Article 8 of the Rules on Personnel Management. <Amended 4/23/2018>

Article 2 (Qualifications) (1) The President of KAIST shall appoint to the tenure track, faculty who receive a remarkable evaluation for activities in Education, research, university-industry cooperation, and contribution/volunteering, or faculty recognized as authoritative figures in a specific area of expertise following deliberations by the Faculty Personnel Committee; subparagraph 1 below shall apply to those appointed on or after January 1, 2007, and those appointed on or before December 31, 2006, may choose to be subject to either subparagraph 1 or 2 at their desire: <Amended 3/1/1995, 9/2/2002, 7/25/2003, 12/19/2006, 2/14/2008, 8/19/2008, 4/23/2018>

1. Those with qualifications in Article 21 of the KAIST Regulations, regardless of their rank of assistant professor, associate professor, or professor;

2. KAIST faculty members who have continuously served for at least seven years with outstanding educational and research achievements (those serving as professors on or before December 31, 2006, may apply for the tenure track only once within seven years). <Proviso newly inserted 2/13/2007 (2) Amended 12/23/2005; Deleted 12/19/2006

The above selected regulations describe the purpose and manner in which KAIST selects tenure-track professors (primarily including significant accomplishments and length of tenure)

KAIST's startup business performance

KAIST (President Sungmo Kang) released a report on "2014 KAIST-born Venture Company Performance Survey" containing the above information on the 8th. The report aims to systematize the university's support for entrepreneurship and propose effective support programs through the KAIST Business Performance Survey. The report consists of six areas, including "general status of entrepreneurs," "status of entrepreneurial enterprises," "cross-sectional analysis by origin," "cross-sectional analysis by degree," "annual performance analysis," and "status of support for entrepreneurship. "The "General Status of Entrepreneurs" provides a clearer picture of the importance KAIST places on supporting student entrepreneurship and industrial-academic alliances. The "State of Entrepreneurship" shows the

creativity and innovation of KAIST students and their motivation to participate in entrepreneurship.

First, 1245 businesses were analyzed by type of entrepreneur, 929 of which were alumni businesses, accounting for 74.6% of the total; 191 (15.3%) were general businesses (resident businesses), 91 (7.3%) were student businesses, and 34 (2.7%) were faculty businesses. The final educational level of the representatives was in the following order: 515 (41.4%) with a master's degree, 443 (35.6%) with a doctorate, 213 (17.1%) with a bachelor's degree, and 74 (5.9%) with others. The representative degree of the entrepreneurial company is "Master's degree" or higher, because the master's program acquired professional knowledge and skills in a specific field after starting a business.
Of the 1,019 respondents, 719 (70.6%) were from the Faculty of Engineering, followed by 111 (10.9%) from the Faculty of Management, 103 (10.1%) from the Faculty of Natural Sciences, and 86 (8.4%) from other faculties.

An analysis of the regional distribution of the 1,231 companies that confirmed the location of the head office showed that Seoul had the most companies with 462 (37.5%), while Daejeon and Gyeonggi Province had 355 (28.8%) and 273 (22.2%) respectively, and according to the survey, KAIST origin companies are mainly located in the metropolitan area business. The results of the analysis of the annual performance of 1,069 companies based on the end of 2013 showed that the total assets amounted to 12.444 trillion won, the total sales amounted to 10.130 trillion won, and the annual number of employees was 33,465,000. The annual number of employees was 334,650. In addition, the "gross regional product (GRDP)" scale of venture companies shows that Seoul is 1.58 trillion won (0.49% of Seoul's GRDP), Gyeonggi is 5.219 trillion won (1.67% of Gyeonggi's GRDP), Daejeon is 1.782 trillion won (5.53% of Daejeon's GRDP), and KAIST venture companies are responsible for 5.5% of production in Daejeon.

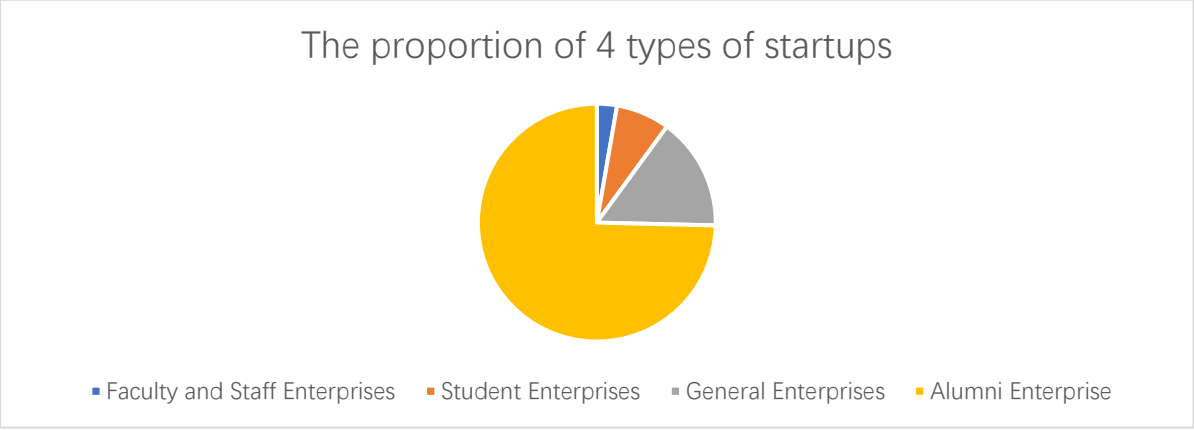


Figure 3-19. Entrepreneur Types and Percentages

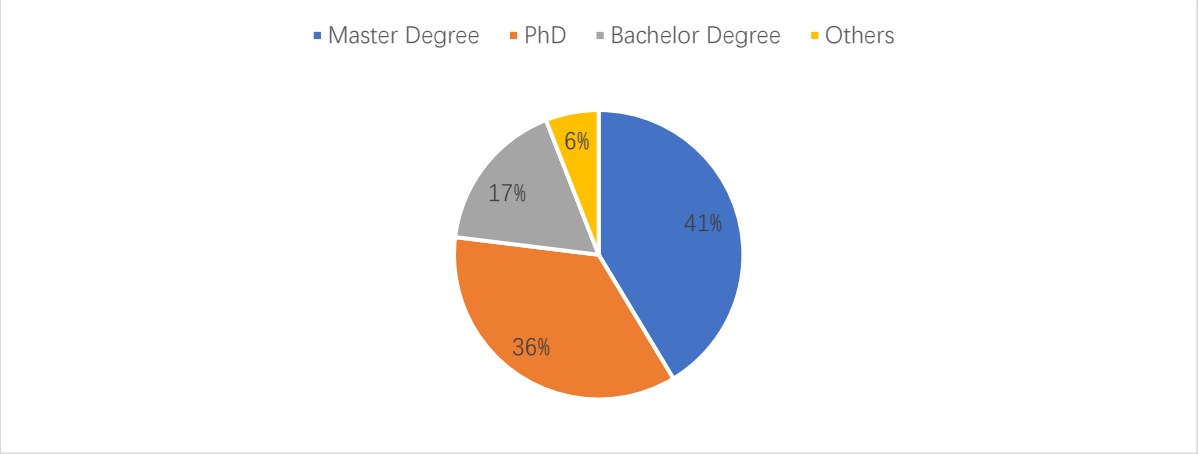


Figure 3-20. Table showing the percentage of degree types for entrepreneurs

KAIST's 2 or 3 star inventions or derivatives and KAIST's well-known faculty inventors

Faculty Inventor

Soonda Choi is a scientist who has made outstanding contributions to the development of satellite construction in Korea. He was the founder of the KAIST Satellite Technology Research Center and led the collaboration between KAIST and Surrey University students to successfully design Korea's first satellite, KITSAT-1, also named "Our Star". [4] The satellite was successfully launched from the Guyana Space Center in 1992. Hee-Nam Jang is a physicist; developed the technique of generation and compression of attosecond pulses, which is considered a powerful tool for probing the subatomic world. Eunseong Kim is a South Korean physicist. He is an experimental cryogenic physicist. His advisor, Moses H. W. Chan, saw the first phenomena that were interpreted as supersolid behavior. in 2008, Kim was awarded the Lee Osheroff Richardson North American Science Award from Oxford Instruments for his contributions to the understanding of solid helium. These technologies are considered to be very important breakthroughs in technology and industry and have made important contributions to human inquiry into physics.

Technology transfer office or TTO-related offices

The highest officer of KAIST TTO is the president, followed by the Vice President for Research, who is mainly responsible for the institute of Technology Value Creation. There are three main sections under Institution of Technology Value for Research which are: Administration team of Institution of Technology Value Creation, Intellectual property & Tech-Transfer Center, Industrial Liaison Center. For Administration team of Institution of Technology Value Creation, the main role of the TVC is to manage the budget and HR of the TVC, such as the opening and management of the technology commercialization exhibition, the operation of youth TLO project, etc.

For Intellectual property & Tech-Transfer Center, mainly responsible for invention evaluation and outstanding IP applications; IP evaluation and registration and maintenance management; management of domestic and international IP offices; IP-related university-industry contracts and management; domestic and international IP marketing.

For Industrial Liaison Center, mainly responsible for cooperation and planning of G-CORE research projects and industry technology needs; management of subsidiaries.
For Hong Kong, KAIST is characterized by its industry-academia-research alliance and its focus on innovative development in the field; KAIST attracts academic leaders and industry support to put innovation into production to solve real problems. In the KAIST TTO office, both the publicity and media parts and the project activities are held in a meaningful way and attract many industries to participate. In this regard, Hong Kong can establish cooperation with more local technological innovation companies to provide students with more vision.

Brief description and history of the technology transfer office or an office related to technology transfer
The intellectual property & Tech-transfer Center functions as a medium linking the university's technology with industry. Through the vitalization of technology transfer through strategic patent management, the intellectual property & Tech-transfer Center is a technology distribution partner, functioning as a medium between the technology supplier and consumer.
The Intellectual Property & Tech-Transfer centre is conducting various projects to revitalize technology marketing through systematic intellectual property management. Through all these efforts, The Intellectual Property & Tech-Transfer centre seeks to establish an active licensing system such as creating a patent portfolio, establishing a patent evaluation system and patent information system, training researchers, and reinforcing investor interviews.
In order to meet the demand for talents and better serve the development of the IT industry, this program was established in 2006 and is committed to training outstanding leaders for the IT industry. Sponsored by the Ministry of Science, ICT and Future Planning, it provides graduate courses with scholarships for talents in IT-related industries, aiming to transfer Korea's advanced business and technology strategies to IT managers worldwide.
KAIST TIC/TBI Established in December 1994, 1997.09 it started by expanding to New Technology Start-up Support Group (HTVC) and absorbed Korea Information and Communication University's (ICU) Startup Incubation Center through a merger in March 2009. selected as a leading university technology transfer organization (TLO) support program in July 2006 and renamed the Office of Industry-Academia Cooperation in March 2003.

KAIST's Vision and Mission 2031 Innovation in Technology Commercialization
"KAIST has students from more than 60 countries around the world, and is the most widely-sourced university in Korea. The university offers full scholarships to students, covering the majority of undergraduate and graduate students, and international students are no exception.
Its vision is to propose solutions to the problems facing our nation and humanity, and to create sustainable global value creation. At the same time, KAIST places special emphasis on the development of students' research skills and overall quality, requiring them to demonstrate professionalism and dedicate themselves to research in the field of science and technology. According to the ranking data of the Korea Joongang Daily, KAIST has more than 80% of its major courses taught in English, and not only that, the university is actively bringing in top-notch international faculty to gradually align with international standards in the mode of schooling and talent development.
KAIST's technology transfer system includes both internal and external organizations. It has a

human resources department, a committee/regulatory office, a budget office, a public relations/cooperation office, and a technology value creation institute. Patents and technologies developed by the University are given priority for transfer to domestic SMEs. The first consideration is to grant non-exclusive rights. Therefore, the human resource department is to provide better human resource services, both in terms of bringing in more creative people and providing more industrial contact programs and more contacts to help contact Korean SMEs. Since the Technology Sector Office deals with issues of intellectual property and use of legal policies, it is necessary to have a supervisory department, which is designed to check the suitability of technology products and their compliance and conformity under intellectual property. As an integrated industry-academia-research office, KAIST TTO must focus on serving high-quality startups or higher-value technology companies, as well as on helping innovative new companies. The Institute for Technological Value Creation occupies an important position as a research arm for the development of new businesses, and therefore provides value to society through the creation of new materials and technologies that can contribute to the realization of a sustainable society. In addition, TTO collaborates with research institutions around the world with the aim of creating new value with a global perspective on the future. The core functions of the Publicity and Public Relations Office include: 1. to be responsible for news gathering and editorial work, to carry out and expand global publicity work, to operate social media accounts (Facebook, Twitter, Instagram, etc.), 2. to liaise with Chinese and foreign mainstream media and expand media relations, 3. to establish a think tank management and service system, to help build a policy research center with international influence 3. establish a think tank management and service system to help build a policy research center with international influence and significant social impact.

Intellectual Property and Technology Transfer Centre:

An IP & Technology Transfer Center is the medium that connects the school's technology with industry. By activating technology transfer through strategic patent management, an IP & Technology Transfer Center becomes a partner in technology distribution, acting as a mediator between technology suppliers and consumers. Creating excellent intellectual property requires first attracting patent applications and registrations, managing patented technologies, applying and promoting excellent technologies, interviewing excellent inventors, supporting overseas patent applications, etc.

The department operation overview: The Intellectual Property & Tech-Transfer centre is conducting various projects to revitalize technology marketing through systematic intellectual property management. Through all these efforts, The Intellectual Property & Tech-Transfer centre seeks to establish an active licensing system such as creating a patent portfolio, establishing a patent evaluation system and patent information system, training researchers, and reinforcing investor interviews. Students who have ideas for developing new technologies but lack the means to do so can rent research space and equipment that can be used to conduct technology research. If the research is successful, they can continue to TBI for more in-depth research and development. After successful development, the technology can be transferred to joint companies for product production.

Introduction to R&D Incubation Support Program (Korea South East Power Co., Ltd.)

The LabStartup program requires that start-up projects be the product of a research project

conducted in a laboratory during participation in KAIST, and the duration of the program is 6 to 8 months, while E*5 is 2 to 3 months. E*5 KAIST has been established for a long time and helps teams start their own business through a well-organized program The program is well organized to help teams start their own business. Through mentor consultation and training, the team examined the need for its items, reviewed the business model, and created a Pitch Deck for the final business plan to be presented to investors. The target is SMEs who wish to realize initial R&D related to power generation equipment and materials. R&D incubation is conducted by the KAIST lab to support SMEs wishing to localize and develop new products. The scale of support is project cost (about 30 million won/company), number of companies (about 10 companies per year)

KAIST's 1 or 2 star events and projects organized by the trade representative
It serves as a platform for students and graduates of the program to connect with various IT-related fields such as government, businesses, and facilities, thus promoting collaboration. KAIST uses entrepreneurship education in industrially strong disciplines as a starting point to build more systematic and organic partnerships with local communities and businesses, with mutual benefits for all three parties, allowing the results of university entrepreneurship education to be industrialized for universities through --Regional synergy contribution.
For example, the R&D Incubation Support Program of Korea South East Power Co., Ltd. is a program that supports the establishment of R&D feasibility, marketability, likelihood of success, and commercialization strategies to improve the chances of successful commercialization of excellent ideas owned by SMEs. It targets SMEs that wish to realize initial R&D related to power generation equipment and materials. It also provides KAIST Lab incubation R&D support for SMEs wishing to realize localization and development of new products. Scale of support: Project cost is about 30 million won and the number of companies is about 10 per year.

Summary and Conclusions
KAIST is a university that plays an important role in Korea both in the field of science and technology innovation and in the field of science and technology teaching. With the achievements of KAIST in knowledge and/or technology transfer, we can find that the most distinctive feature of KAIST education is that it relies on industry-academia cooperation to promote entrepreneurship education, forming a very ecological model of industry-education integrated entrepreneurship education. Because the state and local industries have established industry-university cooperation foundations with long-term and continuous nature within universities, almost every institution has set up industry-university cooperation centers or industry-university cooperation colleges, and most universities have also arranged their own entrepreneurship colleges, entrepreneurship support groups, and even entrepreneurship clubs to the industry-university cooperation centers, and even merged the homepages of their websites. This feature is very realistic and is a result-oriented model with sustainability.

KAIST is committed to fostering innovative, scientific talent with an enterprising and collaborative spirit, the will and enthusiasm to pioneer new fields of research, students with a sense of ethics and deep thinking about humanity and the environment, and a desire to

contribute to the nation and society. We also place great emphasis on the introduction of faculty and outstanding researchers, as well as strengthening ties with science and technology companies. KAIST has established more than 100 research centers and has established close cooperation with companies and has conducted a lot of scientific research in the research centers through university-company cooperation, and has realized the transformation of the results.

KAIST aims to nurture innovative talents for the Korean industry and to be a significant base for raising the level of technological innovation in Korea and leading the country's innovation development. The university is committed to creating a new engine of growth for Korea through interdisciplinary and comprehensive research and contributing to the happiness and well-being of humanity through the development of science and technology. The university has made significant contributions at the national and regional levels by developing research talent through research in the field of technology and by providing important scientific talent for national space development research through Korea's Human Resource Space Development Fostering Program. KAIST has developed a systematic program structure in the fields of environment, water, transportation, and construction through research on sustainable green growth, which confirms KAIST's important role in promoting the development of the Korean nation and humanity.

3.3.9. National University of Singapore

Basic Information

Founded in 1905 as a medical school to serve the local community, National University of Singapore (NUS) is the oldest higher education institution in Singapore. It has a full range of disciplines, including humanities and social sciences, science, engineering, business, law, architecture, computer science, dentistry, Yang Luling Medical College and Yong Siew Toh Conservatory of Music, Lee Kwan Yew School of Public Policy, and East Asia Institute. NUS has 8 research clusters: Ageing, Asian Studies, Biomedical Science & Translational Medicine, Finance and Risk Management, Integrative Sustainability Solutions, Maritime, Materials Science, and Smart Nation. NUS has 8 subjects that rank in the world’s top 10: Architecture/Built Environment, Chemical Engineering, Chemistry, Civil & Structural Engineering, Computer Science & Information Systems, Environmental Sciences, Materials Science, Statistics & Operational Research. The campus is also home to the Temasek Life Sciences Institute (TLL), data Storage Institute (DSI), Information Institute (I2R), Materials Research and Engineering Institute (IMRE), Molecular Cell Biology Institute (IMCB), Quantum Technology Center (CQT) and other advanced research institutions.

Since the 1980s, with the economic structure transforming into the innovation-driven economy,

the research institutes in the universities attracted increasingly attention. In 1992, the National University of Singapore started to set up the technology transfer office, paying attention to the innovation and creativity. However, the patent activity was not famous at that time. The rate of technology transfer and the rate of spin-offs were minimum until the year of 2000.

In 1997, the Asian financial crisis caused the recession of Singapore economy, which helped the Singapore government to promote the transformation of National University of Singapore to innovation and technology transfer. Under the rule of transforming economic structure and driven forces, the government, the university, and the industry started to collaborate and form an interactive relationship. Hence, the government started to recognize the necessity of accelerating the transformation to an innovative and knowledge-based economy.

At that time, the then newly NUS appointed President of the National University of Singapore is the main driver of the strategic transformation of the school. The president Shih Choon Fong was educated at Harvard University and has worked for GE and worked as the Dean of graduate school of the Brown University. With the strong support of the Singapore government, President Shih has not only played a crucial leading role in the transformation of the university, but also constructed a set of systematic strategies for the transformation of the university into an entrepreneurial university.

NUS now offers a comprehensive approach to education, research and entrepreneurship by nurturing future-ready graduates, engaging in high-quality research that transforms lives, and creating a vibrant innovation and entrepreneurship ecosystem in Singapore and Southeast Asia. It is built with the support of three pillars - education, research and entrepreneurship.

NUS provides a transformative educational experience that offers a global outlook that is rooted in Asia. Aside from gaining broad and deep knowledge inside the classroom, students can pursue internships at deep-tech start-ups and take classes at prestigious partner universities in some of the most exciting cities around the world.

For their faculty and researchers, NUS provides a base where they can undertake the multidisciplinary research that has made NUS a thought leader in Asia. NUS particularly emphasizes research on active ageing; Asian studies; bio-medical sciences and translational medicine; energy and environmental and urban sustainability solutions; finance and risk management; materials science; maritime studies; and the smart nation.

NUS’s educational programmes and research activities complement its efforts to stay ahead in entrepreneurship education and technology entrepreneurship. The university provides platforms and programmes such as BLOCK71 and the NUS Start-Up Runway, where the faculty and students can advance innovation and entrepreneurship, commercialize technological developments, and further their synergies with industry.

The recently established Innovation 4.0 building (i4.0) symbolizes the integration of education, research and entrepreneurship at NUS. It is a hub where complementary research programmes and institutes are co-located to facilitate collaborations and enable the creation of spin-offs

from NUS's digital R&D efforts. Several national research programmes have been brought together at i4.0, including AI Singapore, the Singapore Data Science Consortium, and the National Cybersecurity R&D Laboratory. The building also houses the corporate laboratories the school have set up in collaboration with major companies such as Grab and Singtel, as well as international research centres such as the NUS-Tsinghua Extreme Search Centre.

NUS is a research university with a solid teaching and research team and a vibrant academic research culture. It actively participates in various research projects and makes substantial contributions to Singapore and the world. The NUS research strategy is to strengthen the influence of research results through cross-field synergy. NUS regularly collaborate with government departments, the industry, and outstanding domestic and overseas academic partners to ensure that NUS research can truly solve real-world problems.

NUS has made great progress on the patent development and knowledge transfer. From 2008 to 2018, the number of patents increased from 25 to 90, the project value increased from 376 to 782. Besides, the school has consistently been engaged in collaboration with industry and other universities. The following table concludes technology transfer outputs from 2008 to 2018.

NUS's Technology transfer office: Industry Liaison office (ILO)

With the guidance of transforming the NUS into the top university around the world, President Shih set the goal to transform the university into a global knowledge hub. The strategy of the university suggests that NUS will compete with its peers on a global scale and gain a certain reputation. More importantly, the strategy and the new goal would stimulate the innovative and entrepreneurial spirit of students. As a city-state, Singapore is lack in natural resources and small market share. The success of knowledge commercialization requires the spirit and ability of universities to participate in global competition, as well as collaboration, simultaneously. One of the most important components to set up the global innovative university is to hire the most excellent engineers, researchers, and talents. Therefore, the Singapore government give more and more financial grants to the university to attract more talents and share their practical knowledge with students.

The NUS ILO is the technology translation and commercialization arm of the NUS, aims at transforming NUS technologies and talents into investible, scalable deep tech start-ups. The NUS ILO helps to translate innovative research into impactful new products and companies by providing technical, business and legal expertise that supports the commercialization of NUS technologies. In Financial Year (FY) 2020/21, the office oversaw the issuance of 130 technology licenses and the formation of 30 Singapore-based spin-offs, 13 of which came from the Graduate Innovation Research Programme.

Professor Freddy Boey is responsible for the innovation and enterprise affairs in NUS since 2019. Prof. Boey graduated with a Bachelor of Engineering (Materials Engineering) from Monash University, Australia, in 1980, and a PhD from NUS in 1987. As the Senior Vice President for Graduate Education and Research Translation since January 2018, he oversees

NUS' initiatives and activities in the areas of innovation, entrepreneurship and research translation, as well as graduate studies.. Previously, Prof. Boey pioneered the use of functional biomaterials for medical devices in Singapore. He and his research team have filed 118 patents and founded several spin-offs. His customizable hernia mesh has received US and China FDA approvals, with US-China funding. His fully biodegradable heart stent company, Amaranth, which is funded by a Silicon Valley VC, has received buy-in from the US-based Boston Scientific for wide-ranging US FDA clinical trials. His recent spin-off, Peregrine, which uses a nano drug delivery system for glaucoma, won the 2014 Singapore President's Technology Award. His research has been published in over 361 top journals with 18,000 citations. He has an H-Index of 72.

He previously served as director on the boards of the Government Technology Agency of Singapore (GovTech) and Defense Science Organization. He remains a Director for the Health Sciences Authority, Prof Boey also contributes on many boards of nationally funded research centers. He is a Fellow of the Institute of Materials (UK) and the Institution of Engineers Singapore, a Founding Fellow of the Academy of Engineering, Singapore, and had been a member of the National Cybersecurity R&D Laboratory and Singapore Rail Academy Board.

The NUS ILO provide different ***initiatives and programs*** as well as related support to researchers, including Minimum Viable Product Studio (MVP Studio), Joint University Medtech Programme (JUMPstart), and Graduate Research Innovation Program (GRIP). The university has already set a comprehensive system of technology transfer activities.

Launched in 2018, the ***NUS GRIP*** is the ILO's flagship innovation program. Based on their extensive experience working with deep technology, the program will provide step-by-step guidance to NUS Postgraduate students and researchers to train them as entrepreneurs to transform the university's world-class research through their own deep technology start-ups. From providing all the knowledge and skill sets necessary to create their own start-ups, providing the industry linkages to real world problems, to providing the mentorship, funding and other support necessary to take the start-up off the ground. Those who join the programme will get hands-on mentorship by experienced commercial champions, step-by-step guidance to start, develop, and grow an investable deep tech start-ups, access to Master engineers and NUS resources, including labs and prototyping support to build their Minimum Viable Product, be matched to co-founder with complementary skillsets, and investment funds of up to S$100,000 by NUS. Since October 2018, GRIP has completed 7 runs with 128 teams and 348 participants.

The ***MVP Studio*** by NUS IILO was established to create commercially focused prototypes of NUS technologies. The prototypes are built by teams of apprentices under the guidance of Master Engineers, who are highly experienced engineers with years of industry experience. Following MVP Studio methodology, much thought is put into designing these prototypes and building them efficiently and quickly. This enables students and researchers to demonstrate the use of NUS technologies in specific applications. The Master Engineers and apprentices apply their varied skills, creativity and know-how to the prototypes so that our researchers and start-ups can more effectively seek feedback from the market and iterate their products quickly. The MVP Studio is an easy-to-access meet-up point where start-ups, SMEs and MNCs can visit to find out how their businesses can benefit from NUS technologies. Coupled with NUS's diverse

reach in the entrepreneurial community as well as collaborations with government agencies such as BCA and EnterpriseSG, we are able to connect researchers and technologies to industry partners.

There are some success stories. One example is EnvironSens, an NUS spin-off company that has licensed a water toxicity monitoring technology from NUS. This is being developed into the Integrated Intelligent Biosensor (I2BioS), a real time system that can continuously detect the illegal or accidental discharge of heavy metals into trade effluent wastewater (liquid waste discharged from business or industrial processes). EnvironSens got Patents for technology filed in Singapore and worldwide on July 2016 and July 2017 respectively before incorporated on December 2017. The company was awarded a grant of SGD$2.4 million in 2018, under PUB's Competitive Research Program (Water). Another example is Attonics Systems, a spin-off from NUS in 2015 after 10 years of R&D to provide fast, robust and smallest size devices for in-the-field detection and analysis of substances (gases, liquids and solids). Attonics Systems invented, built and demonstrated a new compact and static spectrometer platform, the Multi Phase-Shifting Array Spectrometer which outperforms conventional Fourier transform spectrometers in terms of speed, ruggedness and portability. The co-founder got NUS Licenced technology from ILO in 2015 and raised pre-series A funding in 2018.

NUS has made great progress on the patent development and knowledge transfer. From 2008 to 2018, the number of patents increased from 25 to 90, the project value increased from 376 to 782. Besides, the school has consistently been engaged in collaboration with industry and other universities. The following table concludes technology transfer outputs from 2008 to 2018. In 2020, NUS accounted for around 30% of tech start-ups in Singapore, and NUS-affiliated start-ups accounted for 20% of venture capital funds raised by companies based in Singapore.

Table 3-24 technology transfer outputs of NUS[133]

year	number of patent granted	new project launched	project completed	research collaboration	collaboration with industry	project value ($ million)
2008	25	743	369	142	-	376
2009	28	834	785	178	157	469
2010	40	1021	901	214	-	482
2011	38	530	1056	258	223	436
2012	40	9302	950	263	83	579
2013	56	1100	970	292	94	589
2014	51	1000	930	415	108	757
2015	102	814	687	366	105	714
2016	115	1110	1170	353	112	745
2017	119	625	1287	248	78	742
2018	89	1021	865	117	57	782

Source: The NUS 2008-2018 annual report, https://nus.edu.sg/annualreport/

NUS's IP policies

NUS is a publicly funded organization with a dedicated mission to transform the way people think and do things through education, research and service. The university therefore focuses on creating, disseminating and applying knowledge through research and education for the benefit of Singapore and its people and the global community as a whole.In the process of creating, disseminating and applying knowledge, Intellectual Property is developed or created by university members primarily in the form of patents as well as copyright to written and audio visual and other works.

In order to ensure that the knowledge created through research and education in the university will reach and benefit the wider community in Singapore and the world, NUS encourages publication and/or application of such knowledge. One of the methods to apply the knowledge is through commercialization of this Intellectual Property for the greater good.

The following table summarizes IP achievements by 2018.

Table 3-25 Retrieved information as at 18 July 2018

Invention disclosures	304
Patent applications	540
Patent applications (families)	374
Patents granted	119
Patents granted (families)	84

Note: A patent family is a collection of patent applications covering the same technical content but filed in various countries. The applications in a family are related to each other through priority (a first application in a country) claims.

The stipulated review period for an invention disclosure at ILO is 90 days. ILO bases its decision on patentability (which is subject to the three criteria described above) as well as the commercial potential of the technology. This could include an evaluation of the market need, potential regulatory and government hurdles, and initial interest from relevant companies. NUS is the legal owner of the invention and patent rights. Should NUS choose not to file a patent application for their invention or abandon their application at any stage, they can make a request that NUS assign the invention rights to them. NUS grants rights on a case-by-case basis.

The ***main purposes*** of the IP Policies in NUS are:

1) to clarify and regulate the protection, management and commercialization of university IP; 2) to delineate the rights and obligations of the university and the university members with respect to the IP created or developed in the course of university research; 3) to motivate the creation, development and dissemination of IP by providing appropriate financial rewards to the creators and the university.

The ***general rule*** of the ***disclosure*** of IP is: if a university member becomes aware of IP first conceived or reduced to practice in the course or furtherance of university research which he/she thinks can be commercialized and wishes to commercialize, then the member shall promptly report the IP to ILO.

NUS regulates the ***ownership*** of IP as follows: unless otherwise expressly specified in the policies, all rights, title and interest in IP discovered, created or developed in the course or furtherance of university research shall vest in and belong to NUS.

Upon receipt of a full and true disclosure in the Invention Disclosure Form, NUS may determine such means for ***patent protection*** and ***IP commercialization***. The decision to file for patent protection and the scope of the patent application is based solely on the commercial potential of the IP as determined by ILO and not on its scientific merits.

Revenue received by the university from the commercialization of IP owned by the university, shall be shared between the university member and the university. Revenue shall not include funds received for research support, and a certain amount of costs shall be deducted from the revenue.

All Revenue after deductions for expenses and costs shall be divided between NUS, the university member and his/her center, institute or faculty, as the case may be, as follows:

Table 3-26 allocation of IP revenue

University member/faculty member	50%
Faculty/department	30%
University	20%

The Inventor shall ***pay to the university back*** for license fees and revenues of: 1) up to 15% of gross sales of all products, processes or services which use, embody, incorporate, are based on or derived from the IP sold, provided or otherwise disposed of by the inventor, or his/her sub-licensee or any agent or distributor to end- users; and 2) up to 15% of any income including upfront fees, milestone payments and other fees not accounted for by royalty payments (whether in the form of cash, shares or otherwise) received by the Inventor less any legal and licensing expenses associated with the protection and commercialization of the IP incurred by the inventor.

NUS's tenure policy

In NUS, tenure track refers to faculty members interested in and with the potential for sustained excellence in both teaching and research. Assistant Professors are appointed on term contracts, while Associate Professors and Professors may be appointed either with tenure or on term contract.

NUS introduced a teaching - only career pathway in 2008, which was reframed as an 'educator track' in 2015. The 2015 reforms sought to reinforce the status of the educator track, through improving the incentives for academics following this pathway, including enabling the progression to Full Professor with tenure. Despite these changes, challenges with the educator track remained, including:

1) a lack of clarity about the pathways available for progression, due in large part to the lack of explicit promotion criteria to describe teaching achievement at each 'rung' of the career ladder; 2) the limited range of references available to evaluate teaching achievement, with an over-reliance on student ratings, widely perceived at the institution as 'fake-able'; 3) ongoing concerns about the quality of external review and benchmarking of candidates' teaching achievement such as difficulties in implementation, leading to a perception that promotion based on teaching was less 'rigorous' than promotion based on research; 4) a lack of clarity as to the place of 'research' in career progression; whether those on the educator track should be research-active, and if so, whether this should be 'pedagogical' research or discipline-specific research; 5) taken together, these factors militated against the institutional respect the educator track was intended to inspire.

For academic appointments, candidates must at least possess a recognized university degree with other qualifications depending on the positions. Overall, they are mainly separated by full-time appointments and part-time appointments as follows:[134]

- Full-time appointments:

Tenure track: Faculty members interested in and with the potential for sustained excellence in both teaching and research. Assistant Professors are appointed on term contracts, while Associate Professors and Professors might be appointed either with tenure or on term contract.

Research Track: Staff members with focus on conducting fundamental research of high international quality, including Research Assistants, Research Fellows, Senior Research Fellows, Associate Professor (Research) and Professor (Research). They are on term contracts of 1 – 3 years in the first instance.

Educator Track: Faculty members have a strength in teaching. They demonstrate a reflective attitude that informs their design, delivery, and assessment of courses to advance student learning. They are expected to be highly knowledgeable and collegial educators, who at higher ranks make their teaching and educational contributions public in appropriate ways so as to improve institutional practice. Because domain knowledge is essential for university teaching, disciplinary research is regarded as an advantage.

Practice Track: Staff members are scholar-practitioners with professional skills and expertise in industry to complement the teaching and research enterprise of the University. They also contribute significantly to the outreach activities of NUS Appointments are to Associate Professor (Practice) and Professor (Practice).

Visiting Scheme: Academic staff from other international institutions invited to share their professional expertise. They may be engaged in the teaching, research or review of specific programes of strategic importance. They are on term contracts, with duration to be mutually agreed upon before the visit.

- Part-time appointments:

Adjunct Scheme: Staff members are qualified and experienced individuals from industry or the professions to undertake teaching as well as collaborative and supervisory work related to

research and development in NUS. The appointments may be on a semester basis or up to 2 years at a time, with a normal workload of 8 hours per week.

Part-Time Teaching: Staff members appointed to meet short-term needs for teaching staff. Appointments may be up to 1 academic year at a time.

NUS's Entrepreneurial arm: NUS Enterprise

NUS Enterprise, the entrepreneurial arm of the National University of Singapore (NUS), plays a pivotal role in advancing innovation and entrepreneurship at NUS and beyond. It actively promotes entrepreneurship and cultivates global mind-sets and talents through the synergies of experiential entrepreneurial education, active industry partnerships, holistic entrepreneurship support and catalytic entrepreneurship outreach. Its initiatives and global connections support a range of entrepreneurial journeys and foster ecosystem building in new markets. These initiatives augment and complement the University's academic programmes and act as a unique bridge to industry well beyond Singapore's shores.

Since early 2000, NUS has been infusion its core competencies, education, research, with the spirit of enterprise. Today, NUS is one of the largest incubators of start-ups in Singapore, and nine NUS-supported start-ups are now unicorns, which are new companies valued at more than one billion US dollars. NUS Enterprise is an instrumental in aggregating resources and support for the start-up ecosystem in NUS. Three important roles of NUS is to nurture talents, provide supporting infrastructure and connect with the world. In 2020, NUS accounted for around 30% of tech start-ups in Singapore, and NUS-affiliated start-ups accounted for 20% of venture capital funds raised by companies based in Singapore.

NUS Enterprise provides a range of incubation programmes to help students nurture their business ideas. Entrepreneurs and start-ups emerging from the University's various programmes segue naturally into the NUS Enterprise Incubator, where they have access to a host of initiatives and connections to help them in their entrepreneurial journey. These include funding, mentorship, legal and business advisory services, validation, incubation and acceleration programmes, and physical co-working space with market access. The Hanger is the campus-based incubator for NUS students and alumni start-ups. NUS Enterprise organises programmes throughout the year for the start-ups at the Hanger. To date, more than 500 start-ups have graduated from the various incubation centres on campus, including the Hanger.

To support established start-ups to access technology, talent, new markets and funding opportunities, BLOCK71 is a natural progression from building an entrepreneur to building a vibrant start-up ecosystem. Today, BLOCK71 is Singapore's largest tech ecosystem. More than 1,000 start-ups have benefited from it. It is reported that BLOCK71 companies are more connected to players within the ecosystem than compared to start-ups that are outside BLOCK71. BLOCK71 also play a vital role in helping start-ups access much larger markets through its overseas springboards, including eight locations around the world. More than 10 years on, BLOCK71 is a global connector. Through BLOCK71, NUS Enterprise has gone beyond the typical incubator/ accelerator role to also serve as a community aggregator,

ecosystem builder, talent provider, corporate innovation partner, and, more recently, global connector. With locations now existent around the world, BLOCK71 has not only helped connect Singapore start-ups to overseas markets, but has helped position Singapore as the centre of innovation and entrepreneurial opportunity within Southeast Asia.

NUS Enterprise also launched some specialised incubators, such as the NUS Agritech Centre, Port Innovation Ecosystem Reimaged at BLOCK71(PIER71) and Innovation Cybersecurity Ecosystem at BLOCK71(ICE71). Since 2018, the partnership between Maritime and Port Authority of Singapore (MPA) and NUS Enterprise on PIER71 is important and synergistic. MPA bring on board industry access as well as partisanship, while NUS Enterprise provides knowledge in terms of building start-ups as well as innovation ecosystems. The vision for PIER71 is to help establish Singapore as leading global centre for maritime technology. Bring together a comprehensive and highly interconnected ecosystem of start-ups, entrepreneurs, investors, maritime companies and incubator to advance this maritime innovation and technology space further. To date, more than 80 maritime start-ups have benefitted from the PIER71 programme, and 50 of them have received grant to embark on pilot projects with maritime companies. Six innovations have become commercial solutions. In the 2022 Leading Maritime Cities Report by DNV and Menon Economics, Singapore topped the maritime technology category for the first time, which reflects how the PIER71 community is makng waves beyond Singapore's shores.

In addition, numerous events including workshops, seminar series, hackathons and the flagship InnovFest festival are held each year for the benefit of the wider start-up community. In 2020, more than 430 companies/projects were incubated and over 400 events were held across our network of incubators and accelerators.

As a flagship festival organized by NUS Enterprise and Unbound [135] -an internationally recognized market-leading platform connecting grassroots innovation with corporates, brands and governments, ***innovfest unbound*** is the largest innovation festival in Asia. More than 13,000 entrepreneurs, brands, corporate entities, investors, tech start-ups and delegates from over 80 countries convened for the 2018 event, with notable participants including Tony Fernandes of AirAsia, Anthony Tan of Grab and Prince Andrew, the Duke of York. The two-day festival in June hosted five different stages offering a variety of panel discussions, keynote speeches and workshops, with the FutureNow stage showcasing NUS innovators and technologies.

In the 2021 innovfest conference, NUS signed two memorandums of understanding to promote more cooperation among start-ups, industry, government, academia and regional participants. NUS reached the first memorandum of understanding with the Singapore University of Technology and Design. The two universities will jointly cultivate the next generation of entrepreneurial talents and promote the development of innovation and entrepreneurship activities.

NUS's funding schemes

NUS provides plenty of financial supports for the professors, students, start-ups, and some entrepreneurs, in terms of NUS enterprise-startup Singapore founder grant, NUS alumni startup

catalyst, LOTOS NUS fund, Philip Yeo innovation fellows program, startup Singapore equity, startup Singapore tech grant, technology acceleration program, graduate research innovation program, etc. The funding schemes and financial supports help the entrepreneur teams and technology transfer teams to focus more on their projects and research on better products.

Startup SG Founder provides a platform for matching mentors to start-ups, as well as funding up to S $30,000 to first-time entrepreneurs with innovative business ideas by matching S $3 to every S $1 raised by the entrepreneur for up to S $30,000. Besides, NUS will provide an additional S $20,000 cash investment to increase total funding to S $50,000. Companies will also receive corporate secretarial and accounting support for 12 months. In return, NUS ask for a nominal percentage in equity. This cash investment is bundled together with the grant funding, and recipients will receive both if their application for funding is successful.

The Lotus-NUS Fund is a collaboration between the Lotus Life Foundation and NUS Enterprise. The Lotus-NUS fund provides seed funding for social impact-driven start-ups that are founded by NUS-affiliated Singaporeans. The aim and goal of the fund is to accelerate their growth beyond ideation or technology prototyping stage to a stage where the start-ups can attract further funding to build a sustainable and scalable venture. The fund provides seed funding of S $25,000 for each selected applicant. The fund will be disbursed in 2 tranches, each tied to completion of pre-determined milestones. Besides, NUS Enterprise and the fund will provide mentorship and relevant incubation support for selected applicants. The fund will select some indicators to evaluate the performance of the behaviors, in terms of value proposition, social impact, market potential, financial model, and team strength.

Summary and conclusions

As the oldest and largest public university in Singapore, NUS stands out for its breadth of faculty and depth of research output (Fetters, Greene and Rice 2010). Considering the small slope of Singaporean domestic market, NUS needs to stand on a global view and improve knowledge transfer. Under the new vision for the university issued by President Shih, NUS is aimed to become a global knowledge enterprise. Specifically, NUS attaches more importance on global competition as well as entrepreneurial workings related to research and education activities, especially on the commercialization of knowledge and production of entrepreneurial-minded students.

The mission is in accordance to the national strategy of R&D of Singapore. RIE five-year plan is formulated by Singapore government to grow its national research capability. Under each plan, NRF provides capitals for NUS to develop basic research and retain top scientific talents. To develop a base of scientific capabilities and IP, RIE invests to build research centers, innovation hubs and spin-offs in national key development fields which changes accordingly. RIE can also attract a great number of top foreign experts to work on challenging research problems in NUS. RIE has consolidated NUS’s position of the national innovation center in academia and industry.

To purse the mission of the two dimensions mentioned before, NUS established an exclusive administrative department NUS Enterprise to further approach in technology and knowledge commercialization and globalization. Reporting to the President directly, NUS Enterprise assigns its own CEO who generally all had technology commercialization experience before. Now, NUS Enterprise consists of four major institutions with various functions: NUS ILO Office for licensing and management, NEC for entrepreneurship supports, NOC for overseas education, and business units including NEX for continuing education, NUP for campus press, and NTHPL for technology maintenance. One useful contribution of this working framework is its effort in creating and coordinating synergies across sectors and functions. Under this successful model, several initiatives like funding, programs, facilities and equipment, research institutes and centers have been well developed. This ecosystem builds a vibrant entrepreneurship community in NUS.

3.3.10. University of Macau

The strategic research layout of the University of Macau

The University of Macau (UM) focuses on the main needs of Macau and the country and promotes the development of innovative technology by making full use of its advantages to cultivate a source of innovative technology for Macau's sustainable development, with the support of the Central Government and the Government of the Special Administrative Region of Macau (SAR). UM actively supports China's development strategy for GBA, which aims to develop the area into an important node and technological innovation highland in the so-called 'Guangzhou-Zhuhai-Macau Science and Technology Corridor' in western GBA.

The university focuses on supporting disciplines that reflects both Macau's unique characteristics and global trend. A '3+3+3' research blueprint, which comprises three state key laboratories, three emerging research fields, and three interdisciplinary research fields, has been established. The first '3' refers to three state key laboratories. The three labs conduct cutting-edge scientific research in ultra-large-scale integrated circuits, traditional Chinese medicine quality research, and Internet of Things applications for smart cities. The second '3' refers to three emerging research fields, namely precision medicine, advanced materials, and regional oceanology. The third '3' refers to three interdisciplinary research fields, namely cognitive and brain sciences, artificial intelligence and robotics, as well as data sciences. Through establishing a new blueprint for scientific research and development, the university hopes to attract scientific and technological talent, give full play to its research strengths, and cultivate a source of innovation.

Macau is not only a world-famous gambling destination, but has also become increasingly known in recent years for the cutting-edge chips developed by UM's State Key Laboratory of Analog and Mixed-Signal VLSI. The university now has a world-class chip measurement platform and is the best in the world in terms of analog-to- digital converters. Chinese medicine

research is a unique research area at UM, which covers Chinese medicine quality research, international standards for Chinese medicine, development of innovative drugs and health products, and the formulation of Chinese medicine standards in the European Pharmacopoeia Union and the United States Pharmacopoeia, as well as the commercialisation of research results. The State Key Laboratory of Internet of Things for Smart City focuses on the innovation of theoretical research results for complex urban ecosystems. Working with science and technology institutions in Macau, the lab uses the latest technologies to help various departments apply smart city technology, 5G communication technology, and Internet of Things technology in their daily operations in order to improve their ability and efficiency in management, execution, and response. UM attaches great importance to the development of artificial intelligence, and has achieved outstanding results in such fields as pattern and image recognition, classification, as well as object tracking and recognition. UM has also established partnerships with numerous national scientific research institutions such as the Chinese Academy of Sciences (CAS). So far, it has established five joint laboratories with research institutes under the CAS.

UM has completed many high-quality research projects, with the results of some applied research projects showing great promise for industrial application. For these projects, the university has initiated the process of industrialisation. Some of these projects have even led to new projects that have attracted the attention and interest of the related industries. In the future, UM will continue to fulfill its mission of serving society with innovative technology and research, and will continue to promote collaboration in scientific research and education with universities in the GBA, take advantage of its high degree of internationalisation of universities, and cooperate with world-class universities to jointly lead innovation and higher education in western GBA."

Institute of Collaborative Innovation (ICI): integrating interdisciplinary research fields

In order to promote the integration of interdisciplinary research fields, UM has set up an academic unit, the Institute of Collaborative Innovation (ICI). Through cooperation in interdisciplinary research leading to consensus and smartness, ICI plays a key role in the advancement of scientific discovery, training of staff and economic development. ICI center focuses on three interdisciplinary projects, including artificial intelligence and robotics, data science, and cognitive and brain sciences.

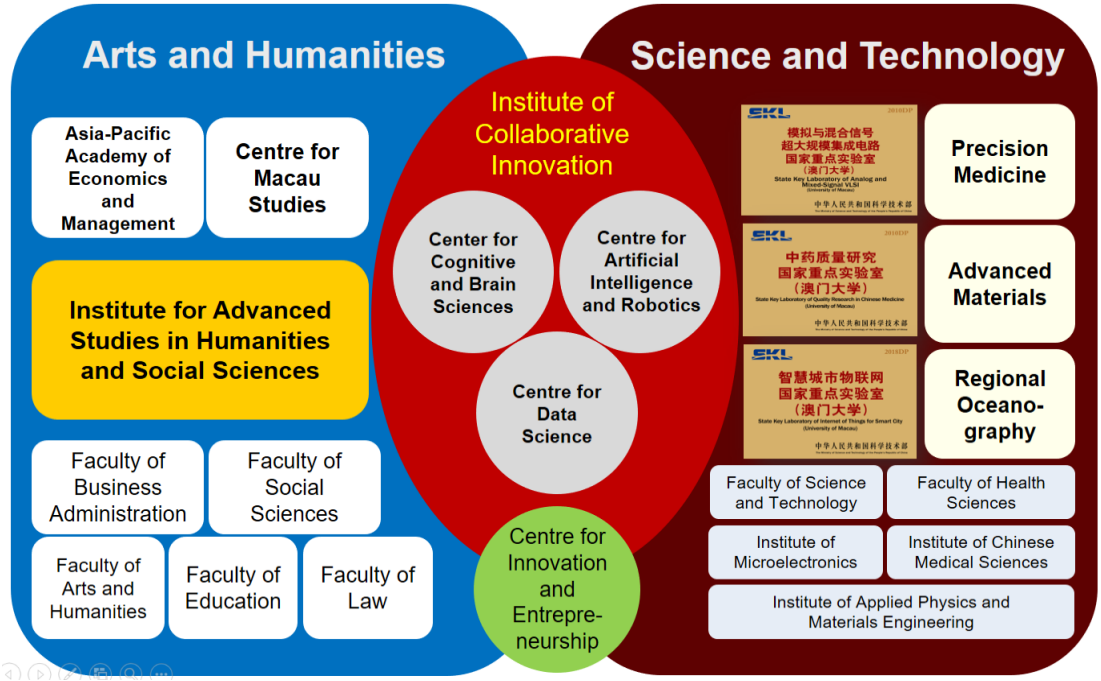


Figure 3-21. An illustration

Three Interdisciplinary Research Fields focus on:

Artificial Intelligence and Robotics. The Centre for Artificial Intelligence and Robotics focuses on computational intelligence algorithms, visual and pattern recognition, data intelligent analysis and prediction, machine translation, human language technology, natural language processing (NLP), human-machine communication, autonomous driving, intelligent robots, etc. The Centre plays a crucial role in developing Macau into a smart city at present and in the future.

Data Science. The Centre for Data Science is committed to train a new generation of data scientists, conduct various interdisciplinary research on data, promote in-depth exploration of knowledge and establish predictive mechanisms and models to guide the applications of data science in all levels of human life, with the aim of enhancing the development of new technology industries and contributing to the society.

Cognitive and Brain Science. The Centre for Cognitive and Brain Sciences consists of four platforms: neuroimaging, brain intervention, cognition and behavioral data collection and high-performance computing platforms. The four platforms complement each other and realize the integration of multi-dimensional and large-scale data acquired from brain imaging, eye movement, behavior, physiology, clinical observation, etc., which can help develop a multi-level and all-round research centre for cognitive and brain sciences.

UM and smart city development

With the support of the Macau SAR government and the Science and Technology Development Fund, in 2018, UM obtained approval from the state government to establish a state key laboratory of internet of things for smart city development. The lab is dedicated to solving key scientific and technical problems related to internet of things for smart city development by proposing fundamental and general theories, algorithms, and systems. Since its establishment, the lab has been focusing on five areas, namely smart sensor and communication network, urban big data and smart technology, smart energy, smart transport, as well as urban public security and disaster prevention.

Platforms

The University has established two practical platforms for industry-academia-research: the first industry-academia-research base of the University of Macau in the Greater Bay Area based on the Zhuhai Institute of Science and Technology (Zhuhai Institute of Science and Technology), and the Hengqin branch of the three State Key Laboratories of Chinese medicine quality research, analog and mixed-signal ultra-large-scale integrated circuits and the Internet of Things for smart cities set up in the Zhuhai Institute. In order to break through the bottleneck in the transformation of technological achievements, the University has used the institutes as an innovation carrier, dovetailing with human and industrial resources in the Pearl River Delta region and linking with angel investment funds to build a comprehensive transformation and cultivation system for the University's outstanding basic and applied research results towards industrialisation.

Zhuhai UM Science & Technology Research Institute

To implement the “Outline Development Plan for the Guangdong- Hong Kong-Macau Greater Bay Area”, strengthen the construction of demonstration zone of in-depth cooperation among Guangdong-Hong Kong-Macau, build Macau into a world tourism and leisure center and a commercial and trade cooperation service platform between China and Portuguese-speaking countries, and promote Macau’s participation in the development of the Guangzhou-Shenzhen-Hong Kong-Macau Science and Innovation Corridor, University of Macau (UM) established Zhuhai UM Science & Technology Research Institute (ZUMRI) in Hengqin, Zhuhai, which is its first industry-education-research demonstration base in the Greater Bay Area.With the research strength of UM’s three state key laboratories and its preponderant disciplines, there are 5 research centers and 1 business training center in the ZUMRI, which are Microelectronics Research Center, Traditional Chinese Medicine Research Center, Smart City Research Center, Medical Research Center, Advanced Materials Research Center and Executive Training Center.

Conclusions

The University has restructured the Office of Research Services and Knowledge Transfer to comprehensively strengthen the awareness of research services and intellectual property protection. It formulated the Regulations on the Management of Intellectual Property Rights of the University of Macau and refined Regulations on the Management of Intellectual Property Rights of the University of Macau to effectively protect and extend high-quality research results. The University of Macau Technology and Innovation Company Limited (UMTec) was reorganized, which is specifically responsible for the management and industrialisation of intellectual property rights of the university The UM Innovation and Technology Co., Ltd. (UMTec) was reorganized to be responsible for the management and industrialization of UM's intellectual property rights, and to create a mechanism for the efficient flow of innovation elements in the process of innovation source support, achievement protection, incubation and cultivation, and knowledge evaluation. The number and quality of patent applications filed by the University has grown rapidly in recent years. Based on the patented technologies licensed by the University, some technology products have already moved from the R&D stage to the trial sales stage, while some related products are in the R&D and testing evaluation stage.

As an important measure to promote the development of industry, academia and research in Macau, UM has established an Innovation and Entrepreneurship Center under the Collaborative Innovation Research Institute to promote good interaction between UM and the two governments, schools, enterprises, incubators, venture capital institutions, entrepreneurial mentors, etc., and It focuses on assisting teachers and students to transform their creative ideas into practice, providing them with an industry-university-research support platform for innovation and entrepreneurship, and forming a new talent training mechanism while promoting industrial development to fully cultivate innovative and entrepreneurial talents.

Due to Macau's special status of the "One Country, Two Systems' policy, and the development of the Greater Bay Area, Macau has been placing more focuses on Innovation and Technological development. The Macau government has more strategies and policies for Innovation and Technology and has established more innovative network. The University of Macau has received several fundings from various sources and have collaborated with different companies to strengthen technological development which helps Macau to grow into a Technological Hub. Besides, due to the overall small size of UM, the university's research strategy can be summarised as 'focusing on key areas', 'making use of advantages', 'creating peaks', 'highlighting characteristics', and 'strengthening cooperation'."

3.3.11. Tsinghua University

Basic Information

Tsinghua University, located in Beijing, is a top university in China. Since its establishment in 1911, Tsinghua University has long been ranked among the top universities in China for a number of achievements. Scientific research projects are an important support for conducting

high-level academic research, producing first-class academic results and cultivating first-class talents. An important source of scientific research projects and funding for Tsinghua University is the National Science and Technology Program (special projects, funds, etc.). In 2021, the university was awarded 689 projects from the National Natural Science Foundation of China, 34 projects from the National Key Research and Development Program, 11 projects from the National 2030 Major Project, The annual contract amount exceeds 2.9 billion yuan. In terms of achievement awards, Tsinghua University has received a total of 607 national science and technology awards by 2020. Among them: 2 winners of the National Supreme Science and Technology Award, 84 National Natural Science Awards, 159 National Technical Invention Awards, and 362 National Science and Technology Progress Awards. In terms of papers and publications, according to the data published by the China Institute of Science and Technology Information, Tsinghua University has maintained the first place in national universities for 28 consecutive years since 1993 in terms of the number of papers indexed by Engineering Index (EI).

Extensive and rich knowledge and technology transfer infrastructure

Tsinghua University started its knowledge transfer work in the late 1980s **(Zhang et al., 2018)**. After 40 years of development, currently, there are six types of university technology transfer organizations co-existing in Tsinghua University – cf. Figure 3-22 **(Zhang et al., 2018)**:

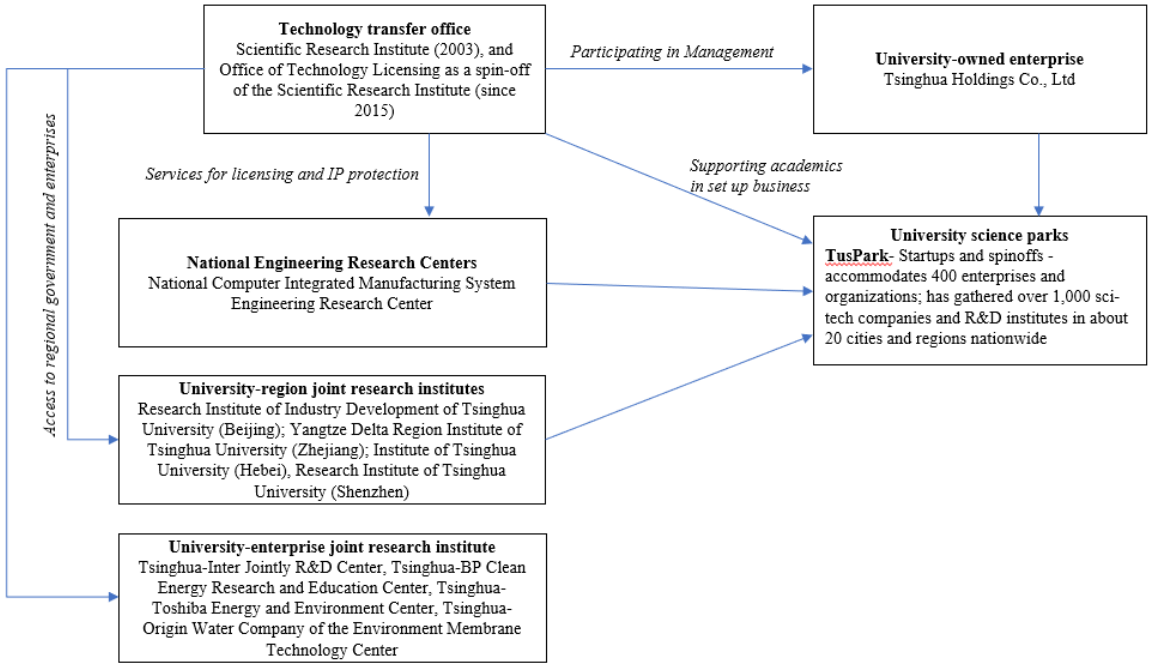


Figure 3-22 Relations between six co-existing university technology transfer organizations in Tsinghua University

In August 1995, the Tsinghua University Enterprises Group (清华大学企业集团) was founded and approved by the Ministry of Education and the State Economic and Trade Commission, to be responsible for the management of all the enterprises by Tsinghua University, no matter it was created by the faculties or the departments. Tsinghua Holdings Co., Ltd. holds shares in those companies on behalf of Tsinghua University (see Figure 3-23). *In 2018, the company ranked No. 137 in China's Top 500 enterprises by revenue and No. 3 by R&D efforts, commercialized 56 national key scientific achievements (**Tsinghua Holding, 2021**).*

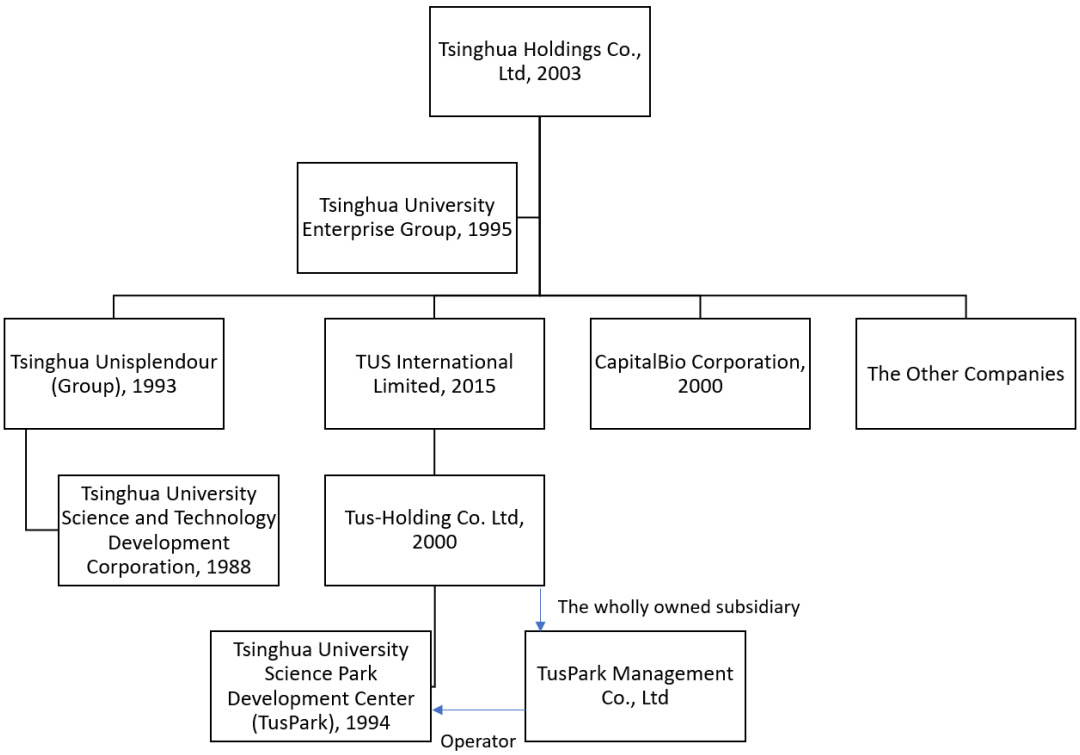


Figure 3-23 The investment relationship of Tsinghua Holding Co, Ltd.

Furthermore, Tsinghua University could not have such outstanding achievement without its active research cooperation with various parties. Tsinghua University has established scientific and technological cooperation with many departments of the central government. This process generally includes joint research on special technologies, the establishment of research funds, cooperation in applying for national science and technology programs, technical consultation and services, application of high technology equipment, and joint construction of research centers. When cooperating with local governments at all levels, Tsinghua University has taken many measures, as follows.

(1) To drive the development of industry-academia-research cooperation by means of project cooperation;

(2) setting up University-Local Science and Technology Cooperation Fund;

(3) building "University-Industry-Research Cooperation Office" with key regions.

In terms of university-enterprise cooperation, Tsinghua University established the Tsinghua University-Enterprise Cooperation Committee ("EECC") in 1995 and the Overseas Department of EECC in 1996. Since its establishment in 1995, there have been 190 member organizations in China and abroad. In terms of overseas cooperation, Tsinghua University conducts forward-looking and high-level scientific research cooperation with world-class universities, research institutions and overseas famous multinational enterprises through various modes, such as joint research institutions, framework cooperation, commissioned R&D, joint R&D, establishment of cooperative research funds, and overseas technology licensing and transfer. As of April 2022, there are 162 national key research institutions in operation and a total of 150 university-level research institutions.

Office of Technology Transfer

Introduction of Office of Technology Transfer

Office of Technology Transfer, founded on June 6, 2014, is the supporting institution of Tsinghua University. It is responsible for the transformation of scientific and technological achievements and the management of intellectual property rights such as patent rights, Copyrights and technical secrets. Institute of technology transfer's mission is "promote technology transfer, service national strategy, promote the economic development, promote social well-being" and its goal is creating a world-class university technology transfer agency and enhancing the service, innovation, transformation forces and influence.

University technology transfer work is a highly professional and complexity of system engineering, from the horizontal dimension, the participation main body is numerous, including professors, students, technology transfer institutions, scientific research personnel and other related financial assets management institutions, intermediary service institutions, entrepreneurship and management talents, investment institutions, entity enterprise, etc. Its work flow is complicated and there are many links, including tracking R&D progress, evaluating and screening results, organizing intellectual property protection, promoting technology maturation, carrying out market promotion, organizing business negotiation, drawing up transaction plans, performing approval procedures, promoting project implementation, and follow-up tracking services.

Intellectual property protection is the basis for the transformation of scientific and technological achievements. With the continuous and rapid development of the university's scientific research work, the number of intellectual property rights has grown steadily, and the quality of intellectual property rights has improved continuously. Office of Technology Transfer strengthens protection for research achievements in key fields, organize patent distribution at home and abroad, and cultivate high-value IPR. From 2016 to 2020, the university has applied for 16,847 domestic patents, 11,852 domestic patents, 2,123 overseas patents, 1,443 overseas patents, and 1,539 software copyright registration applications.

In recent years, under the overall coordination of the school intellectual property management leading group, the technology transfer system of the school has been increasingly improved,

and the technology transfer service level has been constantly improved. At the same time, Tsinghua University has established an intellectual property protection and operation system combining "line and point", carried out patent navigation analysis around the industrial line of key disciplines, and laid out intellectual property with key projects as the focus, effectively promoting the growth of both quantity and quality of the intellectual property. Based on the characteristics of Tsinghua University's disciplines and the needs of national key industries, Tsinghua University has organized a number of patent information navigation activities focusing on key technology fields such as artificial intelligence, new energy, and automotive networking, and guided key disciplines and projects to carry out scientific research in an orderly manner under the collaborative promotion of Tsinghua University Technology Transfer Institute and Library Patent Information Center.[136]

From 2016 to 2021, the university transformed 679 scientific and technological achievements with a contract value of 3.7 billion yuan, involving 4,057 intellectual property rights such as patents. A number of key scientific research achievements in electronic information, life and health, high-end equipment, new materials and other disciplines and industries have been translated into practice, making positive contributions to national and regional economic and social development. The *Organization Structure is* presented in Figure 3-24.

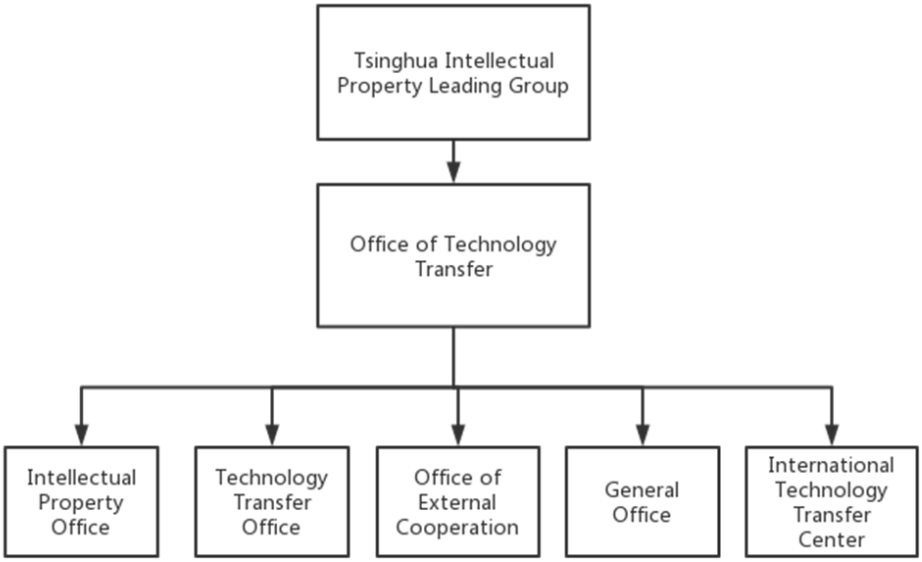


Figure 3-24 The organization of Tsinghua Office of Technology Transfer

Office of technology licensing

The activities of Office of technology licensing (OTL) is the most crucial **(Zhang et al., 2018**). OTL is the university level organization, that mainly deals with four kinds of affairs -

technological reward, patent management, knowledge transfer, and legal affairs (**Tsinghua University Office of Technology Licensing, 2020**).

The mission statement of OTL is:

- To promote the academic impact and social reputation of Tsinghua University
- To accelerate the knowledge transfer activities like commercialized products and service
- To offer reasonable rewards to stimulate further knowledge/technology transfer activities by university actors.
- To bridge between universities and enterprises.

The primary manager is the patent management leading group, who takes control of the OTL.

The effort that OTL has made can be roughly divided into three parts. The *first* is to ensure all the regulations regarding knowledge transfer can work effectively. It strictly supervises faculties and those enterprises in partnerships. It promotes the motivation of knowledge transfer by protecting the interest of patent owners.

The *second* is to elevate the efficiency of knowledge transfer. While Tsinghua has performed well in knowledge transfer, there remains much to improve. So far, only less than 40% of patents in Tsinghua has been commercialized. And OTL is endeavoring to take advantage of these unused patents. Traditionally, patent owners should pay annual fee to maintain their ownership, which has led to a pattern that some patent owners think it not worthwhile to keep the ownership and the patent becomes invalid. To deal with the loss, OTL is seeking for a way out that it grants the authority of use to small-to-medium-sized enterprises, who only need to pay the annual patent fee for maintenance. After the commercialization proves to be a success, the enterprise pays a certain proportion of revenue in return (**Tsinghua Office of Technology Transfer, 2020a**).

The *third* is to improve the quality of KT service. OTL is currently devoted to form a professional and marketized team to provide service. It is seeking for talents in the labor market, which can enrich their experience in commerce. In the meantime, it is cultivating talents who can simultaneously deal with technological, legal, and commercial problems. Also, The OTL is seeking to enhance its collaboration with other IP service facilities or KT service facilities. It hopes to gain more experience from precedent success.

Guided by its mission statement, OTL has organized many activities to promote the ability of innovation and knowledge transfer. One interesting example is the IP class. In 2018, OTL held a series of IP classes to promote the awareness of patent application and ownership. The first class was held on May 18th to introduce the definition of knowledge transfer, relevant policies and application process. In the class, Yousheng ZHANG, the vice-director of OTL, introduced some typical cases in Tsinghua to elaborate his points. What's more, he also introduced how to better take advantage of patent policies to protect researchers' scientific findings.

This series of IP classes, currently consisting of six lectures, covers every aspect of the patent application, management, and commercialization. The activity strongly promoted students' and faculties' awareness of IP protection and KT motivation.

To further facilitate its knowledge transfer activities, Tsinghua University issued two crucial policy documents (**Tsinghua Office of Technology Transfer, 2020b**).

1. The first is the *Management measures for evaluation and disposal of scientific and technological achievements and benefit distribution in Tsinghua University*. It is aimed to standardize the evaluation and disposal of scientific achievement. It legalizes the duty and rights of patent owners and KT offices. Also, following the city-level regulations, it ensures the benefit that patent owners can enjoy from the knowledge transfer activities.
2. The second is the *Regulation of contracts* at Tsinghua University. It is a supplementary document that legalizes the regulation in the first document. It covers every aspect that can be involved in signing contracts. To ensure that all KT activities can be carried out in compliance with regulations, the university established a contract management office.

Transformed results

Ultra-low power near-sensing AI chip——Nanjing Meishen Intelligent Technology Co., LTD

With the gradual deepening of always-on perception application scenarios, the market demands for always-on perception become more demanding. How to achieve ultra-low power consumption, always-on perception with low resource consumption and real-time response has become a current challenge. The project uses analog information conversion technology to solve the energy efficiency bottleneck, and reduces the energy consumption of the continuous intelligent sensing computing system by utilizing the high energy efficiency characteristics of analog computing. The analog calculation design idea of this project carries out signal processing operation before ADC conversion to extract the required information. The AIC analog-information calculation circuit is designed at the front end of the system to directly process the collected analog signals, achieving significant gains in computing speed and energy efficiency.

At present, related technologies have completed the technical verification of circuit flow wafer verification, system flow wafer verification and upgrade system verification, and have comprehensive patent protection and design experience. In November 2020, nanjing Meishen Intelligent Technology Co., Ltd. has been registered through the transformation of scientific and technological achievements of Tsinghua University.

A key technology of digital energy exchange system

The rapid growth of energy storage demand, and the current lithium battery safety and economy is not ideal contradiction. The design defects of traditional battery energy storage system

highlight the main problem facing battery application: battery system lacks fine-grained control ability to overcome the "short board effect".

Digital energy exchange technology, based on the reconfigurable cell network will go through each monomer battery simulation continuous energy flow discrete into a series of "energy", and then by means of information technology for battery "energy" on the space-time two dimensional digital dispatching and restructuring, thus fundamentally solve the traditional analog battery systems inherent in the "short board effect", It greatly improves the efficiency, life, reliability and safety of battery system.

At present, this technology is mature. In terms of marketization, large-scale energy storage has formed cooperation with Huadian Group, China Three Gorges Group, State Grid and China Southern Power Grid. At present, 60MW is under construction and planning (10MW/30MWh for Huadian and 50MW/100MWh for Sanxia). IDC is deeply bound with China Mobile to jointly develop and promote digital energy cabinets. Currently, China Mobile has signed a framework contract of 2.47 billion yuan. The next three years will be a large-scale marketing stage, and the revenue is expected to reach and exceed 1 billion yuan quickly, with an annual growth rate of more than double. In terms of intellectual property, 7 patents have been converted and 4 have been granted.

Rich resource endowments and infrastructure for entrepreneurship development at the university

TusPark

In 1994, Tsinghua University established Tsinghua Science Park (TusPark) for “promoting the commercialization of research results, zoning affiliated-enterprise area and university’s education and research area, and improving the environment and land-scape surrounding the campus”. At present, it has more than 1,000 technology companies and R&D institutions. TusPark is one of the nation’s first incubators providing equity investments (in this regard, applying the ‘Venture Capital+ Incubator’ model to help small start-ups overcome the constraints of funding), entrepreneurship training and network building (Gao and Hu, 2017; Zou and Zhao, 2014).

In August 1999, TusPark was included in the overall plan of Zhongguancun Science and Technology Park, which has provided key support of its development. Soon, there was a wave of entrepreneurial enthusiasm for college students in Tsinghua Science Park, and the newly established science park ushered in the first batch of Tsinghua entrepreneurial students. Qiu Hongyun was one of them. In 1999, "Shimeile" founded by him received a 2.5 million investment from Shanghai Department Store and sold 30% of its shares. He was hailed as "the first Chinese college student to start a business."

After more than 20 years of exploration and practice, TusPark has developed into a world-class university science park. It has established more than 150 incubation bases across the country and has incubated more than 5,000 service companies, including 69 "Diamond Enterprises" and 127 "Golden Seed Project" companies. Among them, 41 companies have been successfully

listed. Overall, TusPark has provided an effective platform for these university affiliated enterprises. Tsinghua's affiliated enterprises on TusPark grew better than those not on TusPark, e.g. R&D funding can rely on the capital market rather than on the university (Zou and Zhao, 2014).

TusPark also has many well-known enterprises, which includes international companies, such as Microsoft, NEC and Schlumberger, and domestic companies such as Sohu, Purcell Networks and Kuaishou. It has strengthened school-enterprise cooperation. On the one hand, companies can make use of the university's resources and technology to develop the Chinese market. On the other hand, Tsinghua University can acquire research funding through cooperation with companies.

i-Space

Nanshan Collaborative Entrepreneurship Center (i-Space) was jointly established by the Shenzhen Graduate School of Tsinghua University and the People's Government of Nanshan District in May 2014. It aims to promote the integration and collaboration of interdisciplinary innovation teams by integrating various resources of innovation and entrepreneurship. There are currently 19 projects in total.

To promote the transformation of excellent entrepreneurial projects, it provides professional and comprehensive entrepreneurial incubation services such as entrepreneurship counseling, management consulting, investment and financing docking, and infrastructure for all settled teams. For instance, the Tsinghua i-Space Maker Space is an on-campus innovation and entrepreneurship space under the funding of the Shenzhen Technology and Innovation Commission, which aims to provide students and teachers with venues for creative practice, team work, event salons and conference exchanges. As for financial support, the i-Space Student Entrepreneurship Fund is a special fund to support students, alumni, faculty and staff to carry out entrepreneurial activities and entrepreneurial projects. So far, it has received a total of 12 million donations from the society.

i-Space has two featured projects to improve graduate school students' entrepreneurship, including "Postgraduate Innovation and Entrepreneurship Improvement" Project and Entrepreneurship Elite Class. The "Postgraduate Innovation and Entrepreneurship Improvement" project aims to enhance the innovation capability of graduate students. The teaching scheme is designed around five aspects, including technology intersection, innovative application, industry exchange, global vision, and industrial practice, realizing the integration of teaching and practice. As for the Entrepreneurship Elite Class, it is an important part of the school's graduate training system. Since 2013, it has enrolled nearly 700 people, covering more than 20 majors. It has gradually formed a complete training scheme in terms of innovative thinking and creative training, practical ability training, and complete incubation of excellent entrepreneurial teams.

So far, i-Space has held a series of events to help students develop their innovative capabilities, such as Innovation Salon and Tsinghua Innovation Training Camp. The Innovation Salon invites well-known experts and entrepreneurs to discuss innovations in five areas, including

technology, market, model, product and design, through teaching combined with practice. As for Tsinghua Innovation Training Camp, based on the curriculum of Tsinghua's "five innovations" education model and entrepreneurial nursery incubation model, the training camp is a two-month practice training on innovation and entrepreneurship, which is carried out in conjunction with major universities in the Greater Bay Area (**Tsinghua Shenzhen International Graduate School, 2021**).

X-lab

The National Science and Technology Program is an important source of scientific research projects and funding for Tsinghua University. In 2020, Tsinghua University has 610 National Natural Science Fund projects, 30 National Key R&D Program of China projects, 6 National Science and Technology Major Project projects, 197 Ministry's and National Commission's Scientific Research Project and 102 Beijing Science and Technology Program Fund projects. The annual contract value was more than 2.3 billion yuan. Among the projects, Tsinghua x-lab has been doing pretty well.

Tsinghua's x-lab is a university-based education platform designed to foster student creativity, innovation and entrepreneurship, referred to as "Three Innovation (Creative, Innovation and Entrepreneurship) Space". It was formally established on April, 2013.

X-lab advocates the educational concepts of interdisciplinary, exploring the unknown, experiential learning and teamwork. It is committed to explore new talent education models around Three Innovation and to help students learn the knowledge and skills of creativity, innovation, and entrepreneurship. It aims to cultivate students' creativity, including creative spirit, creative thinking, creative ability and execution ability. It offers mentoring by industry and financial experts, professional consultancy in the legal and design areas, access to x-lab educational and training events, access to x-lab online resources and uploaded educational material, legal support documentation and best practices guides, evaluation and follow-up consultancy meetings with x-lab personnel trained in business, law and design and free use of the x-lab work space (**X-lab, 2021**).

Table 3-27 Examples of major Tsinghua x-lab's events to promote entrepreneurship and innovation

Type	**Name**	**Brief description**
Training and competition	Tsinghua University President's Innovation Challenge	Founded in 2013, it focus on innovation that promotes social progress.With the goal of promoting social progress and solving important problems facing the economy and society, it focuses on creative, innovative and entrepreneurial projects in the fields of environment, education, health, etc.

League	Youth Education Chain League (YECLeague)	A blockchain education innovation and industrial innovation alliance jointly established by well-known universities, scientific research institutions, and industry organizations across the country.
Competition	2021 Tsinghua x-lab Kunshan Huaqiao "Smart Future" Innovation and Entrepreneurship Competition	Jointly organized by Tsinghua x-lab and Kunshan. It aims to deepen the cooperation of production, education and research between universities and enterprises and promote the vigorous development of local industries.
Training	Tsinghua University Student's Innovation Ability Enhancement Project	Founded in 2015, it provides postgraduates with innovative ability training, including "thinking and skills", "interdisciplinary learning", and "innovation and entrepreneurship practice"
Program	Uni Era	An industry-university-research collaborative innovation platform jointly initiated by Development Research Think Tank of China, National Center for Schooling development Programme, Tsinghua x-lab, YECLeague
Program	University-enterprise Collaborative Innovation Plan	Select the entrepreneurial team of Tsinghua University that has entered the market to connect with large enterprises. It aims to enhances the market competitiveness of entrepreneurial teams, and achieves a win-win situation for large enterprises and entrepreneurial teams.
Training	innovate48 (in48)	Initiated in 2017, through the full guidance of expert mentors and 48 hours of high-intensity concentrated special training, it helps novices in innovation and entrepreneurship solve their doubts about how to turn innovative ideas into feasible entrepreneurial projects.

Course	x-Cute Entrepreneurship Learning Camp	Initiated in 2016, it provides training on business models and business plans
Forum	2013 “Creation•Horizon” Technology Frontier Forum	Teamed up with TEDxTHU to bring a forum on the frontiers of science and technology. It focus on creativity and innovation in the field of science and technology, and show that technological progress has brought us different perspectives on the world.
Trips	Approach TEEC member companies: Iqiyi	It is an off-campus learning mode for Tsinghua x-lab to go deep into the society and enterprises to expand their horizons and increase insights

Proactive involvement in promoting regional development through knowledge/technology transfer beyond university-industry collaboration

Infrastructure. So far, Tsinghua University has established 459 research facilities, 134 of which were established with companies. Additionally, it has established 14 labs with foreign facilities (**Tsinghua University, 2020**). In 2019, it signed contracts with enterprises or government, valuing more than 2060 million yuan in total. To keep the pace of development, Tsinghua delivered more than 288 million yuan in 2019 as an award for those who have contributed significantly to the KT achievement (**Tsinghua Office of Technology Transfer, 2020c**). Tsinghua University provides various kinds of help in the commercializing process. It would put outstanding scientific findings on the official website and attract investors to contact patent owners.

Domestic Partnership. Tsinghua University has developed multiple partnership models. The first is university-region technological collaboration, in which the university establishes research institutes with the governments of localities where these institutes are located. Tsinghua has been reinforcing its in-depth collaboration with these national strategic development regions and further extending its university-region collaboration program. The collaboration now includes strategic regional economic and social development, joint-cultivation of innovative talents, development of regional special industries and backbone industries, construction of innovation platforms, joint tackling of scientific and technological problems, and promotion of international collaboration.

To promote university-region collaboration, the Domestic R&D Management Office has been actively promoting technology transfer of Tsinghua's key research results to cooperative regions and enterprises. In the meantime, Tsinghua has been actively integrating various resources to promote the transformation and industrialization of scientific and technological results by setting up scientific and technological collaboration funds with regional governments. It has established several "industry-university research collaboration offices" with regional

governments. For example, Tianjin Hwatsing Technology (collaboration between Tsinghua University and Tianjin municipal government); Turing AI Research Institute in Nanjing (collaboration between Tsinghua University and Nanjing municipal government); Tsinghua University's long presence in Shenzhen → notably Tsinghua University Shenzhen Research Institute and Tsinghua-Berkeley Shenzhen Institute (TBSI), which involves collaboration with UC Berkeley as well.

Overseas Partnerships. While Tsinghua University is devoted to developing domestic partnerships, it also attaches equal importance to overseas partnerships. One of the university units responsible for international collaboration is Overseas R&D Management Office (**Tsinghua University, 2021**). Guided by the principles of "complementary advantages, reciprocity, world-class achievements and mutual development", Tsinghua University has established extensive collaborations with many world leading universities, research institutes, and multinational enterprises. It developed these partnerships by 1) establishing joint research centers and joint research projects. 2) establishing centers of knowledge interchange with overseas enterprises. 3) commissioned research and development (**Tsinghua University, 2019**).

Stellar patenting and technology transfer records

The bullet points summarized some of the latest figures regarding the performance of knowledge and technology transfer activities based in Tsinghua University (**Li, 2018**):

- received $89.7 million from technology transfer in 2015 and $97 million in 2016;
- licensed 287 patents in 2014 and 405 patents in 2017;
- established spinoffs based on the university patents – 18 in 2015 and 31 in 2016.
- In 2019 had more than 600 scientific projects approved by the national government, valuing more than 15 billion RMB.
- gained more than 2.6 billion RMB contract research in 2019.

In 2017, the school's domestic, foreign and regional patents continued to maintain a relatively high number. The total number of domestic applications was 2,636 and the total number of foreign applications was 492. The total number of domestic authorizations is 2019 and the total number of foreign authorizations is 380.

The status of domestic and foreign patent applications in recent years is shown in the Figure 3-25 – Figure 3-27 below (**Tsinghua University Intellectual Property, 2021**):

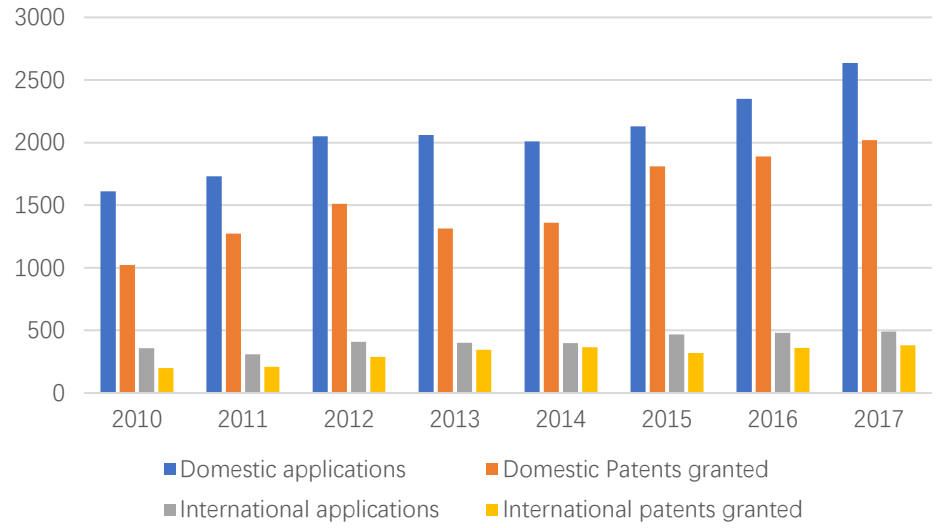


Figure 3-25 Domestic and International patents at Tsinghua University

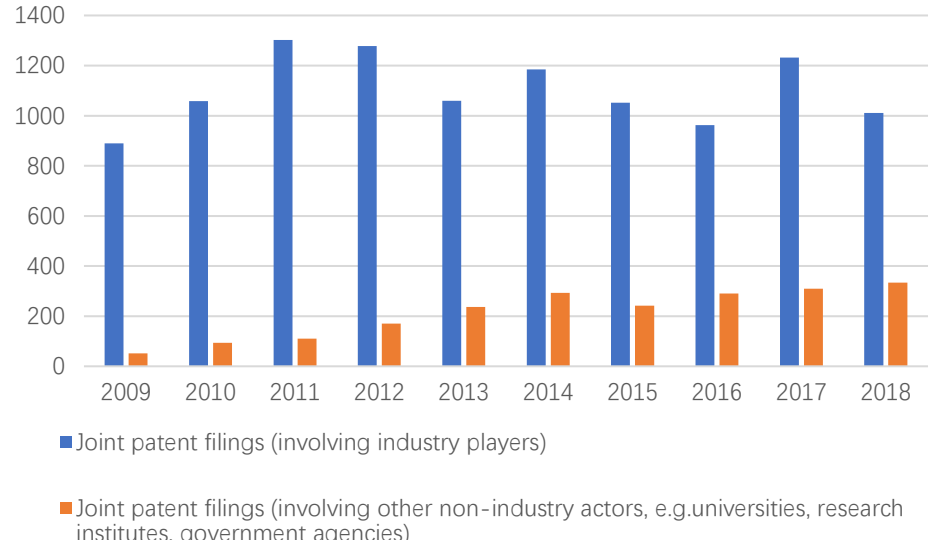


Figure 3-26 Patents in collaboration with industry and non-industry

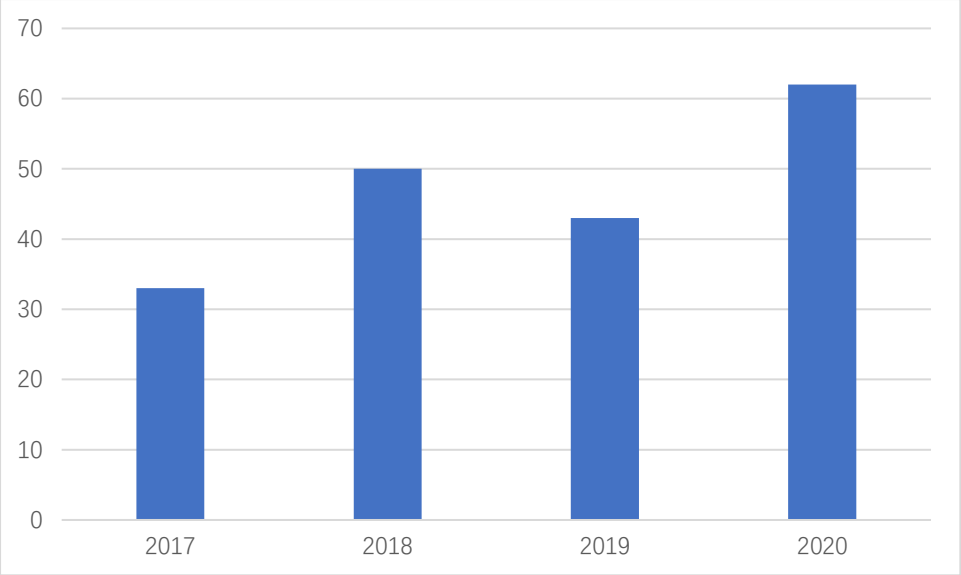


Figure 3-27 University spinoffs

Conclusion

Tsinghua University is one of the top universities in the world. With the strong support of the government, it has made outstanding achievements in the field of scientific and technological innovation and technology transfer. Tsinghua has an independent research institute OTL (Office of Technology Transfer) to support technology transfer, which has successfully translated many research achievements into market value. Besides, there are many entrepreneurial bases and laboratories for innovative research and entrepreneurship, which incubated many excellent start-ups.

3.3.12. Shenzhen University

Introduction

Sanctioned by the Ministry of Education of China, Shenzhen University was founded in 1983. Shenzhen University has closely followed the pace of Shenzhen Special Economic Zone and has been committed to reform and rapid development. The University adheres to the motto of "self-reliance, self-discipline, self-improvement" and strives to become "the Special Economic Zone University, the Window University, and the Experimental University." As a unique institution of higher learning in the Shenzhen Special Economic Zone, the University promotes a distinctive and innovative campus culture.

SZU provides students, faculty, and staff with rich scientific research facilities. There are three national engineering laboratories, one national engineering center, two key laboratories of the Ministry of Education, and 38 provincial key laboratories. The University has been fully committed to supporting research excellence. In recent years, Shenzhen University has made great breakthroughs in scientific and technological innovation, and its R&D investment has increased rapidly. The university has undertaken 6,700 vertical science and technology projects at all levels, including 367 projects approved by the National Natural Science Foundation of China in 2019, ranking 16th in China and 2nd in Guangdong. It has undertaken 120 key and major scientific research projects above the national level, with a total subsidy of more than 500 million yuan. The total funding for scientific research has been growing at a rate of 100 million yuan per year, reaching 1.338 billion yuan in 2019. Four national platforms and 47 provincial-level and ministerial-level platforms have been set up. SZU has won 4 national awards, 48 provincial and ministerial awards and 40 municipal awards. In 2019, the number of patent applications reached 1,281, with 650 patents granted, including 415 invention patents. The number of PCT patent applications was 249, increasing 25.13% from 2018.

In 2018, SZU alumni generated the most wealth among all Chinese universities, and in 2019, it ranked third. The annual tax paid by companies set up by SZU alumni in Shenzhen is 10 times the Shenzhen municipal educational funds on SZU every year.

The University proactively promotes "internationalization in talents training, research cooperation, faculty development, and cultural exchanges." It has worked with 248 overseas universities to provide high-quality student exchange programs, joint degree programs, research collaborations, and a variety of other forms of international collaboration and partnerships.

With the strong backing of Shenzhen municipality, SZU has evolved alongside socioeconomic development of the Guangdong-Hong Kong-Macau Greater Bay Area. Facing the world, the University will foster high-quality innovative and entrepreneurial talents in the spirit of reform and innovation, strive for cultural leadership to realize innovative and qualitative development, and build the high-level Special Economic Zone University for the people.

Key Policy Documents

In 2017, the school issued the Outline of Cultural Innovation Development of Shenzhen University which focuses on the innovation and entrepreneurship education of college students, and aims to promote the integration of talent cultivation and social needs and strengthen the development of the platform for joint Shenzhen-Hong Kong university students' innovation and entrepreneurship bases. The university aspires to demonstrate the school philosophy of “down-to-earth and self-improvement,” and strengthen the spirit of “self-reliance, self-discipline, self-improvement” for enhancing cultural character of “openness and tolerance, dare to be first,” and enriching the connotation of SZU spirit.

"The development of Shenzhen University is not for ranking, but for the actual application. We focus on the needs of economic and social development, to make breakthroughs on the core and key technologies, and to promote urban transform and upgrade." said the university president, Qingquan LI. Shenzhen University attaches great importance to the original

innovation ability, aims to solve key problems in related fields of Shenzhen pillar industries, and encourages researchers to make great efforts to resolve key technical problems in key areas. Focusing on the plan of "two zones", Shenzhen University has put forward the overall plan of promoting the construction of world-class university and first-class disciplines as well as the work plan of accelerating the establishment of world-class university. Shenzhen University will become a high-level university in special economic zone in accordance with Shenzhen's modernization, internationalization and innovation through a 5-year construction cycle and become one of the world-class universities. By the middle of this century, SZU will establish itself as a world-class city university matching its status as a pilot demonstration zone.

Programs and Funding to promote culture of innovation and entrepreneurship

SZU Student Innovation and Development Fund & SZU Students' Innovative Development Fund for Basic Experiment Project

SZU Innovation and Development Fund mainly subsidizes students' creative ideas, innovative projects and teams, and provides funds and guidance for creative and innovative students. This fund does not subsidize the entrepreneurial projects that have already been set up. All full-time undergraduates and research students can apply for the fund. In 2019, SZU Innovation and Development Fund subsidized 118 undergraduate innovation and entrepreneurship training programs, of which 40 were approved by the national level and 78 by the provincial level.

SZU Students' Innovative Development Fund for Basic Experiment Project is one of the general projects of SZU Innovation and Development Fund. It is mainly in the face of full-time undergraduate students. This fund does not set technical threshold and encourages students to "participate in the scientific subject and carry out researches in the labs". This fund aims to lay a foundation for undergraduate students to carry out in-depth scientific research, to participate in high-level discipline competitions, to clarify the research direction of graduation projects and even start their own businesses.

The amount of funding for the SZU Students' Innovative Development Fund for Basic Experiment Project is 2000 yuan for category A and 4000 yuan for category B of natural science projects. The amount of funding is 1000 yuan for category A and 2000 yuan for category B of humanities and social science projects. Projects can be individual or team projects (with no more than 5 participants). The applicant should be the person in charge of the project. Each person can only apply for one project and cannot participate in other projects. Approved projects must be completed within one year.

SZU Undergraduate Innovation and Entrepreneurship Training Program

SZU Undergraduate Innovation and Entrepreneurship Training Program consists of innovation training program, entrepreneurship training program and entrepreneurship practice program.

In the innovative training program, an undergraduate student or team, under the guidance of the tutor, independently completes the design of innovative research project, the preparation of research condition, the implementation of the project, the research report writing, the academic results communication and other work.

In an entrepreneurship training project, an undergraduate team, under the guidance of the tutor, prepares the business plan, carries out the feasibility study, simulates the enterprise operation, participates in actual enterprise practice, and writes the entrepreneurial report.

In an entrepreneurial practice project, an undergraduate team, under the joint guidance of school tutor and enterprise tutor, proposes an innovative product or service with market prospect based on the results of early-stage innovative training project (or innovative experiment).
All undergraduate students are eligible to apply. The project team members are encouraged to come from different disciplines and grades.
Generally, the project implementation cycle is 1 ~ 2 years, and the project leader must finish the project before graduation.
The applicant shall not apply for different projects at the same time.

Shen Chuang Cup, the International College Students Innovation and Entrepreneurship Competition
Shenzhen University has twice successfully hosted the "Shen Chuang Cup," the International College Students Innovation and Entrepreneurship Competition. It was supervised by the Ministry of Science and Technology, the Ministry of Education, the Ministry of Finance and the All-China Federation of Industry and Commerce and sponsored by the Shenzhen Municipal People's Government and the Torch High-tech Industry Development Center of the Ministry of Science and Technology. It was jointly organized by Shenzhen University and more than 20 well-known universities and enterprises at home and abroad. The competition aims to encourage young college students around the world to integrate international vision, international elements and Chinese elements in innovation and entrepreneurship, and to promote exchanges and cooperation in innovation and entrepreneurship education at home and abroad.
There were international college students from more than 50 countries and regions and 80 universities from around the world, and more than 10,000 college students and 2,000 innovative entrepreneurial projects from more than 200 universities in China signing up for the "Shen Chuang Cup" contest. In the end, the returned overseas graduates from Illinois Institute of Technology and the University of Sheffield won the championships of the two competitions respectively.
The competition always adheres to the concept of "innovation, coordination, green, openness and sharing." It also insists on sharing resources, platforms, responsibilities and results, which gives each participant a full sense of acquisition.

Entrepreneurship Park of Shenzhen University (the College Student Innovation Park
In July 2009, Shenzhen University established the College Student Innovation Park whose development and management was coordinated by the Innovation Park Management Committee consisting of the head of the principal's office, the human resources department, the supervision and auditing office, the finance department, the logistics department, the graduate department, the student department, the Youth League Committee, the Ministry of Education, the Department of Experiments and Equipment, the Ministry of Science and Technology, the Department of Social Sciences and the Alumni Association.

School of Entrepreneurship
In March 2016, Shenzhen University established the School of Entrepreneurship, with the vice

president as the dean, and the other principals of the relevant units as deputy deans. The university built a coordinated and resource-integrated mechanism and gathered the resources of the whole school to jointly create "curricular+ extracurricular," "on campus + off campus," "online + offline," "theory + practice," and "elite + public" modes.

Greater Bay Area International School of Innovation

In July 2018, in order to implement *the Opinions of the State Council on Promoting the High-quality Development of Innovation and Entrepreneurship to Create an Upgraded Version of "Double Creation", the Opinions of the General Office of the People's Government of Guangdong Province on Deepening the Integration of Production and Education*, and *the Notice of Shenzhen Municipal People's Government on Further Strategic Development of Emerging industries Implementation Plan*, Shenzhen University and the Hong Kong Polytechnic University jointly established the "Greater Bay Area International School of Innovation". Relying on the School of Entrepreneurship, "Greater Bay Area International School of Innovation" focuses on the industrial key areas and strategic emerging industries in the Greater Bay Area. With needs of the science and technology industry innovation, the school will explore a talent training model that combines industrial development, and open new disciplines and majors for cultivating applied talents with strong sense of innovation and excellent ability, and becoming a high-level international innovation college undertaking high-quality international resource exchange, high-level policy research, high-level personnel training, high-value project incubation and so on.

Facilities and equipment - Shenzhen University Entrepreneur Alliance

The Entrepreneurship Park started the preparation of upgrading the software and hardware of its incubation function in early 2015, in order to comply with social development, serve the national political and economic strategy, and further meet the growing needs of college students. To build a gathering platform for makers and entrepreneurs and to strengthen the front incubation of entrepreneurship are the important foundation projects for upgrading entrepreneurial park. Therefore, in May of 2015, on the opening day of the 11th Shenzhen International Cultural Industry Fair, the school entrepreneurship park, in cooperation with the heads of 56 units from 10 entrepreneurial student organizations of SZU and 46 off-campus enterprises, jointly established Shenzhen University Entrepreneur Alliance at Shitouwu Square in SZU.

The Shenzhen University Entrepreneur Alliance is composed of internal and external organizations, including 21 entrepreneurial student associations in SZU, 34 social incubators, and more than 100 group members from investment institutions, innovative start-ups, and industry associations. The Alliance's executive agency in SZU (also known as the Shenzhen University Entrepreneur Alliance Secretariat) has set up 10 departments on the Houhai Campus and 4 departments on the Xili Campus, with more than 120 student members.

Since its establishment in May 2015, the Shenzhen University Entrepreneur Alliance has always been committed to "encouraging innovation, developing makers, supporting entrepreneurship, pooling resources, school-enterprise cooperation, and persisting in win-win." By strongly supporting the school's entrepreneurial student organizations, it has prospered the

culture of innovation and entrepreneurship. Besides, it supports student makers to do their entrepreneurial practice, builds gathering platforms for makers and entrepreneurs, creates the active "flow" for entrepreneurial projects, and develops a dual-inspired atmosphere with investment value. The Alliance also helps students' entrepreneurial projects to connect with off-campus enterprises, market resources and social capital, conducts regular roadshows, builds investment and financing platforms, and supports college student's teams from Shenzhen, Hong Kong and Macau to start businesses in Shenzhen in accordance with market rules. It cooperates with enterprises to develop a series of "Business Startup" courses, which are taught by entrepreneurs, investors, high-ranking executives, technical experts and other outsiders.

Up to now, the Alliance has gathered nearly 100 internal and external institutions in the school, including 21 entrepreneurial in-campus student organizations, social incubators, investment institutions, innovative start-ups, industry associations, and corporate associations and so on. It also has organized and co-organized nearly 500 innovation and entrepreneurial activities, which has made important contributions in forming an active and innovative campus culture atmosphere for the school and creating an "upgraded version of Shenzhen University's innovation and entrepreneurship education."

Based on the resources platform of the Shenzhen University Entrepreneur Alliance, the organization has cooperated with well-known enterprises such as Tencent, Alibaba, Apple, Amazon (China), MUCFC, UOOC.ONLINE and SZOIL to invite entrepreneurs, high-ranking executives and technical experts and jointly opened 25 series of courses called "Business Startup," including 11 credit system courses and 14 certificate courses.

Shenzhen University Professional Entrepreneur Tribe is jointly built by Shenzhen University College of Entrepreneurship, College Departments and well-known enterprises. Through classroom teaching, innovative experiments, project research, maker development, and entrepreneurial incubation together with strategic emerging industries such as the Internet, biology, new energy, new materials, and new generation information technology, future industries such as marine, aerospace, life and health, fields such as advanced manufacturing and science and technology fields related to people's livelihood improvement, and cultural and creative fields, they jointly cooperate to explore the development opportunities of related industries and innovative industries, and carry out cooperation in innovation and entrepreneurship training, maker team cultivation, entrepreneurship project incubation and scientific research transformation. Among these student maker teams, 57 project teams received special funding from the Shenzhen Science and Technology Commission for a total of 7.85 million yuan.

Entrepreneurial Project of Shenzhen-Hong Kong Innovation and Entrepreneurship Base for College Students

On the basis of the existing experience and resources of business incubator and innovation entrepreneurship education, Shenzhen university establishes The Incubation Base for Shenzhen and Hongkong Students Innovation and Entrepreneurship. This Incubation Base aims at building four platforms of innovative education and training, the incubation for start-ups, the acceleration of mature companies' development, the innovation ecology of enterprise cluster. It is for the integration of the entrepreneurship education and training, the incubation of start-

ups, the enterprise financing, the crowd funding, the entrepreneurship business space and other functions, to provide one-stop business service for young college students.
There are three types of projects funded:
(1) Ordinary entrepreneurship projects
Ordinary entrepreneurship means that service or merchandising, self-employment, hiring others and building a business can be achieved by existing mature franchise systems, Internet platforms or sales networks.
(2) Innovative entrepreneurship projects
Innovative entrepreneurship refers to self-employment, hiring others and building a business by applying technological innovation, management model innovation, cultural creativity, etc., to create new products or provide innovative services, influence human consumption behavior or improve social production efficiency.
(2) Public Welfare Entrepreneurship Projects
Public welfare entrepreneurship refers to solving the long-standing social problems or meeting the special needs of some social groups by using the means of market allocation of resources and entrepreneurship. The standard to judge public welfare enterprises is their positive impacts on society, rather than profits and return on investment (ROI).

Technology transfer office or TTO-related offices
SZU Department of Science and Technology
SZU Department of Science and Technology is mainly responsible for the application, funding and management of university scientific and research projects. The Department consists of several offices with specific functions highlighted below.

- Office of Intellectual Property Management is in charge of scientific research platforms, scientific research achievements, patents, international cooperation, postdoctoral workstations, etc.
- Office of National Funds, National and Ministrial Project Management is in charge of national and ministrial projects, science and technology planning and policy, etc.
- Office of Provincial, Municipal, District and University-level Project Management is in charge of provincial, municipal, district and university-level scientific research projects, school-local cooperation and other work.

Technology Transformation Center of SZU
In December 2011, the Technology Transformation Center of Shenzhen University was established, and in February 2014, it was confirmed by the Ministry of Science and Technology as the fifth batch of "National Technology Transfer Demonstration Institutions".
With the geographical advantages of SZU, the Technology Transformation Center aims to establish a market-oriented innovation platform integrating science and technology research and development, scientific achievement transformation, talents cultivation and enterprises incubation, providing one-stop and network technology transfer service.
On the basis of the research capability, scientific and technological achievements scientific research platform and other resources of the university, the Technology Transformation Center

establishes close cooperation and agreements with local government innovation service centers, incubators and innovation parks to organize technology trading activities, patent transfer and to provide services to the research teams and high-tech enterprises.

Entrepreneurship Park of Shenzhen University (the College Student Innovation Park)
Entrepreneurship Park of SZU provides a platform for innovation and entrepreneurship practice activities for graduates with less than one year of graduation, graduate students and undergraduates above the fourth grade (including the senior year) who want to start their own businesses. It mainly supports science and technology innovation projects, as well as projects with market potential and competitiveness, and unique and creative business models. In order to continuously expand the scale and intensity of supporting students' entrepreneurship, SZU welcomes alumni enterprises and social donations to join the student Entrepreneurship Fund.
Entrepreneurship Park of SZU was established in July 2009 and set up the Entrepreneurship Park Management Committee to coordinate its development and management. The Committee is led by the head of the University, and other members include the heads of the Principal's Office, Human Resources Department, Supervision and Auditing Office, Finance Department, Logistics Department, Postgraduate Department, Student Department, Youth League Committee, Academic Department, Experiment and Equipment Department, Science and Technology Department, Social Science Department and Alumni Association.

The first phase of the Entrepreneurship Park is located in High-tech Park in Nanshan District, Shenzhen, covering an area of 690 square meters. In 2010, Shenzhen University increased its investment, moved the Entrepreneurship Park into the campus and expanded the park area to 2,000 square meters. In addition, the school introduced professional consulting agencies in the form of purchasing services to provide systematic entrepreneurship training for students with innovative entrepreneurial intentions. It also provided one-stop services for students' entrepreneurial projects and entrepreneurial teams, such as consulting, diagnosis, information, and intermediary services including government preferential policies for entrepreneurship support, subsidy policies, and consulting and agency for business, law, and taxation.
In May 2015, the school cooperated with Shenzhen Education Bureau, Municipal Foreign Affairs Office (Hong Kong and Macau Affairs Office), Youth League Committee and Shenzhen Polytechnic to jointly establish the Shenzhen-Hong Kong Innovation and Entrepreneurship Base for College Students relying on the construction and development of the school's Entrepreneurial Park (See section 2.4.2). The aim is to build four platforms, including innovation and entrepreneurship education, start-up enterprise public welfare incubation, accelerated incubation of mature enterprises, and innovation of enterprise clusters, for young college students in China Mainland, Hong Kong, Macau and Taiwan. It is to gather makers, creativity, innovation, projects, capital, industrial chain and market, as well as to integrate entrepreneurship education, entrepreneurship training, entrepreneurship incubation, venture capital financing, equity crowdfunding, and maker space to provide a one-stop entrepreneurial service for young college students among Four Places across the Taiwan Straits.

After 2015, the school made full use of the central government's special funds for the development of local colleges and universities, special funds for high-level university

construction, daily school funding and social donations, and set up the Shenzhen University Student Innovation and Development Fund (See section 2.3.1). It allocates more than 10 million yuan each year to support students' entrepreneurial projects, providing funding, guidance, activity venues, and communication platforms. From 2009 to the first half of 2018, the investment in personnel, funds, venues, water and electricity, and property in the Entrepreneurship Park was equivalent to more than 30 million RMB, and the funds for supporting students' entrepreneurship were 18 million RMB.

According to the report of the third-party data survey agency, the proportion of graduates' self-employment of SZU is significantly higher than the average of National Key universities. As of the first half of 2018, Entrepreneurship Park has incubated a total of 271 university startups (including 15 projects for Taiwan, Hong Kong, Macau and ethnic minorities with a total subsidy of nearly 500,000 yuan),with 70% of teams continuing their business, 5 companies with sales or market value of more than 100 million, and nearly 30 companies with more than 10 million.

Summary

SZU is probably one of the universities in Mainland China that pay the most attention to the scientific and technological innovation, transformation of scientific and technological achievements and entrepreneurship. This is mainly due to the fact that Shenzhen has always been at the forefront of entrepreneurship and the economic reform. Local governments have made great efforts to promote scientific and technological innovation to drive economic development. They have introduced a lot of policies and made great investments to attract and encourage talents to innovate and start businesses in Shenzhen. SZU also makes good use of national and municipal funds to hold various projects and carry out cooperation with universities, research institutions and enterprises in the Greater Bay Area, so as to provide sufficient support and a good entrepreneurial environment for talents. It has successfully incubated many start-ups and high-tech enterprises and realized the successful transformation of scientific and technological achievements.

3.3.13. Southern University of Science and Technology

Basic information

Originally founded in 2010, the Southern University of Science and Technology (hereafter referred to as SUSTech) is an innovation-oriented public university administrated by the Shenzhen municipal government with the aspirations to become a top-tier international university. In 2012, the Chinese ministry of education (MOE) endorsed its establishment, acknowledging the university as a piloting platform for exploring both a modern university path with Chinese characteristics and an innovative talent training model. In 2015, the Department of Education of Guangdong Province, Shenzhen Municipal Government and SUSTech signed the Agreement of the Co-construction of SUSTech to be a High-level University of Science and Engineering. Seven years after its recruitment of the first cohort of

students in 2011, SUSTech was granted by MOE the right to confer doctoral and master's degrees in 2018, which has been the fastest institution to obtain the authorization in China. The global university ranking of SUSTech is also rising rapidly. It entered the Times Higher Education (THE) World University Rankings for the first time in 2018 among the top 350 universities and is soon ranked as the 162nd best University in the world and 9th within the universities in mainland China in 2022. Among the performance indicators in the latest THE ranking, SUSTech ranks 33rd worldwide and 1st in China for its excellent performance in paper citation index.

As a testing ground for educational reform, SUSTech aims to promote the scientific and technological achievements and cultivate outstanding and innovative talents, with the goals of serving the needs of building an innovation-oriented country and transforming Shenzhen into a modern, international city of innovation. Presently, SUSTech has eight schools and 28 departments, concentraing on the development of emerging disciplines and interdisciplinary disciplines related to new energy, new materials, new generation of information technology, energy conservation and environmental protection, biotechnology and biomedicine. Of those disciplines, computer science and technology, and biological sciences have been ranked among the top of Times Higher Education World University Rankings 2021. In the second batch of the Double First-Class Initiative released by MOE in Feb 2022, one of the disciplines of SUSTech (i.e., mathematics) was included in the project list. This marks the first time a university located in Shenzhen been included in a national plan to raise the global competitiveness and meet the national strategic goals of the Chinese higher education system.

According to the Scientific Research Work Conference of SUSTech in 2021, the university has focused on five main areas: the infrastructure construction of advanced light source, innovative and intelligent manufacturing, cutting-edge biotechnology, sustainable development. Five university-level entities have been established centered around these key target fields, including the Institute of Innovative Materials, the Institute of Frontier Biotechnology, the Institute of Innovation and Intelligent Manufacturing, and the Shenzhen Institute of Sustainable Development. In November 2021, the first National Natural Science Foundation of China Basic Science Center project "Research and Intervention on the Pathogenesis of Nervous System Diseases" led by SUSTech was officially approved, which is also the first basic science center that gets approved in Shenzhen. SUSTech has also shown exceptional growth in the transformation of scientific and technological achievements apart from the basic research development. Professors are actively engaged in the technology transfer activities. As mentioned in the Report on Scientific and Technological Innovation Capability of Guangdong Universities, the university's scientific and technological achievements have been transformed rapidly in the past three years, and the quality of horizontal projects has been continuously improved, with the contract amounts in 2017- 2019 exceeding RMB 108 million , RMB 124 million and RMB 123 million respectively.

Meanwhile, the University is dedicated to nurturing top-notch innovative talents with patriotism, global vision, core competencies, and innovation. It has set to be a global first-class university deeply rooted in Chinese soil as its goal. In 2017, the University Council proposed the "University Cultural Construction Plan". In 2018, the University formulated the "Five-year

Action Plan" and proposed the "Ten Major Actions", which include a plan to present a motto to embody the University spirit by 2022. In 2021, SUSTech embarked on a new journey toward the second decade to build toward its world-class status goal. Creating a motto was on the schedule at the right time. In the spring meeting on strategic planning and development, proposals for the motto were discussed and the selected plans were prepared for the follow-up revisions. On September 1, the new motto was formally established and revealed by President XUE at the opening ceremony of the new academic year. As a new type of research university in the new era, SUSTech insists on cultivating newcomers who are respectful, innovative, and willing to take responsibility in serving the country and benefiting society.

An experiment of modern university model: elements and features

Locally adapted disciplines: a university with Shenzhen's spirit. The key disciplines targeted by SUSTech are in accordance with the strategic oriented industries proposed by Shenzhen municipal government to a great extent. Traditional subjects on civil engineering or geology attract less of the attention from SUSTech. Comparatively, the fields with greater emphasis are more related to quantum physics, advanced materials, catalytic chemistry, artificial intelligence, life health and biomedicine, next-generation mobile communication technology, integrated circuits, advanced manufacturing, and aerospace. These fields, which have emerged in the era of fourth industrial evolution, frequently appear in the development plans and task lists released by the Shenzhen municipal government. It also matches the innovation spirits of Shenzhen, indicating the desperate need for SUSTech to become a high-level university.

Talent cultivation: "1+1+1". SUSTech insists on the classes being small and personalized, ensuring that the teacher-student ratio is within a reasonable range and that each teacher is responsible for a certain number of students and is accountable for their growth. Students should be paired with personalized dual advisory system to ensure their communication with the professors, which is different than that of many universities in mainland China. SUSTech operates under the credit system, tutorial system, and residential college system. The residential college system aims at the overall development of students, while the tutorial system focuses on the professional education of students. Through a first-rate talent training system, it fosters a sound personality, a solid foundation, and outstanding capabilities, with high-quality talent providing vision, social responsibility, innovative spirit and practical ability.

A unique university governance system: Chinese conditions adopting western means. The highest decision-making body was planned as the university board before the official approval of establishing SUSTech. Givin the contradictions between the existing governance system of Chinese higher education institute, the university boards were positioned as the advisers with the university presidents appointed by the government. The university is now led by the President under the auspices of the University Council, with full faculty participation in the governance of academic affairs. The university's senior management is composed of the Board of Regents, the University Council, the Presidential Executive Council, the Academic Degree Evaluation Committee, the Academic Committee, the International Advisory Council and the Faculty Committee.

PI (Principle Investigator) system. SUSTech strives to create a strong academic atmosphere by introducing independent PI (Principle Investigator) system and team alliance. Even the newly-recruited faculties are allowed to have their own independent laboratory and start-up funding, and can form an independent subject group and apply for projects and funding independently. Assistant professors and above could apply for different types of funding programs ranging from Shenzhen Talent Peacock Plan to the Ministry of Education's "Excellent Youth", "Jieqing" and "Changjiang Scholars" programs.

High proportion of faculty members overseas and English-instructed curriculum. SUSTech positions itself as a international university with global views. The university now has a campus environment with over 90 percent faculty with overseas experience and an bilingual curriculum.

Reward system for faculty involvement in technology transfer

The technology transer office of SUSTech has issued the Interim Measures for the Protection of Intellectual Property Rights and the Transformation of Scientific and Technological Achievements of Southern University of Science and Technology, in which the patent application process is defined, as well as other clarification on the transformation of patent results, inventions on the job, and the duties of the management orgnizations at all level. According to this document, the net proceeds obtained by the university's job-related scientific and technological achievements through technology licensing or technology transfer shall be distributed in the following proportions: 30% shall be owned by the university, 40% shall be awarded to the achievement accomplishers (teams) and other personnel who made important contributions to the transformation of the achievements, and 30% is used as subsequent scientific research funds for the person who accomplishes the achievements. In a latest report released by the technology transfer office, 50% of the net cash income shall be awarded to the achievement accomplishers with the project title and trading price disclosed on the official websites.

If the scientific and technological achievements are transferred by stock from technology investment, a portion of the equity gained from the technology equity is awarded to the person who completed the scientific and technological achievements and other personnel who have made important contributions to the transformation of the achievements (usually no more than 75%). For example, in one of the cases in transferring a drug systhesis technique, 40% of the proceeds of the achievements are awarded to the project holder, 30% for subsequent scientific research activities, 15% to the department where the holder, and 15% to the university as scientific development fund. These motivates the researchers in SUSTech to engage in transferring their research outputs. In 2017, researchers received equity awards amounting to $110 million, with per capita awards reaching $11.795 million. In the Annual Report on the Transformation of China's Scientific and Technological Achievements released in 2020, SUSTech ranked 3rd in the list of the total amount of cash and shares awarded to individuals by university/institutions among the 3,450 public institutions of higher education and research institutes in 2019.

In recent years, SUSTech has implemented new incentives following the Notice issued by both the national and municipal government regarding conferring the ownership or rights of long-

term use of job-related scientific and technological achievements on scientific researchers. As one of the recommended entities in Shenzhen for the provincial pilot project on the single-line management of scientific and technological achievements of universities and research institutes, SUSTech adopts a incentive method of conferring the ownership of job-related scientific and technological achievements before transformation (conferring ownership before transformation) rather than offering cash after transformation (transformation before offering rewards). An example of this kind of incentives could be reflected in transfering the technology "a compound in the treatment of SARS-CoV-2 infection and 5 other intellectual property rights." The patent will be jointly owned by the SUSTech and the achievement accomplishers, with SUSTech accounted for 25% of the share, and those who completed the results accounted for 75% of the share. Both holders may receive the corresponding proceeds in the form of cash or equity, and the proceeds received by the university will not be rewarded to the achievement accomplishers. The conversion price (including cash and share price) shall not be less than RMB 0.9 million. Until 2020, 4 programs of conferring the ownership or rights involving 43 intellectual property rights have been carried out, of which 26 intellectual property rights have been industrialized.

Technology transfer office: intellectural property management and service platform

Established in 2016, the Technology Transfer Office (TTO) of SUSTech is an independent functional department in charge of innovation and technology industrialization and technology transfer. It is a specialised agency to coordinate and manage the university's intellectual property work and guide the implementation of the transfer and transformation of intellectual property. Their main duties include:

- The management and operations of intellectual property, mainly deal with Intellectual property application, high-value patent cultivation, collaborative dispute resolution. TTO provides the research teams with guidance in developing patent porfolios. The research team first put forward the demand for patent layout to the office and discuss the preliminary plans with the office. An intellectual property search agency are involved in the subsequent stages, and meet with the team and office on a regular basis until the porfolios have been confirmed;

- Institution management, establish and improve the Industry-Academia-Research ecosystem. A series of documents has been formulated, such as the Administrative Measures for the Protection and Transformation of Intellectual Property Rights and Scientific and Technological Achievements, Measures on the Use of University Resources by university-run Enterprises (for Trial Implementation), and the Administrative Measures for the Establishment or Shareholding of Companies with Intellectual Property Investment (for Trial Implementation);

- Transformation of scientific and technological achievements. IP licensing/transfer/investment; legal, financial investment and financing advisory and other enabling services;

- Horizontal project (cooperation with enterprises). The evaluation and approval are usually carried out by SUSTech Industry-Academia Research Working Committee; Vertical project (issued by the government)
- External cooperation. Including comprehensive cooperation with local governments (joint establishment of research institutes, industrial parks, etc.), science and technology institutions (co-constructed with enterprises); Scientific research platforms (government-led, co-constructed with other universities).

Since 2018, the office has assisted in the development and navigation of patent porfolios in response to the strategic needs of Shenzhen. The key targeting fields focus on solid-state batteries, cancer early screening technology, 5G communications, superhard materials, medical devices, and smart cities. In 2021, 797 patent applications were submitted, including 728 domestic patent applications (domestic invention patents accounted for 84.5%). 313 patents were authorized, including 303 domestic authorized patents (including 198 domestic invention authorized patents). The trend of the patent number in each year is displayed in Figure 3-28.

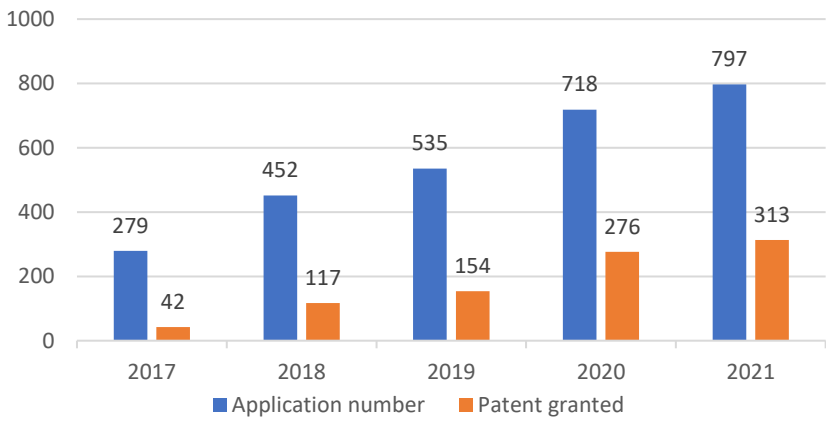


Figure 3-28 Annual number of patent applications and granted patents in SUSTech

Industry-University-Research Collaboration: leading actors and working mechanisms

Industry-University-Research Working Committee leads the industry-university-research work in SUSTech. The members of the committee are the president, the vice president in charge of the industry-university-research work, the school's chief accountant, the scientific research department, the technology transfer center, and the heads of the school of science, engineering, life, innovation and entrepreneurship and others. The main responsibilities of this committee include:

- Management of the industry-university-research collaboration and formulation of relevant policies to ensure that the work is legal, efficient and orderly;

- Making decisions on activities related to technology transfer, equity investment and transfer, and other major industry-university-research assets. This duty is carried along with the technology transfer office, particularly in the application of hoziton projects and construction of joint laboratories;
- Arrangement of personnel for the industry-university-research system;
- Making decisions on key activities concerning industry-university-research collaboration.

The operation units for carrying out the industry-university-research collaboration work include: the Technology Transfer office, the Asset Management Company Limited and the School of Innovation and Entrepreneurship; the business platform of the SUSTech Education Foundation is also an integral part of the school's industry-university-research work system. Among them, the asset management company, as the operation and management platform of the school's operating assets, also has business platforms such as science and technology park companies, investment fund companies and incubator companies. The Technology Transfer Office is responsible for the day-to-day management of the university's intellectual property rights and the establishment and management of the university-industry-research cooperation platform.

It is interesting to note that as a relatively new school, and unlike many universities, the vast majority of the technological achievements of the Southern University of Science and Technology have been transformed into equity since 2016. This is mainly because most of the partner companies are technology start-ups, and it is difficult to come up with large sums of money at the early stage. To manage the potential drawbacks occurred during these modes of technology transfer, from 2020 onwards, SUSTech's wholly-owned asset management company is invovled to handle all equity matters, including decisions on capital increases, setting up branches, etc. This kind of modern corporate structure suggests that many things can be decided by the board of directors of this company, without the need to report to various committees of the university.

Three pillars of "Research, Innovation and Entrepreneurship"

School of innovation and entrepreneurship established in 2016. In order to highlight the characteristics of "research, innovation and entrepreneurship," SUSTech officially established the School of Innovation and Entrepreneurship in August 2016, taking into account the new trends in science and technology innovation and its duties to cultivate talents with an innovative mind and entrepreneurial heart. The school is committed to the cultivation of engineering masters and engineering doctors, corporate leaders, general education on innovation and entrepreneurship, the construction of innovation and entrepreneurship bases, and the construction of an industrial research platform based on a school-enterprise joint laboratory. A "bridge" linking high-tech enterprises and SUSTech is expected for establishing this general education platform for innovation and entrepreneurship. Until August 2021, The school has established a high-level faculty team with 23 research professors within the school, 42 teaching and research professors from other schools or international universities. There are 42 professors in the departments of mechanics, materials, mathematics, biomedical engineering, electronics,

computer, environment, etc. who actively participate in the transformation of production, education and research. At present, 390 executives and experts from large enterprises, high-tech enterprises, and engineering research institutes in the industry have been hired as industry professors and industry mentors, and the team will continue to expand steadily.

Innovation talent program: elementary courses + entrepreneurial practices + a dual mentor training. The innovation talent program is a full-time professional degree programme provided by the School of Innovation and Entrepreneurship of SUSTech and various departments within the university as well as renowned research and development institutions and enterprises outside the university. Drawing on the philosophy of "Research, Innovation and Entrepreneurship," the programme is oriented towards practical problems, supported by professional knowledge and integrated with research projects. It is the first full-time professional degree programmes integrating innovation education, interdisciplinary technology development and entrepreneurial practice. Students first study professional basic courses, industrial design, business administration and humanities in the School of Innovation and Entrepreneurship and relevant departments, and then engage in advanced engineering technology research and application in the School of Innovation and Entrepreneurship or cooperative research institutions and enterprises. Industrial partners include Beijing Collaborative Innovation Research Institute, Hong Kong Applied Science and Technology Research Institute and other well-known enterprises such as Huawei, ZTE, DJI. Particularly, this program tends to work with companies located in Shenzhen in terms of training or internship opportunities, positioning itself as one dual to train excellent R&D staff for Shenzhen industry.

iLEAP with HEC Paris Business School: future business leaders program. In 2019, the School of Innovation and Entrepreneurship at SUSTech launched the iLEAP Future Business Leaders Program with HEC Paris Business School. Supported by Green Pine Capital, this program aims at young and middle-aged entrepreneurs who are just starting their own businesses or young entrepreneurs specialized in hard technology, and second-generation entrepreneurs who are seeking the transformation of family businesses. The core courses in this two-year program are related to business leadership, innovation and entrepreneurship, transformation and upgrading, and frontier technologies. Ultimately, iLEAP strives to foster and nurture the future technological leaders of the Greater Bay area and contribute to the local economies and the rest of the world.

SUSTech Asset Management Co., Ltd: a platform for incubation and operation. Established in December 2014, SUSTech Asset Management Co., Ltd. (hereinafter referred to as the "Asset Company") is a state-owned assets operating company wholly owned by SUSTech, and is the only platform for outreach investment and business of the University. The Asset Company embraces the three pillars of "Research, Innovation and Entrepreneurship" to promote the transfer of SUSTech's scientific and technological achievement, so as to contribute to the socio-economic development of Guangdong-Hong Kong-Macau Greater Bay Area as well as that of the country. It has a centre for the promotion of industrialisation of scientific and technological achievements, which is responsible for integrating available resources from government departments, schools and enterprises at all levels, and promoting the

industrialisation of innovation achievements, and the construction and operation of science and technology parks and incubators, and nurturing high-tech enterprises. Together with the technology transfer office, a platform is set up for the incubation, investment and operation of spinoffs. On December 24 2020, the General Office of the State Council issued the Notice on the Construction of the Third Batch of Demonstration Bases for Mass Entrepreneurship and Innovation. SUSTech Incubator Management Co., Ltd., a wholly-owned enterprise of SUSTech Asset Management Co., Ltd, was approved to build a national demonstration base for dual innovation in the direction of "global entrepreneurship", and to build the SUSTech Science and Technology Park. This is the first national-level platform in the field of entrepreneurship of SUSTech.

Xili Lake International Science and Education City: a new project for transferring knowledge and a new approach for the securitization of Intellectual Property Assets. The science and education city has become a project of the Ministry of Science and Technology to support Shenzhen's effort at building a pilot demonstration area of socialism with Chinese characteristics. It is also a major strategic platform for Shenzhen to promote the construction of the Guangdong-Hong Kong-Macau Greater Bay Area (GBA) along with the pilot demonstration area. As one of the project members, SUSTech participated in Xili Lake International Science and Education City Intellectual Property Securitization and Transformation of Scientific and Technological Achievements Summit Forum in 2020. Mao Weiping, Deputy General Manager of Shenzhen High-Tech Investment Finance Guarantee Company Limited, announced the "High-Tech Investment Xili Lake International Science and Education City Intellectual Property Support Plan" at the forum. It is reported that the plan specifically supports the transfer and transformation of scientific and technological achievements of universities and scientific research institutions in Xili Lake International Science and Education City, starting from providing intellectual property pledge equity debt financing products for start-ups incubated with scientific and technological achievements, and gradually exploring the ecuritization of Intellectual Property Assets such as intellectual property pledge financing products for future income rights. It is expected that Nanshan District will continue the collaboration with Shenzhen High-tech Investment Group to enrich the financing channels for start-ups incubated by universities and scientific research institutions in the Science and Education City.

Conclusions

SUSTech is a university with the innovation spirit of Shenzhen, and serves as a distinctive model for practicing the innovative institutional measures in the background of Chinese education system reform. Although it is a relatively new university with probably the shortest establishment years, it has made remarkable progress in achieving scientific and technological development. Thanks to the abundant financial resources and policies provided by Shenzhen government, SUSTech has estaliblished high reward system and working mechanisms with certain degree of autonomy to attract high-level talents and also high-quality students. Besides, it is interesting to note that the disciplines set up by SUSTech are oriented to developing the high-end technologies, which is highly in accordance with the strategic missions and tasks listed by the Shenzhen government. Professors in SUSTech are encouraged to commercialize

their research products, and a great portion of the technology transfer activities are generated in the joint laboratories. The high percentage of the professors with working experiences overseas has founded an international platform for carrying out more collaboration activities. The principles of keeping small-class course and the establishment of residential college and dual mentor tutorial system have provided SUSTech with a open and interactive campus environment. Different types of innovation courses and the entrepreneurial system with dual mentor training also nurture the students with a more open-minded entrepreneurship perspective.

3.3.14. Jinan University

Basic information

Jinan University (hereafter referred to as JNU) is a public university listed in the Double First Class University Plan and jointly administrated by the Overseas Chinese Affairs Office of the State Council and the Chinese Ministry of Education. Its predecessor, Jinan Academy, was founded in 1906 in the late Qing Dynasty, serving as the first state-run university to enroll overseas Chinese students. The historic multicultural environment has made JNU a popular destination for foreign students and JNU is now the most international university in mainland China. The faith of spreading knowledge and Chinese culture is reflected in the motto of JNU, i.e., loyalty, sincerity, integrity and respect, impacting on the collaboration and education models of JNU. As of November 2021, JNU has signed 652 academic exchange and cooperation agreements with 402 higher education institutions and cultural research institutes in 61 countries and regions. Besides, JNU has established 147 internship bases for Hong Kong and Macau students, accepting more than 2,700 Hong Kong and Macau interns each year and making it the largest and most extensive extra-curricular internship activity for Hong Kong and Macau students in China.

JNU is also the first comprehensive university to establish its own school of medicine in China back in 1970s, which has been jointly developed by the Ministry of Education, the Overseas Chinese Affairs Office for the State Council and the National Health and Family Planning Commission in 2015. 13 JNU disciplines, covering clinical medine, have entered the top 1% of ESI (Essential Science Indicators) subjects in the world in 2021. The others include: engineering; chemistry; pharmacology and toxicology; materials science; biology and biochemistry; agricultural sciences; environment/ecology; botany and zoology; molecular biology and genetics; general social sciences; neuroscience and behavior; and a newly added discipline of computer science. In the same year, JNU has made its debut on the QS World University Ranking lists, placing as the 33rd in Mainland China and top 650 worldwide.

Interdisciplinary biobiopharmaceutical projects as a key area

According to the Annual Report on the Transformation of Science and Technology

Achievements in China released by the National Center for Science and Technology Assessment in April 2020, Jinan University ranked first among the top 10 universities in China in terms of the contract amount for the transformation by transfer, licensing and evaluation investment (RMB 438.02 million) in 2019. It was followed by the Central South University and Tsinghua University, with the contract amount of RMB 425.85 million and RMB 397.77 respectively. One of the most recent and representative cases of JNU is transferring the global development rights of a type of anti-tumor drug that was jointly developed by JNU and Shanghai Institute of Materia Medica of the Chinese Academy of Sciences, to a pharmaceutical company with a contract worth nearly RMB 800 million. Comparing the proportion of the contract amount fallen into different disciplines, remarkable achievements have been made in the research and application of medicine-related subjects, comprising the key innovation outputs of JNU. This fits the own characteristics and advantage of JNU, also indicating the prioritized attention paid by the university administration. As mentioned by JNU president Song Xianzhong in his response to Guangming Daily, "We are not targeting at an all-inclusive improvement, instead, we are focusing on facilitating the breakthroughs in key disciplines such as pharmacy and medicine for meeting the national strategy and social needs (**Guangming Daily, 2021**)."

The university – industry collaboration activities regarding the technology and knowledge transfer, especially in the fields related to biomedicine, large contribute to achieving large amounts of contracts. Dated back to Early 1999, JNU established the Biopharmaceutical Research&Development center which specialized in genetic engineering drug research, bioactive material tissue engineering research and development and the transformation and application of its achievements. This center later established Shenzhen-Hong Kong Ji Da Biotechnology Development Company with Shenzhen-Hong Kong Industrial (Group) Company, which won a contract of 10 million in the first China Hi-Tech Fair in the same year. In 2001, JNU and the Guangzhou Science and Technology Bureau founded a biomedical research platform and incubator under the policy guidance of Guangzhou Municipality to prioritise the development of high-tech biotechnology and promote the development of biomedicine. The incubator is a high-tech service platform with independent legal personality, operating under a modern enterprise system and with a high degree of operational autonomy. A National Engineering Research Center for Genetic Engineering Drugs was founded in 2006, supported by governments at the provincial and ministerial levels or above. Laboratories were renovated with construction of a small pilot production plant and acquisition of instrumentation and equipment, the latter of which acted as an indispensable part for efficiently delivering commercialization products. A marketing department was usually set in alignment with the department of new drug development and basic research. A close relationship was also spotted between the Institute of Medicinal Chemistry and Biology of JNU and a pharmaceutical company located in Guangzhou (Lixin pharmaceutical). In 2017, Jinan University and Lixin Pharmaceutical jointly established a laboratory, mainly concentrating on the tumor immune targeted therapeutic drug products. These platforms have generated significant technology outputs, aiming at the commercialization of traditional Chinese medinces, chemical and biological medicines and biotechnology. Together, these efforts have formed a relatively comprehensive innovation chain in JNU, starting from the basic research to the marketing and

promotion of the biomedicine products.

To recognize the promising projects and utilize the research funds, JNU participated in the municipal university (college) joint funded project co-constructed by Guangzhou government in addition to other partnerships mentioned above. This project was one of the innovative measures by Guangzhou to further promote the reform of “streamline the government, delegate power, and improve government services” in the field of science and technology in 2020. Aiming at the development of provincial and municipal high-level universities and "Dengfeng Hospital (high-level hospital)" in Guangzhou, universities are encouraged to carry out application-oriented basic research and strive for original innovation breakthroughs from zero to one. Under the ex ante funding approach, a one-off payment is made after the project is established. As one of the 15 participating universities and institutions, JNU’s approaches include first select a number of basic and applied basic research projects that meet the needs of Guangzhou's economic and social development and the university's academic construction, and through two years of cultivation, let these research projects become more mature, and strive to produce new results and nurture more research talents.

Featuring Guangdong, Hong Kong, and Macau scientific cooperation and talent training

As one of the first overseas Chinese institutions, JNU insists on its unique advantages of serving the national "Belt and Road" Initiative and the construction of Guangdong-Hong Kong-Macau Greater Bay Area (GBA). Early in 2007, JNU made platform construction the focus of work, seeking niches in the intersection of disciplines and scientific collaboration with GBA. A number of joint laboratories were co-founded by JNU and universities in Hong Kong and Macow since then, including the JNU-CUHK Joint Laboratory of Regenerative Medicine built in 2017, the JNU-HKUST Joint Laboratory for Neuroscience and Innovative Drug Research founded in 2008 and the Collaborative Laboratory for Brain Function and Health Between HKU and JNU founded in October 2008. The Collaborative Laboratory for Brain Function and Health was established as the Guangdong-Hong Kong-Macau Institute of CNS Regeneration (GHMICR) in 2012.

In recent years JNU has made great efforts in promoting “new engineering” and extended their collaboration with the greater bay areas. For example, the university has initiated the construction of first-class research institutes such as the Greater Bay Area Environmental Science Laboratory, Biomedical Science Center, Cyberspace Security Laboratory and Smart Industrial IoT Engineering Center to serve the innovation-driven development of GBA; various think tanks such as the GBA Spatial Economic Analysis and Decision Information System, Intellectual Property Research Institute, Green Development Think Tank, Public Opinion Monitoring and Big Data National Governance Research Institute, and Modern Service Industry Innovation and Development Research Center.

At present, Jinan University has established university-city cooperation with many cities and regions, including Guangzhou, Shenzhen, Zhuhai, Foshan, Dongguan, Shaoguan, Huizhou, Zhaoqing, Zhongshan, Jiangmen, Maoming, Heyuan and Ningguo in Anhui Province, and has set up nearly 100 industry-university-research platforms, such as collaborative innovation

centres, engineering centres, industry-university-research bases and university-enterprise joint laboratories with Zhuhai, Shaoguan, Dongguan, Huizhou and Zhaoqing, including the Jinan University Research Institute. The Shaoguan and Dongguan Research Institutes have been recognised as new R&D institutions in Guangdong Province. Meanwhile, JNU has established "The General Institute of Local Studies of Jinan University" and "Management Committee of the Institute of Local Studies of Jinan University Committee", with these bodies coordinating the planning of the university's and development of local research institutes. Additionally, JNU has signed strategic cooperation agreements with Guangxi Investment Group and Guangzhou Urban Development Fund and other companies, respectively jointly established relevant industry research institutes, and reached a consensus on jointly launching and establishing relevant industry scientific and technological achievements transformation funds to promote the transformation of scientific and technological achievements in this field.

"Jike Fund": jointly initiated by JNU and Guangdong CSM Venture Investment Management

The Guangdong Jike Achievement Transformation Venture Capital Fund (hereinafter referred to as "Jike Fund") was jointly initiated by Jinan University and Guangdong CSM Venture Investment Management (GDCSM) in 2019, focusing on the investment in scientific research institutions, new research and development institutions, scientific and technological transformation projects of universities. It was the first venture capital fund that JNU participated in investing in the transformation of scientific and technological achievements. Jike Fund was then officially established in 2020, with its managing partner including Guangzhou Science and Technology Achievement Industrialization Guidance Fund Partnership (Limited Partnership). JNU Education Development Foundation and Capital Management Co. Ltd. JNU Science Park are among the shareholders and it is interesting to see that the chairman of the first Investment Advisory Committee of the JNU Education Development Foundation is also the Chief Executive Officer of GDCSM. The resource network of alumni entrepreneurs seems somehow emphasized, targeting at a closed loop of which while realizing efficient and accurate transformation, industrialization and capitalization of scientific research achievements in universities, the investment income of the fund can also feed back the benign operation and sustainable development of the alumni foundation. The high presence of the alumni entrepreneur alliance in connecting the university and industry is also one of the features in the knowledge transfer activities in JNU.

In the articles we accessed from its official website, it is claimed that GDCSM provides incubation and cultivation support from various aspects such as capital, market resources and management to guide and help talents to innovate and start their businesses. With the help of professional investors, JNU is equipped with advanced abilities to collect, select, invest and cultivate high-quality scientific and technological transformation projects with a more market-oriented mechanism. A "golden triangle" is expected, comprising outstanding scientists, outstanding entrepreneurs, and qualified capital experts. Until recently, Jike Fund has successfully completed the investment in science and technology innovation enterprises such as Anglo-Meida, Ilikang, Vizont, and Boyite Technology. Anglo-Meida pioneers in minimally invasive interventional intracavitary imaging products in the medical field, also being as a

cooperation project by President Li Baojun from the Institute of Nanophotonics of Jinan University. Vironte is a leading anti-cancer immunotherapy biopharmaceutical company in China, with the chief scientist and chairman being Professor Yan Guangmei, who was formerly an associate of Sun Yat-sen University and now serves as the President and Dean of Sun Yat-Sen University School of Medicine. Boyite Technology was founded by a scientific research team led by Academician Liu Huanbin, the former President of South China University of Technology. According the CEO of GDCSM, the next newest project that JFST will invest in is the projects generated by Chen Gong, who is the Director of the Brain Repair Centre of the Guangdong-Hong Kong-Macau Institute of Nerone generation and Professor of JNU. The in situ brain regeneration technology developed by Professor Chen Gong has fundamentally solved the century-old problem of central nervous regeneration and opened up new avenues for the treatment of major brain diseases such as stroke and Alzheimer's disease.

Top-level design for technology transfer: office of scientific R&D + Science and Technology Park

Market-oriented, :"1+2+3+X". A leading group was formed in charge of the technology transfer activities in 2018, based on the Implementation Plan for Accelerating the Transformation of Scientific and Technological Achievements. Two committees were established to provide consultation service for decisions making, including the Advisory Committee on Transformation of Scientific and Technological Achievements of JNU and the Management Committee of Local Research Institutes of JNU. The operation and supporting organizations include: Technology Transfer Centre, the General Institute of Local Research and the University Science and Technology Park. The information of the technology transfer centre, however, is hardly retrieved. Instead, we found that the office of scientific R&D is responsible for the patent examination and intellectual property management. Meanwhile, the relevant services and collaboration activities could be reached by clicking the website of the office of scientific R&D rather than technology transfer office. For the transfer of conventional patents with a transfer amount of less than RMB 1 million (inclusive), the report system of the Advisory Committee on the Transformation of Scientific and Technological Achievements shall be implemented, and the transfer shall be handled directly by the science and technology management department after the examination and review process conducted by the science and technology management department and the legal affairs department of the university.

Incentives and performance evaluation system for faculty engagement

How to improve the incentive system to enhance faculty engagement for technology transfer activities has always been a central reform focus of JNU. In the Jinan University High-level Construction and Comprehensive Reform Plan (2015-2020) and 28 Articles of Jinan University High-level University Construction Reform released in 2016, JNU stresses that the majority of the transfer income shall belong to the project team and the awards and remunerations of the project team should be increased. Along with the Implementation Plan for Accelerating the Transformation of Scientific and Technological Achievements at Jinan University, policies were formulated regarding the distribution of proceeds from the transformation of scientific and technological achievements and the use of related funds. For scientific and technological

achievements transformed by way of technology transfer or licensing, 85% of the net income shall be awarded to the accomplished person (team), 5% shall be awarded to the institution-level unit, and 10% shall be retained by the university. For scientific and technological achievements in the form of investment, 85% of the shares or the proportion of capital contribution shall be awarded to the person (team) who completes the achievements, and not more than 10% of the transformation proceeds shall be used as incentives or intermediary fees for providing transfer and transformation services. Compared to other universities in Guangdong province (such as Sun Yat-sen or South China University of Technology), JNU has made some statements about the rewards for the intermediates. The high percentage of rewards motivates the faculty members, however, it remains a question whether the technology transfer intermediaries or the relevant offices receive adequate incentives.

When designing the classification and performance evaluation system for the faculty members, JNU set four different types of positions: teaching and research, teaching-oriented, research-oriented, social service and technology promotion. The promotion conditions and evaluation criteria vary based on the types and the disciplines of the position. For example, the items for the social service and technology promotion highlight patents, horizontal projects and other transfer outputs compared with other positions. Positions like this can attract talents who may not have sufficient publication records, and they can provide more promotion opportunities for faculty members who specialize in applied research. There are some other documents such as the Jinan University Teaching and Research Staff Leaving Post Entrepreneurial Personnel Management Measures (Trial) and the Jinan University Teaching and Research Staff Off-campus Part-time Management Measures (Trial) issued in 2017. Although we have difficulty accessing the content of these documents, the information we collected from other sources suggest that they have made some clarification on the identities of the people who leave their posts to start businesses, how they could participate in part-time jobs outside the campus, and the distribution of rights and income during their leave. The implementation of these policies is of great significance for accelerating the transformation of scientific and technological achievements in JNU, encouraging scientific researchers to devote their efforts and serve the society.

Entrepreneurship program/ the twin-engine innovative and entrepreneurial talent cultivation system

Entrepreneurship education at Jinan University dates back to 2003, when the Centre for Entrepreneurial Economics Research and Experimentation was established at the Zhuhai Campus (then Zhuhai College). The Centre has an entrepreneurship laboratory and an economics laboratory, nurturing a number of entrepreneurial enterprises and a large group of students with an entrepreneurial spirit. In 2006, an experimental park for university students' entrepreneurship was built in the main campus of Jinan University. In early 2009, Jinan University took the lead in proposing the idea of an entrepreneurship academy, and since then neighboring schools have established different types of entrepreneurship academies one after another. After nearly three years of development, Jinan University has continued to enrich and improve the system according to its own conditions, resources and development strategies, and

has formed a three-creative education system that focuses on entrepreneurship education, innovation combination and creativity education. In November 2011, the School of Entrepreneurship was established, with the objective of stimulating and guiding future entrepreneurial action with the spirit of entrepreneurship.

Micro Incubation Centre for young entrepreneurs. Micro Incubation Centre, inheriting more than ten years of entrepreneurship education from the School of Entrepreneurship of JNU, collaborates with resources from all walks of life to create an innovative entrepreneurial ecology and early incubation platform for young entrepreneurs. With the mission of entrepreneurship education, entrepreneurial enlightenment and business incubation, the Centre helps entrepreneurial teams to solve the problems and difficulties they face in the process of starting their own business through polishing and coaching. The Micro Incubation Centre has a professional team of mentors, the support from famous universities in China, extensive social resources. In general, this Micro-incubation Education Matrix consists of the following elements: Micro-incubation as the centre to generate different forms of innovation and entrepreneurship education and activities, including entrepreneurship training camps, entrepreneurship labs; roadshow polishing sessions; entrepreneurship funds; Incubator alliances and other structural components. Among them, the Entrepreneurship Training Camp and Entrepreneurship Lab can be subdivided into: Internet Plus Competition, Youth Creation Challenge Cup Competition, Executive Development Programs (EDP), General Studies and other different forms of innovative and entrepreneurial activities that combine theoretical courses with practical activities. E-Book Reading, New Business Model, Entrepreneurship Culture Festival and Venture Capital Lecture Hall are all entrepreneurial education activities and practical projects that are indispensable for the Micro Incubation Centre. The Micro Incubation Centre creates a platform for entrepreneurs to incubate innovative entrepreneurial projects, solves problems in entrepreneurial teams, helps entrepreneurs to find assistance in terms of collaborative teams, business resources and funding, and uses its own ideas to help entrepreneurs out of the dark moments in entrepreneurship.

WE Hong Kong, Macau and Overseas Chinese Youth Zhongchuang Space (WE space). In November 2016, the WE space of JNU was officially inaugurated, becoming the first innovation space in China dedicated to young people from Hong Kong, Macau, Taiwan and overseas. The WE Space was registered in 2019, focusing on incubating projects in biomedicine, new-generation information technology and cultural and creative industries. A two-way on-campus and off-campus mentoring system was applied in the Space, as well as the implementation of project polishing system and investment matching system. Since its establishment, the WE Space has incubated more than 200 innovative and entrepreneurial teams and more than 70 companies have been registered. Until December 2021, the Space has 41 entrepreneurial projects under incubation, of which 22 projects have been hosted or participated in by members from Hong Kong and Macau.

Conclusions

The characteristics of overseas Chinese culture inherited in Jinan university have enabled the university to implement "universities of overseas Chinese + elite school" development strategy.

Alumnus hold an indispensable part, as implied from the amounts of entrepreneurship funds or the venture capitals with the university. Compared to other universities in mainland China, Jinan university emphasizes the spreading of Chinese culture and provides abundant resources for the students in Hong Kong and Macau, which has been highlighted as the fourth role of Chinese universities in the national government reports. Jinan University takes the construction of new R&D institutions as a starting point to serve the urgent needs of national regional innovation, and emphasizes the integration of industry and education to promote key technology research in the industry. Particularly, the university has created a platform system for the transformation of scientific and technological achievements, and has established university-city cooperation with many cities and regions such as Guangzhou, Shenzhen and Zhuhai, and co-established Jinan University Research Institutes with Foshan, Zhuhai and Shaoguan.

Drawing on its existing strengths in biomedicine-related technology transfer, Jinan University has increasingly devoted and built a whole chain and comprehensive system of transferring and transforming scientific and technological achievements in the mode of "career-oriented management + market-oriented operation". The office of scientific R&D is mainly responsible for handling the intellectual property management and other transformation activities of scientific and technology development, supported by the Jinan university science and technology park. Faculties in Jinan university are encourgaged to engage in entrepreneurship and technology promotion, with a specialize position set distinguished from the research-oriented or the teaching-oriented positions.

3.3.15. South China University of Technology

Basic information

South China University of Technology (SCUT) is a key university directly under the Ministry of Education, which entered the list of "Project 211" in 1995 and "Project 985" in 2001, and was selected as one of the "Double First Class" universities in 2017. The university has built 27 national research platforms and 185 provincial and ministerial research platforms, ranking among the top universities in China and the first in Guangdong. From 2019 to 2020, SCUT has ranked in the top 3 of the top 30 national universities for scientific and technological innovation for two consecutive years; and it ranks first in the scientific and technological innovation capabilities of undergraduate universities in Guangdong Province. For a long time, SCUT has scored 100 points in the overall support index and the transformation index of scientific and technological achievements in the "Evaluation Report on Supporting Local Economic and Social Development of Major Universities in Guangzhou", ranking first among Guangzhou universities.

Through the implementation of the New Engineering Plan, the university has actively built the "College + Research Institute + R&D Centre + Industry Alliance" approach to the integration

of industry, academia and research, effectively promoting the transformation of scientific and technological achievements from internal circulation to "internal and external circulation". Since 2009, the university has won a total of 38 awards (including 2 gold and 3 silver) as the first patent owner, ranking first among universities in China in terms of the number of patents awarded. At present, the campus has established the School of Biomedical Science and Engineering, the Wu Xianming School of Intelligent Engineering, the School of Microelectronics, the School of Molecular Science and Engineering and other "new engineering" schools that are in urgent need of industrial development in the Guangdong-Hong Kong-Macau Bay Area, as well as a number of research institutes such as the South China Institute of Advanced Soft Matter Science and Technology and the "Huagong-HKUST" Joint Research Institute. "These institutes have created a powerful new engine for the future industrial development of the Greater Bay Area.

Mechanisms and key policy documents of technology transfer

Selecting Talents for Station. SCUT is one of the first universities in China to carry out the reform of the institutional mechanism for the transformation of scientific and technological achievements. As a prestigious engineering university serving the Pearl River Delta, SCUT started the "Saturday Project" since the 1980s. Every weekend, a large number of faculties leave the school and enter the factory workshops, which has played an important role in supporting the industrial and agricultural development of the Pearl River Delta. In 2008, seven ministries and commissions including the Ministry of Science and Technology and the Ministry of Education jointly issued the implementation plan of the Innovation Project of Science and Technology Commissioners from the Ministry of Science and Technology of Hundreds of Schools, Thousands of People, Enterprises. In response to this implementation plan, SCUT released the Measures for the Selection and Appointment of Enterprise Science and Technology Commissioners in a timely manner, and formulated a series of incentives and safeguards in terms of wages and benefits, personnel assessment, and professional title promotion. Through this traditional "peer-to-peer" approach, SCUT not only promotes the direct transformation of the relevant technical achievements, but also effectively strengthen the close interactions between the university and the industry.

Promotion policies. In 2014, SCUT took the lead in issuing "Several Opinions of South China University of Technology on Promoting the Transformation of Scientific and Technological Achievements." Later in 2015, the university released the "Several Opinions of South China University of Technology on Servicing Innovation-Driven Development and Further Promoting the Transformation of Scientific and Technological Achievements." This document, often referred to as Ten Rules of SCUT, proposed to reward as much as possible the proceeds from the transformation of scientific and technological achievements, allowing scientific and technological personnel to carry out innovation and entrepreneurship on a full-time or part-time basis. SCUT further improved the evaluation mechanism for scientific research personnel and set up a series of professional titles such as professors specialized in technology promotion, researchers, and senior engineers. The assessment criteria for different positions were set to encourage the majority of scientific research personnel to actively serve economic and social development. For full-time or part-time faculty members engaged in science and technology

innovation and entrepreneurship, the economic and social benefits created, the application of developed products, the transformation of patent results, the number and amount of horizontal scientific research projects undertaken are taken as the main basis for asssessing the performance of their duties and the promotion of their professional and technical positions.

A one-stop service platform. In 2017, SCUT set up the Leading Group for Transformation of Scientific and Technological Achievements and Management of State-owned Assets of Enterprises, and the Office for Transformation of Scientific and Technological Achievements. The university then issued the Management Measures for Transformation of Scientific and Technological Achievements of South China University of Technology (trial), providing a one-stop approval service for the transformation of scientific and technological achievements such as entrusted technology contracts, patent technology licensing, transfer, and patent technology shareholding by enterprises and institutions. In the past decades, SCUT has successively established five major technology R&D and transformation bases, including the Zhongshan Institute of Modern Industrial Technology, the Guangzhou Institute of Modern Industrial Technology, the South China Collaborative Innovation Institute, the Zhuhai Institute of Modern Industrial Innovation, and the China-Singapore Institute of Modern Industrial Technology. These institutions have been treated as the innovation and entrepreneurship pilot area of SCUT, in which more favorable policies were carried out and practiced. In general, these initiatives to innovate the mechanism of transformation of scientific and technological achievements have accelerated the pace of transformation of SCUT' s scientific and technological achievements and incubated a number of science and technology-based enterprises.

Leading groups and office for technology transfer

As mentioned in the previous section, SCUT has established a leading group for the transformation of scientific and technological achievements and the management of state-owned assets of enterprises in 2017. The group was authorized to have some approval authority over the disposal of state-owned assets, led by the head of university who were in charge of research and assets. The members in the leading group are composed of the main personnel in charge of personnel, organization, assets, finance, audit, technology and discipline departments of SCUT. In order to ensure that there is a dedicated department responsible for the university's science and technology transfer function, the university has established a Science and Technology Transformation Office, transferring the functions of managing patents and servicing horizontal projects from the former Science and Technology Division to this office. At the same time, SCUT has made the National University Science and Technology Park, which is responsible for the incubation and acceleration of technology enterprises on campus, and the Industrial Technology Research Institute, which is responsible for the transfer and transformation of achievements, the anchor units of the Science and Technology Transformation Office.

In order to further deepen the reform of the science and technology management system and mechanism, SCUT established the Institute of Science and Technology in March 2021, with six operational divisions, including the Division of Science and Technology Planning and Integration, the Division of Basic Research and Base Construction, the Division of Major

Projects and High Technology, the Division of Science and Technology Cooperation and Transformation, the Division of Intellectual Property Rights, and the Division of Advanced Technology, as well as four affiliated units, including the Office of the Academic Council, the Office of the Association of Science and Technology, the General Research Institute of Industrial Technology, and the National University Science and Technology Park. The restructure of the organizations made the Institute of Science and Technology become the the main department responsible for the school's scientific and technological research and the transformation of scientific and technological achievements. Some of its main functions include:

- Formulation and implementation of university-level science and technology development plan, science and technology work plan and science and technology policy;
- Organization, declaration and management of both horizontal and vertical science and technology projects at the national, provincial and municipal levels; planning, evaluation and management of independent science and technology projects;
- Transfer and transformation of scientific and technological achievements and industry-university-research cooperation; Intellectual property management;

In 2021, the Ministry of Education and the Ministry of Science and Technology jointly issued the Notice on the Launching of the First Batch of National Technology Transfer Institutions Specialized in Universities, and SCUT was selected as one of the first batch of pilot universities specializing in national technology transfer agency construction. The goal of the notice was to innovate the mechanism for the transformation of scientific and technological achievements, strengthen the protection of intellectual property rights, improve the overall efficiency of the transformation of scientific and technological achievements in my country, and effectively improve the ability of universities and institutions to serve economic and social development.

Reward system for faculty

The majority of the equity formed by the University's contribution of technology for value will be awarded to the research team, with the allocation ratio being up to 95% of the intellectual property valued at up to RMB8 million awarded to the team and held by the team, and the remainder held by the University's wholly-owned enterprise, the University Asset Management Limited or the National University Science and Technology Park, which is responsible for holding shares on behalf of the University. The university mainly adopts two ways of investment and transformation, namely by transformation by itself and by relying on the various research institutes built in cooperation with the government. In 2016, a team led by Hu Jian, a professor at the university's School of Light Industry Science and Engineering, set up a joint venture company with China Motor Group Zhuzhou Times New Material Technology Co., Ltd. with aramid paper-related technology, and the relevant technology was valued at RMB 66.84 million, accounting for 25% of the shares of the joint venture company, of which 80% (RMB 53.47 million of the technology shares) was awarded by the university to the team that completed the results.

In the first mode, the university requires the investor to bring not only the operating capital and R&D cash of the enterprise to the technical team alone, but also certain market channels for the products of the proposed company to ensure the normal operation of the fledgling enterprise. And for the equity structure of the newly established company, the university respects the wishes of the research team itself and considers factors such as the industry market prospects and the capital investment for industrialisation, and determines the equity ratio of both parties with the investor. Among the nine new high-tech enterprises established by SCUT from 2017 to 2018 through investment transformation, five of them were controlled by the university and the completion team with an equity interest of 65% to 70%, so as to ensure that the university and the completion team have full decision-making power over the operation of the enterprise. The reason for this is that the technology itself is at the forefront of science and technology and the current market demand for the product is not high, so the cash needed to support the research and development of the enterprise requires the R&D team to attract new partners by giving up their original equity in the financing market.

In the mode of relying on local research institutes to invest in transformation, an example is the construction of the South China Institute of Collaborative Innovation jointly established by SCUT and the Dongguan Municipal Government, focusing on the original 3D printing technology in the university's laboratories to feed into a mature market industrial application of patented technology results. The technical achievements are owned by the research institute, and the research institute has established a high-tech enterprise of medical new materials together with social capital through technical pricing according to its own rights and interests.

In order to further ensure the healthy development of the enterprise in the start-up period, the university in principle requires all technology-funded transformation projects to be incubated in the university's innovation and entrepreneurship pilot areas. The university has set up a special fund for the transformation of research results in the basic scientific research business expenses of the central universities to finance the industrialisation research of the university's innovation and entrepreneurship pilot zones, and provides professional master's degree recruitment quota for the teams conducting industrialisation research in each innovation and entrepreneurship pilot zone every year to help promote the innovation and entrepreneurship work of the pilot zones. Based on the characteristics of local industries and policy advantages, each pilot innovation and entrepreneurship zone fully gathers local government resources to provide support for the university's technology-funded projects in terms of talent introduction, funding venues and project acquisition. For example, since 2017, SCUT has set up 10 high-tech enterprises with industry leaders such as KDDI and Guangzhou Hulan Institute, as well as Donghechang Group, a large group that combines finance and industry, in the form of patent valuation capital, of which seven enterprises have settled in the National University Science and Technology Park for incubation and acceleration. NUSSP utilises its cooperation with the Shunde District Government to build the University Science and Technology Park Shunde Innovation Park, which focuses on emerging industries that are key to the development of Guangdong and Shunde, and carries out the transformation of scientific and technological achievements, incubation of high-tech enterprises, training of innovative and entrepreneurial talents, and cooperation between industry, academia and research in areas such as robotics, artificial intelligence, precision manufacturing, advanced materials, bio-environmental

protection, networking and big data. The Park supports the transformation and industrialisation of the relevant achievements of the enterprises in the Park through multiple channels by providing rent reductions for incubation sites and setting up special projects for the industrialisation of start-up enterprises, with competitive selection allocation for enterprises whose scientific and technological achievements are incubated in the Park to declare themselves. The first batch of special fund support schemes launched by the Park in 2018 alone amounted to over RMB 10 million, mainly for supporting Huagong teachers in The start-up enterprises founded in the Park carry out industrialisation applications in the fields of artificial intelligence and the Internet, bio-environmental protection, advanced materials, electronic information and the Internet, intelligent robots, etc.

Collaboration with municipal government

SCUT has also continued to explore new modes and ways of practicing industry-university-research cooperation, and has achieved different forms of docking and cooperation with local governments and enterprises. In recent years, the university has laid out and built new research and development institutions in Guangdong Province, such as the Guangzhou Institute of Modern Industrial Technology (Guangzhou Institute of Industrial Research), the South China Institute of Collaborative Innovation, the Zhuhai Institute of Modern Industrial Innovation, the Zhongshan Institute of Modern Industrial Technology and the Sino-Singapore International Joint Research Institute, to create a pioneering area for the university's policy of promoting the transformation of scientific and technological achievements and a test area for practice. By providing support in terms of funding, venues and professional services, these platforms have given researchers a place to innovate and start their own businesses. It is understood that nearly 100 outstanding scientific and technological achievements of Huagong are implemented and transformed by these platforms every year, and these platforms have become a new engine to promote the innovation-driven development of the region.

Among them, the Guangzhou Institute of Modern Industrial Technology has made significant progress in its construction as a collaborative innovation platform providing comprehensive science and technology services for the main pillar industries and SMEs in Guangzhou and the Pearl River Delta region. In recent years, the Institute has introduced and nurtured 19 R&D institutions at national and provincial levels, extending its functions of results transformation and industrialisation. Five R&D platforms have been built in the Nansha Science and Technology Innovation Centre around industry common and key technologies, including high-end manufacturing equipment, new energy technology, light industry technology and engineering, ship and marine coastal engineering and modern service industry, with a total area of 15,300 square metres; in precision electronic manufacturing equipment, In 2014, Guangzhou Industrial Research Institute was recognized as a national technology transfer demonstration institution.

Modes of Joint laboratories in SCUT

The construction mode of the joint laboratories of South China University could be classified into four types: talent cultivation-led, scientific research-led, production application-led and mixed mode. The main body of the laboratory co-construction is usually the enterprise. In the

talent cultivation-led cooperation mode, the laboratory is mainly based on teaching and training, combining the theoretical knowledge of university teachers with the experience of enterprises. Through the guidance and training of professional and technical personnel in the laboratory, students can acquire skills to meet the needs of enterprises within a short period of time, so that employees of enterprises can improve their professionalism. In the scientific research-led cooperation mode, the laboratory mainly focuses on the development of high-tech products in the industry, the demand for future technology in the market and the conquering of common technical problems in the industry, and carries out the research and development of new technology and new products independently. Therefore, enterprises in this type of cooperation mode mainly provide research and development funds and obtain high-tech products or patented technology to share. In the production application-led cooperation mode, enterprises mainly set up joint laboratories on the basis of their own R&D conditions and attract outstanding technicians from universities to participate in the R&D work of enterprises. The university promotes the cooperation between teachers and enterprises through the input of discipline advantages and teachers' research team and achievements, which makes the teachers' research more close to the development of economy and improves the conversion rate of research results.

SCUT Science and Technology park

SCUT Science and Technology Park is one of the 22 national university science and technology parks approved by the Ministry of Education and the Ministry of Science and Technology. The park is open to enterprises from home and abroad in all aspects, mainly in the fields of electronic information, new materials, bioengineering, environmental protection and electromechanical and optical integration to support the establishment of new enterprises and the industrialization of high technology and its products. Based on the technological, human resources and geographical advantages of South China University of Technology, South China University of Technology Science and Technology Park Limited manages and serves the enterprises and research and development institutions in the Park through the construction and development of the University Science and Technology Park, commercialisation and industrialisation of technological achievements, technology trade, technology intermediation, financing intermediation and training of senior management personnel of enterprises in a modern capital-operated manner, while promoting The Park's venture capital fund has been established by many people. In 2006, the park achieved a total output value of nearly RMB 1 billion. The South China University of Technology Science and Technology Park has become an important platform for market-oriented research and development of high technology, incubation of high technology enterprises, and the absorption and cultivation of innovative talents.

While collecting industry information for the government, venture capital institutions, universities and research institutes, the Park also receives resources from these institutions, including preferential policies from the government, financial support from venture capital institutions and advanced technology consulting services from universities. In addition, the Science and Technology Park provides these preferential policies, sufficient funds and advanced technology to the incubatees, who make full use of the resources to achieve their own

rapid development, and at the same time, report the problems encountered in the process of development to the Science and Technology Park, which collates and analyses the information and provides timely feedback to relevant institutions and units, such as research and investment, to achieve the rapid and efficient transfer of information. The incubatees are in constant communication with the University Science and Technology Park and the Research and Investment Institute, and regularly pay various service fees to the Park, and at the same time, receive relevant assistance from the Science and Technology Park and the Research and Investment Institute. In recent years, the Park has attached importance to the work related to advanced technology transfer and has taken a series of measures: (1) providing advanced technologies to incubatees to assist them in upgrading their technologies; (2) collaborating with a number of advanced companies in the industry to promote the development and transfer of key technologies. Through a series of technology transfer measures, Huagong Science Park has successfully incubated a number of outstanding innovative enterprises such as Huagong Baichuan, Huagong Huanyuan, Yuanzheng Intelligence, Huagong Lia and Huawei Engineering.

Conclusions

SCUT has a long tradition of integrating the laboratory work and industry applications as one of the first four prestigious universities specialized in engineering colleges in China. Focusing on Guangzhou, Foshan and Zhuhai, as well as the other areas in the Pearl River Region, the university has set up "five institutes and one park" development strategy to facilitate the transformation of scientific and technological achievements (including Sino-Singapore International Joint Research Institute, Guangzhou Institute of Modern Industrial Technology, Dongguan South China Institute of Collaborative Innovation, Zhuhai Institute of Modern Industrial Innovation, Institute of Modern Industrial Technology of South China University of Technology, Zhongshan City, and National University Science and Technology Park), deepening the docking of innovation projects with enterprise needs, innovation achievements with real productivity, science and technology with industry and capital, and accelerating the landing and industrialisation of high-tech achievements. Meanwhile, the university invests more than 10 million yuan each year in special funds for intellectual property to support patent quality improvement and patent operation, and places emphasis on the percentage of invention patents, invention grant rate and patent transfer index in patent funding methods and reward policies. SCUT has implemented a series of policies to construct university-enterprise jointly laboratories, cultivating high-value products in superior disciplines such as materials science and light industry technology, and serving the layout of strategic emerging industries in the Guangdong-Hong Kong-Macau Greater Bay Area.

3.3.16. Sun Yat-sen University

Basic Information of Sun Yat-sen University

Sun Yat-sen University (SYSU), founded by and named after Dr. Sun Yat-sen in 1924, has a teaching tradition spanning over a century. Located in Guangdong, the frontier of China’s

reform and opening up, SYSU has established five staggered campuses in the three core cities of Guangzhou, Zhuhai, and Shenzhen in the Greater Bay Area, as well as ten affiliated hospitals, which jointly support the development of the entire University. Under the direct supervision of the Ministry of Education of the People's Republic of China, and strongly supported by both the Ministry and Guangdong Province, Sun Yat-sen University has developed into a modern comprehensive university with a reputation as a top-tier university in China and an internationally renowned university. SYSU is ranked 160th in QS World University Rankings 2022, striving to become one of the world-class universities.

The basic guiding philosophy at SYSU is to be oriented toward academic frontiers, national primary strategic needs, and the national and regional economic and social development, known as the "three orientations". Moreover, SYSU is equipped with a global outlook and committed to being a "comprehensive, innovative and open" institution. The goal of talent cultivation is to nurture high-quality, interdisciplinary and top-notch students with both ability and moral integrity, leadership qualities, a sense of social responsibility and an innovative spirit. To achieve this goal, faculty and staff make unremitting efforts to innovate mechanisms of talent cultivation in accordance with the fundamental principle of "educating with love".

As of December 2020, Sun Yat-sen University has 65 faculties and departments (35 in Guangzhou campus, 20 in Zhuhai campus and 10 in Shenzhen campus), 10 affiliated hospitals, 30 national research platforms, 208 provincial and ministerial research platforms, and 10 local research institutes. Sun Yat-sen University has a strong faculty, with 16,363 total faculty and staff, 4293 full-time teachers, including 1663 with senior titles and 1924 with associate titles, and has many distinguished scholars, including 16 academicians of the Chinese Academy of Sciences, 5 academicians of the Chinese Academy of Engineering, and 84 recipients of National Science Fund for Distinguished Young Scholars. Built on a solid multidisciplinary foundation of humanities, social sciences, natural sciences, medical sciences, and engineering, Sun Yat-sen University is propelled forward by the continuous pursuit of innovation.

Scientific Research Construction of SYSU

Since 2015, Sun Yat-sen University has been actively promoting the "three major constructions" of big research projects, big research teams and big research platforms in scientific research, with the guiding principle of "three orientations", which promotes the implementation of a series of major national strategies in SYSU. Starting from the "big projects" drawn by national strategic tasks, the university organizes "big teams" to guarantee the completion of national tasks and builds "big platforms" to support teams to carry out collaborative research.

The following are the most representative major science and technology innovation platforms and infrastructure, which become a vital support for talent cultivation and science and technology innovation of the university.

- The TianQin Research Center for Gravitational Physics is established in April 2016, and is responsible for the research work of the TianQin Project (space-based gravitational wave detection program)

- South China Sea Research Institute & Southern Marine Provincial Laboratory are established in 2018 to develop the provincial marine laboratories, comprehensive marine scientific research practice ships, marine biological resource banks, and organize major marine scientific research and scientific research voyages.
- The “Sun Yat-sen University” Integrated Oceanographic Research Practice Vessel is the maritime mobile research platform and talent training base, delivered and commissioned into service in June 2021.
- National Supercomputing Center IN Guangzhou is operated and managed by Sun Yat-sen University, located at the Guangzhou East Campus, and put into operation in January 2014.
- Center for Precision Medicine, SYSU is established in August 2015, committed to precision medical science research, becoming the precision medicine big data engineering technology research center.
- High Energy Direct Geometry Time-of-flight Neutron Spectrometer (Sun-light), started in 2019 and expected to be completed in 2022, will be the first material dynamics spectrometer in China.

Besides, according to the Implementation Rules for the Management of Basic Scientific Research Expenses of Colleges and Universities of SYSU released in March 2021, the basic scientific research expenses of the university are based on the principle of “combining integrated planning and independent arrangement, open selection, allocation according to needs, and support on the basis of merit”, focusing on supporting young and middle-aged teachers to improve basic scientific research capabilities, build scientific research teams, and conduct research on crucial core technological innovations and frontier emerging interdisciplinary disciplines. Meanwhile, oriented by scientific research performance and results, the university arranges 15% of the total annual basic scientific research expenses as performance incentive funds to stimulate further development of young and middle-aged teachers.

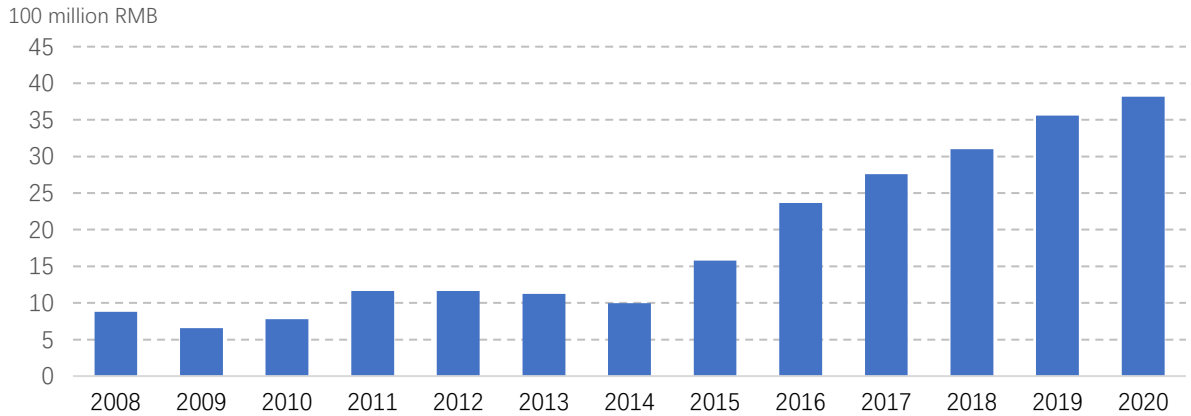


Figure 3-29 Annual Research Funding Received (2008-2020)

Source: SYSU Website, Guangdong Science and Technology Yearbook 2009-2020

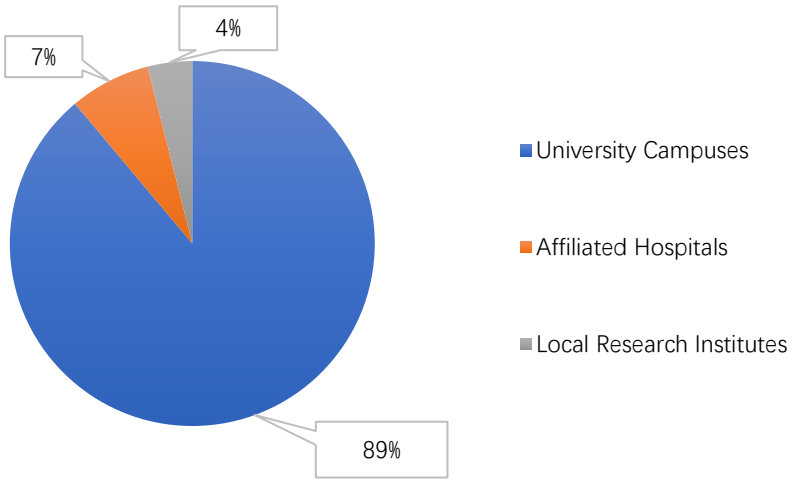


Figure 3-30 Composition of research funding in 2020

Source: SYSU Website

The past decade or so have witnessed an overall upward trend in research funding received by SYSU, with a significant increase since 2015 in particular. Annual research funding received in 2020 amounted to 3.816 billion RMB, consisting of the main campus, affiliated hospitals, and local research institutes. And since the implementation of the National Key R&D Program of China in 2015, Sun Yat-sen University ranks fifth in the total number of projects in Chinese universities.

Moreover, Sun Yat-sen University Science Park is an extension of SYSU in scientific research, technology development and services to the economy and society, also one of the crucial bases for the transfer and transformation of scientific and technological achievements. Since its establishment in 2004, the Science Park has established sub-parks in many places in Guangdong Province in accordance with the construction model of "one university with multiple campuses" of SYSU. And it has formed the pattern of "one park with multiple zones" in Haizhu Main Park, University City Park, Nansha Park and Shenzhen Park. The Science Park has been recognized by the Ministry of Science and Technology and the Ministry of Education as a national university science park, a science and technology entrepreneurship practice base for college students and a national science and technology business incubator. And it has been awarded the excellent assessment and evaluation (class A) of national science and technology business incubators organized by Torch High Technology Industry Development Center, Ministry of Science and Technology for 4 consecutive years (2016, 2017, 2018, and 2019).

The strong research and innovation capacity and resources of Sun Yat-sen University have established a solid foundation for technology transfer and commercialization of scientific and research findings.

Technology Transfer under the Integrated Management of the Office of Scientific Research and Development (Technology Transfer Center) in SYSU

Sun Yat-sen University attaches great importance to technology transfer and keeps improving the related organizational structure and mechanism. In 2004, the Intellectual Property Office was established to be specifically responsible for university intellectual property-related work, which was also co-located with the Office of Industry-University-Research Cooperation to strengthen the implementation and commercialization of IP. In 2006, the Technology Transfer Center of Sun Yat-sen University was established as an institution and platform for the promotion and application of scientific and technological achievements. The Center is responsible for organizing and integrating high-tech resources within the university, transferring technology through cooperation with government and enterprises, as well as continuously improving the quantity and quality of intellectual property through the establishment of sound intellectual property management and international technical cooperation and exchange.

Nowadays, Sun Yat-sen University has integrated relevant management institutions. The Office of Scientific Research and Development, as a comprehensive functional management department in SYSU, is not only responsible for all scientific research-related work, but also carries the function of technology transfer. In fact, the Technology Transfer Center of SYSU becomes the horizontal division under this office.

In the mechanism, SYSU has established a collective decision-making system of the leading group on significant matters of technology transfer. This leading group incorporates intellectual property management into its responsibilities and is the deliberative body for major matters of intellectual property and transformation of scientific and technological achievements of the university to deliberate and form opinions on relevant vital issues.

In general, the Office of Scientific Research and Development works in concert with other departments, with leadership and coordination of the leading group, to form an integrated coordination mechanism and organizational structure for science and technology innovation, intellectual property management and transformation of scientific and technological achievements.

Sun Yat-sen University has been actively engaged in the creation and cultivation of high-quality patents, emphasizing the improvement of patent quality, changing the practice of emphasizing quantity over quality, and proposing the implementation of the “Intellectual Property Quality and Efficiency Enhancement Plan” in the Fourteenth Five-Year Plan of the university.

It is worth noting here that SYSU has been recognized by the Ministry of Education and the State Intellectual Property Office as one of the “First Batch for Transformation of Scientific and Technological Achievements and Technology Transfer Bases in Higher Education”, “First Batch of National Intellectual Property Information Service Centers in Universities” and “National Intellectual Property Demonstration University in 2020”.

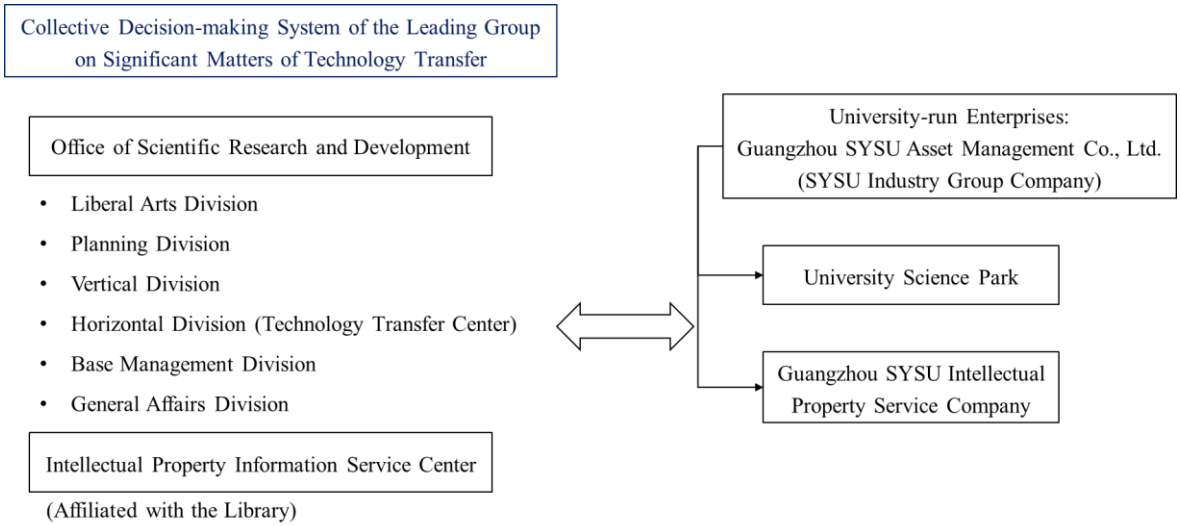


Figure 3-31 The structure of technology transfer-related organizations in SYSU

Technology Transfer-related Management Regulations in SYSU

In terms of the university's rules and regulations, Sun Yat-sen University has kept pace with the times to revise the "Management Measures for Patent Work of Sun Yat-sen University" and "Implementation Measures for the Transformation of Scientific and Technological Achievements of Sun Yat-sen University" in 2019 and 2020 respectively, with the guiding principle of "quality first, commercialization-oriented". Accordingly, a series of transparent and operable work processes have been formed, which provide solid institutional guarantees for intellectual property management and the transformation of achievements.

- Management Measures for Patent Work of Sun Yat-sen University: mainly from the job invention patent application, management, funding, implementation and reward, accountability and other aspects of the regulations.
- Implementation Measures for the Transformation of Scientific and Technological Achievements of Sun Yat-sen University: including general provisions, related institutions and functions, organization and implementation, transfer and license approval procedures, investment for value approval procedures, revenue distribution and incentives, supervision and responsibility; establishing a management system for disclosure of job scientific and technological achievements, patent pre-application evaluation system, and achievements transformation public announcement system.

Patent Pre-application Evaluation System in SYSU

Sun Yat-sen University has set the patent pre-application evaluation work in the form of a system to provide institutional guarantee for patent quality improvement in the Implementation Measures for the Transformation of Scientific and Technological Achievements. The evaluation can be either carried out by the university's office of scientific research and development or entrusted to a private-sector organization. The proposed patent application

filed by the researcher must be subjected to a pre-evaluation review, based on which a decision is made whether to proceed with the patent application.

Since 2019, SYSU has explored entrusting third-party professional agencies to carry out patent pre-application evaluation and completed the bidding process of agency service providers in December 2019, to select 10 patent agencies with professional qualifications, good reputation and high quality, of which 8 patent agencies have been engaged in collaboration so far **(Fan R., 2020; Guangzhou Development Zone Intellectual Property Office, 2021).** The selected patent agencies are required to conduct pre-application evaluation of the proposed patent application submitted by the researcher in terms of innovation, application prospect and other related aspects.

Fundings for Technology Transfer

The SYSU establishes *a patent fund*, which is allocated by the university every year to cover the expenses of applying for patents, maintaining patent rights and patent awards. The basic principle of patent funds is to focus on subsidizing invention patents, appropriately funding utility model patents, and not funding design patents in principle. And the fee standard of funding is not more than 4,000 yuan for each invention patent and not more than 2,000 yuan for each utility model patent.

The unique funding project for the transformation of scientific and technological achievements of SYSU is established independently by using its own internal funds, focusing on supporting the scientific research achievements that possess independent intellectual property rights, have prominent transformation prospects and benefits, and can be commercialized in the near future. Since 2016, the university has been spending over 10 million RMB per year to support the cultivation of high-quality achievements with industrialization prospects. After passing the expert review, the university will fund the project on a merit basis, with proposed funding of 200,000 yuan, according to the notice of the office of scientific research and development on organizing the application of 2021 SYSU's scientific and technological achievements transformation projects. The goal of this project is to overcome the key and core problems in the commercialization of scientific research results, to form new products, new technologies, new processes and new materials, and to generate certain economic benefits, such as the realization of high-value transfer or implementation license of patented technologies, product sales, the construction of joint enterprises by means of technology for equity, etc.

For instance, Exocarpium Citri Grandis in Guangdong is a well-known Chinese materia medica with highly effective antitussive, expectorant and anti-inflammatory effects, but no modern preparations of medicines were previously available. The team of Professor SU Weiwei from the School of Life Sciences researched its druggability and established quality control standards for effective ingredients of Exocarpium Citri Grandis. Based on its effective ingredients, a new Chinese medicine, Hongzhu Capsules, was developed. Then the team project of Hongzhu Capsule received a significant increase in technical value after incubation, successfully completed pre-clinical research and pilot production, actively docked with the market for smooth transformation. Its innovative medicine Hongzhu Capsule has implemented

a patent licensing transfer with a price of 20 million RMB, which set a record for the largest amount of single patent transfer since the establishment of SYSU in 2019.

The distribution of income from the transformation of scientific and technological achievements plays an incentive role:

According to the newly revised implementation method for the transformation of scientific and technological achievements of SYSU in 2020, for net proceeds from the transfer and licensing of scientific and technological achievements, the original distribution model of 7:3 between the inventor and the university is changed to a 7:1:1:1 distribution model. 70% is used to reward the inventors for stimulating the enthusiasm of the innovation subject, 10% is used to reward the department of inventors, for encouraging faculty to support the transformation of researchers and employing part-time transformation managers, 10% is the income of the university and used for expenses of related work and risk money, reflecting the university's sovereignty over scientific and technological achievements, 10% is the university's payment to the commissioned Guangzhou SYSU Intellectual Property Service Company for providing specialized IP services **(Fan R., 2020)**.

The university cedes 20% of the net proceeds from the transfer and licensing of scientific and technological achievements to the company and faculty, which does not affect the income of the inventor and guarantees their motivation. At the same time, this mobilizes the enthusiasm of the faculty for the transformation work, and also enables the company to reap performance incentives that match the effectiveness of the work, thus improving the efficiency of patent transfer and licensing.

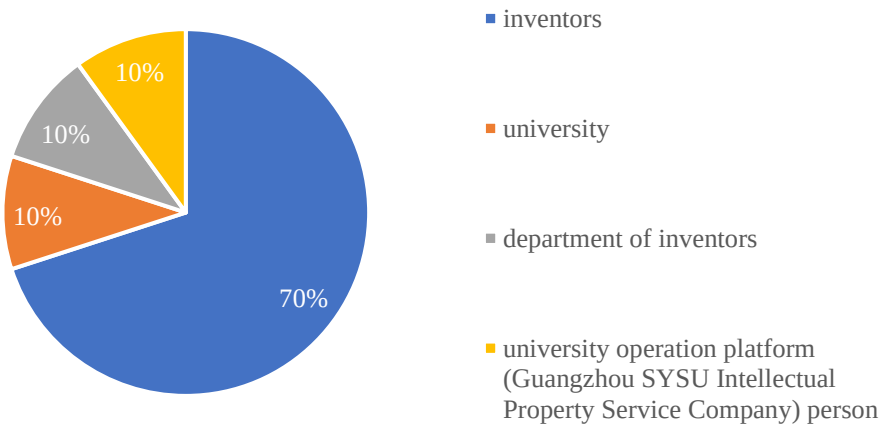


Figure 3-32 The distribution model of net proceeds from the transfer and licensing of scientific and technological achievements in SYSU

Source: Implementation Measures for the Transformation of Scientific and Technological Achievements of Sun Yat-sen University

Besides, if the scientific and technological achievements are commercialized through valuation investment, 70% of the equity formed from the valuation of the scientific and technological

achievements is used to reward the inventors, and the remaining 30% of the equity is held and managed by the university's asset management company on behalf of the university.

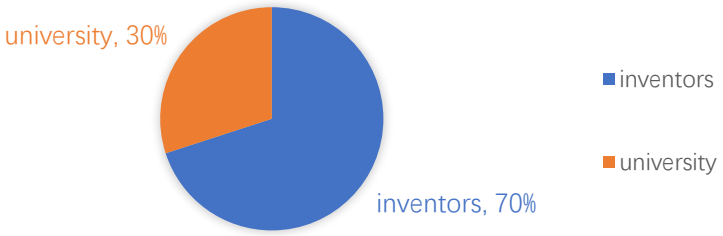


Figure 3-33 The distribution model of the equity resulting from valuation investment of scientific and technological achievements in SYSU

Source: Implementation Measures for the Transformation of Scientific and Technological Achievements of Sun Yat-sen University

Inclusion of Knowledge and Technology Transfer in Evaluation for Faculty Tenure

According to the regulations on the approval of faculty staffing, position setting and appointment in SYSU, there are basic performance requirements for faculty members at Sun Yat-sen University in terms of publishing high-quality academic papers or publications, and hosting or participating in research projects during their tenure. And every three years, the whole university conducts a unified assessment with basic workload requirements for scientific research **(SYSU Information Disclosure Network, 2021)**. For instance:

- Lecturers must publish at least one academic paper (second author or above) on average per year during the evaluation period.
- Associate professors and above must have published academic papers (first author) in each academic year.
- Professors must also preside over at least one scientific research project or a sub-project of the significant national project within the assessment period.

Besides, patents can be converted to scientific research workload on a case-by-case basis, according to the nature, level and benefits, etc. Those who made significant contributions in discipline development, or achieved significant results in teaching, or published papers in the most important academic journals, or had a significant academic impact of research results, or obtained patents with significant application value, can be exempted from the required basic workload assessment after identification and approval.

More importantly, Sun Yat-sen University fully utilizes professional title evaluation and assessment to guide researchers to focus on the quality and transformation of patents. Only the situation of patent transformation is included in the scope of assessment and evaluation, instead

of the number of patent applications or grants, thus avoiding invalid or low-quality patents due to the need for professional title evaluation.

For academic leave, professors, associate professors and lecturers are entitled to six months of paid academic leave, for every five years of continuous service at the University. During the academic leave, faculty members are allowed to work full-time on academic research, and the basic teaching workload requirement is reduced by half during the academic year in which the academic leave is taken. Those who participate in significant research projects and have more important responsibilities in the project are entitled to an additional academic leave with pay for not more than two years after application and recognition, and their teaching workload is exempted from assessment **(Sun Yat-sen University, 2003)**.

Some Statistics on the Results of Technology Transfer

Table 3-28 Overview of Sun Yat-sen University Patents in 2020

Type of Patent	Patent for Invention		Patent for Utility Mode	Design Patent
Patent Status	Application	Licensing	Licensing	Licensing
China Patents	1531	726	75	4
Foreign Patents	64	16	-	-
Total	1595	742	75	4

Source: Sun Yat-sen University Library, Intellectual Property Information Service Center

* Excluding data on patents filed independently by affiliated hospitals and subordinate research institutes of SYSU.

In 2020, Sun Yat-sen University publicly announced a total of 2,416 patent filings, mainly invention patents accounted for 96.73%. And the number of patent grants (successful patent filings) is 849, accounting for 35.14%. According to the international patent classification (IPC), the SYSU patents in 2020 are mainly concentrated in physics accounting for 44%, chemical metallurgy accounting for 26%, and electricity accounting for 21%. In addition, there are 375 patents in cooperation with other institutions or individuals, accounting for 15.52% **(SYSU Library, 2021)**.

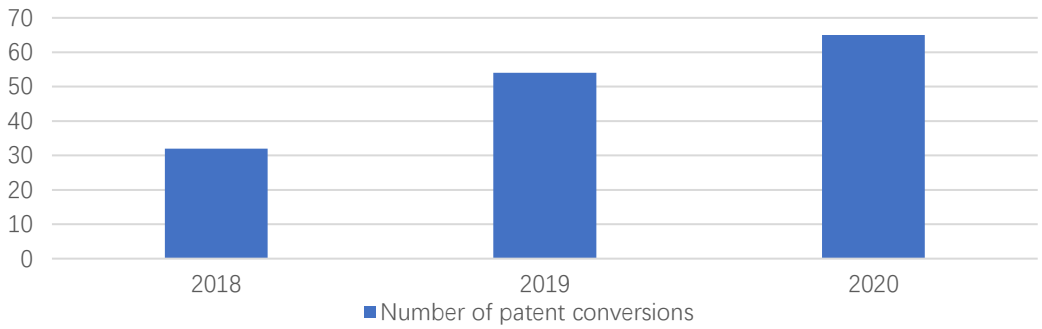


Figure 3-34 Number of Patents Commercialized (2018-2020)

Source: Guangzhou Development Zone Intellectual Property Office; Office of Scientific Research and Development, SUSY; Guangzhou SYSU Asset Management Co., Ltd.

The number of annual patents commercialized at Sun Yat-sen University has been growing steadily in recent years, and 55 patents commercialized have been completed in the first half of 2021 **(Guangzhou Development Zone Intellectual Property Office, 2021)**. To a certain extent, this benefited from the improvement of the service system for the transformation of scientific research achievements and the incentive effect of the adjusted revenue distribution system of Sun Yat-sen University. From 2016 to 2020, the amount of scientific and technological achievements commercialized exceeded 1.5 billion yuan, and the number of patents commercialized reached more than 240, both of which represented a more than 3-fold increase than in the previous five years, while achieving 1 project of 100-million-yuan level and 3 projects of 10-million-yuan level research achievement commercialization projects **(Fan R., 2020; SYSU School Newspaper, 2020)**.

What's more, Sun Yat-sen University has also been successful in setting up joint ventures with enterprises by using patents as shares. In 2016, the school's patent achievements were valued at 33 million yuan to take equity in two companies with technology, involving total equity of 640 million yuan. In June 2017, Sun Yat-sen University participated in the first university science and technology achievements fair, relying on advanced technology support and good display effect to successfully sign 21 projects on site, with a signing amount of up to 44.9 million yuan, involving additive manufacturing, environmental protection and resource utilization, energy-saving and new energy, fine chemicals and other fields **(SYSU, 2017)**. For example, SYSU cooperated with Guangdong Dahuannong Animal Health Products Co., Ltd. to set up a limited liability company, in which the university bought shares with the relevant innovation results. 4 patent projects were valued at 10 million yuan through the appraisal, and the implementing team took 50% of the company shares **(China Intellectual Property News, 2015)**.

Intellectual Property Information Service Center

The construction of the Intellectual Property Information Service Center for Universities is a joint initiative of the State Intellectual Property Office and the Ministry of Education to deeply implement the National Innovation-driven Development Strategy, aiming at improving the

public service network of intellectual property information, further enhancing the ability of universities to carry out intellectual property information services.

In July 2018, SYSU established the Intellectual Property Information Service Center, which is attached to the university's library. In March 2019, the SYSU Intellectual Property Information Service Center was successfully approved and officially licensed as one of the first batch of "National Intellectual Property Information Service Centers of Universities" in China.

Content of Intellectual Property Information Services:

- Patent Consulting: including general consultation on patent basics and the search and utilization of patent information resources, etc.
- Patent information literacy education: training on basic patent knowledge and patent data retrieval and utilization, introducing the commonly used online free public patent search system and the commercial patent database purchased by the library.
- Patent search: searching patent according to the patent, patentee, inventor, or technical field specified by the client and providing the list of patents.
- Patent novelty search: searching for patents with a relevant technical background to examine novelty and inventiveness and providing search reports containing relevant patent literature.
- Patent analysis: collating and analyzing the patent situation of each faculty, research institute and discipline/subject group, cooperating with relevant departments of the university to implement services and decision-making.

Relying on the library's subject and S&T search service team, the Center has carried out a series of services and lectures such as intellectual property information literacy education, patent search and technology patent analysis. On the one hand, the Center has made active efforts to serve the scientific research and innovation of teachers and students and provide institutions and scholars with patent competitiveness analysis and patent navigation for professional technologies, while enhancing their knowledge and awareness of intellectual property protection and improving their skills of patent information mining and utilization. On the other hand, the Center continues to improve the ability and level of intellectual property information service, fully develop the advantages of library information resources and services, and cooperate with relevant departments of the university. In this way, the Center can better provide information support services for the creation, application, protection, and management of intellectual property rights, and help the university's intellectual property management standardization work and "double first-class" construction.

Intellectual Property Service Company: Platform for Transfer

Intellectual property management and the transformation of technical achievements often require professional and specialized and market-oriented services, but researchers have little trust in the third-party companies. Sun Yat-sen University strengthens the construction of the technology transfer talent team by allowing professionals to engage in specialized work to continuously improve the level of technology achievement transformation services.

In August 2017, Guangzhou SYSU Intellectual Property Service Company was established as a wholly-owned subsidiary of SYSU Asset Management Company, by integrating the institutions and resources of operational asset management. The company is authorized and entrusted by the university as a platform for the transformation of scientific and technological achievements and intellectual property management and operation, using 10% of the university's net income from the transformation of achievements to undertake the market-oriented and professional work, constantly improving the service system and broadening the channels for the transformation of achievements. The platform has formed a professional technology transfer team consisting of 12 full-time company professionals and more than 30 part-time managers from faculties to create a four-level integrated system of "school managers - part-time managers from faculties - company professionals - scientific researchers" and solve the problem of understaffing and insufficient professionalism in the school administration **(Fan R., 2020)**.

Based on SYSU, this company serves as a resource-sharing enterprise service platform with intellectual property as its core, to provide a compelling connection between universities and enterprises by pooling and docking the technological achievements of universities and the technological needs of enterprises. Through hosting or co-hosting more than 50 various activities such as matchmaking meetings, exhibitions and roadshows, scientific and technological achievements are effectively promoted and docked to market enterprise resources. At the same time, the company has established a good communication mechanism with relevant industry associations and departments, such as Guangzhou Association for Science and Technology Association, Guangdong IP Protection Association and Guangdong Productivity Promotion Center, to obtain enterprise resources and focus on enterprise technology bottlenecks.

Adhering to the mission of "making the world's creativity a reality", this platform promotes the transformation of scientific and technological achievements of SYSU by providing service such as publication of scientific research results and technical demands, evaluation of scientific research results, technology maturation, and science and technology finance. Here are the main functions:

- Achievement transformation platform: including the promotion, analysis, quotation of achievements, transaction announcement, and hosting results display and matchmaking meeting
- Technical maturation service: carrying out intermediate test phase to transform scientific and technological achievements into products with market maturity

Throughout 2019, SYSU Intellectual Property Service Co., Ltd. promoted the transformation of 15 scientific and technological achievements, increasing 87.5% year on year, and transferred 67 patents, soft copyrights, etc., with an arrival contract value of 15 million yuan, up 20% year on year **(SYSU Industry Group Co., 2019)**. Besides, the company has represented the university's office of scientific research and development in a number of government-organized results matching meetings and cooperated with local governments in organizing precise matching meetings for the transformation of results of Sun Yat-sen University,

establishing effective contacts with more than 80 enterprises **(Fan R., 2020)**.

Entrepreneurship in SYSU

In 2009, the School of Entrepreneurship was approved to be established as a secondary institute under the School of Business. The School of Entrepreneurship conducts entrepreneurship education and training work for all enrolled college students and has launched a series of elective courses on entrepreneurship and innovation, including a total of 8 courses such as Innovation Management and New Product Development, Social Entrepreneurship, and Entrepreneurial Management of Start-up Enterprises.

The entrepreneurial atmosphere was strong, with popular venture capital forums and sharing sessions complementing each other. The university actively hosts entrepreneurship and case competitions to exercise students' organizational skills, promote entrepreneurial and innovative culture, and allow more students with entrepreneurial dreams to have a stage to showcase. The most typical one is the annual innovation and entrepreneurship training program for undergraduates, which provides funding, evaluation and guidance for the established projects, and promotes the demonstration and even transformation and application of excellent results. This inspires students' interest in innovative and entrepreneurial practices and develops their creative and practical thinking and abilities.

Sun Yat-sen University Science Park

Relying on the advantageous disciplines of SYSU, the Science Park combines the advantages of the university's scientific and educational resources with market resources to gather talents, technology, capital, information, and other diversified innovation factors. With the aim of cultivating high-level innovation and entrepreneurship groups and incubating unicorns and listed enterprises, the Science Park actively builds an innovation and entrepreneurship ecosystem, provides diversified value-added services, and serves as an incubator. At present, it has built "SYSU Co-working Space" and "SYSU Overseas Student Entrepreneurship Park", as well as the "Coworking Space - Incubator - Accelerator" technology entrepreneurship incubation chain and multi-level business incubation service system.

By the end of 2019, the "SYSU Co-working Space" has housed 34 entrepreneurial projects and 39 firms have been stationed in the "SYSU Overseas Students Pioneer Park" **(SYSU Industry Group Co., 2019)**. From 2016 to 2020, Science Park has cultivated two listed enterprises, one unicorn enterprise, one "future unicorn" in Guangzhou, and 61 high-tech enterprises **(Guangzhou SYSU Asset Management Co. 2020)**.

Using its own funds, the Science Park has established a multi-level support and incentive system around the whole life cycle of enterprise development, and assisted enterprises in the park to carry out enterprise development planning. From the application of intellectual property rights by start-ups to the listing of enterprises, all of them can receive relevant awards and subsidies from the Science Park. Since 2013, Science Park has been using its own funds to provide incentives to enterprises in the park for obtaining intellectual property rights licenses.

Established in 2017 and implemented since 2018, the enterprise funding covers entrepreneurship, high-growth enterprises, talent introduction and entrepreneurial competitions.

The "Sun Yat-sen University Science Park Cup" Win in SYSU Innovation and Entrepreneurship Competition, jointly organized by the university's student work department of the party committee and Science Park, has been held 14 times so far.

On April 17, 2021, the final round of the 14th competition was held at the Science Park of Sun Yat-sen University. More than 750 students with 184 outstanding projects from over 40 faculties and affiliated hospitals registered for the 14th competition in 2021, including 140 projects in the academic innovation track and 44 projects in the entrepreneurship track **(Sun Yat-sen University Committee of the Communist Youth League, 2021)**. Meanwhile, the Science Park conducted the Innovation and Entrepreneurship Training Camp and Business Simulation Training in conjunction with the competition, further promoting the deep integration of the second classroom with the first classroom. In the form of "promoting innovation and entrepreneurship by competition", the competition has cultivated a number of reserve forces for scientific research and innovation and entrepreneurship.

In 2019, Science Park launched the SYSU training and incubation platform specifically related to the topic of "Internet+", integrating entrepreneurship training and classes, as a three-dimensional, one-stop platform for building innovative and entrepreneurial talent training. By 2020, the platform has developed and put online 51 innovation and entrepreneurship training courses, of which 30 are recorded jointly with the university's higher continuing education center, 11 are translated from excellent foreign public courses, and 10 interviews with outstanding entrepreneurs in science park have been recorded by inviting the heads of successful entrepreneurial enterprises in the park. From the platform's start to September 2020, the number of registered users reached 9,796, and about 50,000 innovation and entrepreneurship students have been trained **(Guangzhou SYSU Asset Management Co. 2020)**.

During the COVID-19 epidemic, the Science Park created the "i Innovation and Entrepreneurship Live" platform to provide online services, organized online policy presentations, launched online "innovation and entrepreneurship" training, and continued to carry out high-quality incubation services. From the outbreak of the epidemic to September 16, 2020, a total of 17 online and offline innovation and entrepreneurship activities were conducted. And Science Park planned 50 free entrepreneurial workplaces to provide "zero cost" entrepreneurial services for college graduates in response to the Guangdong Provincial Science and Technology Department's request to strengthen science and technology innovation services to support entrepreneurship and employment throughout the period of epidemic prevention and control. Free entrepreneurial workstations have been put into use on June 1, 2020, and have already attracted several entrepreneurial projects, such as RuiShi Medical Technology Co. **(Guangzhou SYSU Asset Management Co. 2020)**.

Conclusion

Relying on solid scientific and technological research resources and achievements of SYSU, the Office of Scientific Research and Development, as a comprehensive functional department and coordinating center, is not only responsible for planning and managing the university's various scientific research and innovation work, but also actively carries out technology transfer, which can guarantee the more comprehensive and effective matching and implementation of results transformation. While improving the technology transfer norms and incentive system, the Office of Scientific Research and Development has strengthened cooperation with other service organizations such as IP information service center in library, Guangzhou SYSU IP Service Company and Science Park to serve technology transfer, reflecting the strengthening of the management and service institutional system.

In the technology transfer process, what SYSU has done prominently is to carry out patent navigation and high-value patent cultivation. Around the university's key research teams, SYSU conducts navigation services for patent information retrieval and professional technology analysis, enabling researchers to keep abreast of the latest industrial development and technological innovation trends, providing an important reference basis for better innovation, protection and transfer of technology. A dedicated fund is also set up to support research projects with industrialization prospects, to foster high-quality patent and promote their commercialization. This is an effective means of improving the quality of patent results, thus contributing to the efficiency of the technology transfer.

3.3.17. Fudan University

Basic information

Fudan University, founded in 1905, was the first institution of higher education founded by the Chinese through private fundraising. In the 2021 QS Asian University Rankings, Fudan University is ranked 3rd in China and 6th in Asia. With five State Key Laboratories, nearly two thousand National Natural Science Funds, nearly forty academicians of the Chinese Academy of Sciences, and many outstanding teachers and professors, Fudan University is one of the main forces for the development of science and technology in Shanghai.

Leading organizations for technology transfer

Fudan University has successively established a Technology Transfer Center and a Science and Technology Research Institute in recent years, establishing a workflow starting from patent quality management to promoting the transformation of innovation achievements.

The Institute of Science and Technology is the business department in charge of the scientific and technological research work and the construction and development of scientific and technological innovation capabilities of the whole university. It consists of the General Management Office, the Vertical Research Office, the Project Management Center, the Industry-University-Research Cooperation Office, the Technology Transfer Center, the Base

Construction and Achievement Management Office, the International Cooperation Office, and the Medical Scientific Research Office. Division and other 8 deputy division-level institutions.

For better transfer and transformation of results, the Technology Transfer Centre built an intellectual property management system in 2018. "From patent application to patent transformation, the system plays an important role." The person in charge of the Technology Transfer Centre said that recently, the university is updating the system to include a disclosure system for innovative achievements. In the future, the Technology Transfer Centre will evaluate the innovation results disclosed in the system before patent application, with the aim of realising the commercial value of the patented technology and further improving the quality of patent applications.

For achievements with a high degree of maturity, the Technology Transfer Centre will contact professional companies to conduct in-depth analysis of the market value and application space of the achievements; afterwards, the achievements will be promoted and transferred to the target enterprises and investors by means of holding a results conference, etc. For achievements with a low level of maturity, the centre will continue to follow up and increase the promotion of innovative achievements at the right time. At the same time, the Technology Transfer Centre will also investigate and follow up on the projects that have signed the transformation contract at the end of each year to keep track of the follow-up situation of the transformation. Shanghai Fudan Assets Management Co., Ltd. is entrusted by the university to be responsible for discussing the transformation plan of the investment projects of scientific and technological achievements for value. It is entrusted by the university to strengthen the management of the university's enterprises that invest in scientific and technological achievements for value.

It is worth mentioning that the Technology Transfer Centre has also set up an IPR service hotline to guide researchers to properly handle matters related to IPR and the transfer of innovations in collaborative projects with enterprises. In order to enable researchers to quickly and accurately understand the knowledge related to IPR, the Centre also regularly invites experts in various fields to conduct training and policy presentations on IPR work.

To summarize, currently (since the publication of Fudan University Administration Measures of Commercialization of Science and Technology Achievements in 2021), the governing bodies of technology transfer in Fudan University includes the Institute of Science and Technology in charge of disclosure, application, evaluation and alteration of S&T achievements, the Department of Finance and Asset Management in charge of asset disposal, financial record and equity-related applications, the Shanghai Fudan Asset Management Co., Ltd. In charge of equity investment and management afterwards, and the Department of Human Resource in charge of management on part-time job and off-duty entrepreneurship.

At present, the permitted methods in Fudan University to transfer original achievements in key disciplines is ownership assignments, patent licensing and equity investment. In general, Fudan adopted a generous royalty sharing scheme by entitling inventors 70% of TT income, and the remaining part goes to departments and the university equally. Previously, the team of

Professors Xu Tian and Wu Xiaohui at the Institute of Developmental Biology, Fudan University, successfully developed the vertebrate piggyBac transposon genetic operating system and its patent "piggyBac as a tool for genetic manipulation and analysis in vertebrates", which was translated through a general license. The results of a paper based on the patent were also published in the journal Cell. The relevant technology was used in projects such as "Large-scale mutagenesis and screening of disease and functionally important genes in mice by PB technology", which resulted in the breeding of more than 5,000 mutant mouse strains and the establishment of a large-scale mutant mouse resource. 2019 to 2021, Fudan University licensed the patent to companies in Shanghai, Nanjing and Hangzhou through general licensing, with the total amount of four patent licenses reached RMB 4.8 million. Noteworthily, Fudan University explicitly in its regulation documents encourages technology transfers via equity investment to promote continuous development afterwards.

Apart from the technology transfer of the University, Shanghai Medical College Fudan University and affiliated hospitals also present outstanding achievements commercialization. Fudan has 17 affiliated hospitals, including Zhongshan and Huashan Hospital, both of which are Top 10 hospitals in China. And according to the China's Hospital Ranking of Innovation and Transformation published by China Medical Innovation Alliance in July 2022, three Fudan-affiliated hospitals are listed. Zhongshan Hospital is ranking third, and 70 of its granted patents were transformed. The technology transfer income of Zhongshan Hospital in 2020 and 2021 are 13million and 20 million yuan respectively.

Fudan also has terms and conditions for achievement sharing within the university. Staff, students and alumni who graduate from Fudan within one year can apply for using the achievements for free when they establish or work in innovative firms. And the period of usufruct can vary from one to three years if approved.

Incentives for faculty engagement in technology transfer

Guidelines for part-time jobs and off-duty entrepreneurship. In 2017, the Ministry of Human Resource and Social Security of China published the Guidelines of Encouraging the Innovation and Entrepreneurship of Professionals in Public Institutions. Then in 2019, Fudan set its own administrative terms in this issue. Fudan university released the Interim Regulations of Fudan University on Off-Campus Part-time Jobs and Off-Duty Entrepreneurship for Teaching Staff and listed that: teaching and research positions outside of the university shall not normally take up working hours, and where special circumstances require working hours to be taken up, these shall not exceed one working day per week. Teaching staff outside of teaching and research positions may not take up working hours for part-time work outside of the university. The University encourages staff to take up the following part-time jobs: (a) part-time jobs to serve major national tasks, major strategic needs and key engineering and technology support; (b) part-time jobs that are conducive to scientific and technological innovation and the transformation of results; (c) part-time jobs with public welfare purposes such as government decision-making consultation, poverty alleviation, scientific popularization and legal aid; (d) part-time jobs that are conducive to enhancing the reputation of the University or improving

one's academic level and academic influence. At the same time, for staff who are engaged in part-time activities outside the university, the corresponding departments should strengthen their daily management, annual assessment and appraisal during their appointment.

Faculty who apply to leave their posts to start a business should first sign a contract regarding the transformation of scientific and technological achievements with the university in accordance with the provisions of the "Administrative Measures for the Transformation of Scientific and Technological Achievements of Fudan University". They also need to determine the detailed plan for transferring, and clarify the distribution of income. After the contract is concluded, a written application for leaving the post to start a business is submitted, and the unit where the applicant is based will decide whether to agree or not after comprehensively considering various tasks such as teaching, scientific research, and postgraduate training that the applicant is undertaking. The off-duty entrepreneurship scheme is only for tenured staff and the period is usually three years. During the period when teachers and staff leave their posts to start a business, they need to participate in the university's annual assessment. The assessment level is determined based on the transformation of scientific and technological achievements, social and economic benefits, and the written opinions issued by the enterprise. The "excellence" evaluation will not account for the quota in university; meanwhile the results and achievements in entrepreneurship can also be used for title appraisal.

Conferreing the ownership or rights. In 2020, Fudan has released an Implementation Plan for the Pilot Program of Conferring the Ownership or Rights of Long-Term Use of Job-Related Scientific and Technological Achievements on Scientific Researchers following the policy issued by the nine Chinese central government. Under the guidance of the Leading Group of Intellectual Property Management and Operation of Fudan University, the implementation plan of the Conferring the Ownership or Rights is carried out by the Institute of Science and Technology and implemented after being deliberated and approved by the president's office. After the application for ownership of the scientific and technological achievements of a position is approved, the university and the person (team) who completes the scientific and technological achievements are co-owners, and the person (team) who completes the scientific and technological achievements can obtain 70% of the ownership (the university would share joint-ownership of the remaining 30%). In this case, researchers are granted with the long-term right to use the scientific and technological achievements of their positions. The school grants the achievement accomplishers the long-term right to use the scientific and technological achievements on the job for no less than 10 years, and signs a written agreement to stipulate the transformation plan of scientific and technological achievements, income distribution and other related matters.

A representative case is the project led by Professor Zhao Dongyuan, whose team has worked on the creation and application of sequential mesoporous polymers and carbon materials and won the first prize of the National Natural Science Award 2020. "This is the first successful case of the university's empowerment reform, involving various aspects of R&D creation, commodity transformation and social utility," as introduced by the person in charge

of Fudan University's Technology Transfer Centre. He also explained that that the university gave the right to use the patent to the invention team, who then invested the patent for value, with the university enjoying 30 per cent of all the team's income in the target company.

Representative major platforms and infrastructures for knowledge exchange and cooperation

Fudan University aims to integrate social resources and build an ecological environment for the transformation of scientific and technological achievements, some institutions are located near to the campus to help students and researchers to promote research results through cooperation with enterprises or other forms on the basis of academic research and strive to commercialize them, such as:

- Zhangjiang Fudan International Innovation Center

In order to actively connect with the construction of Shanghai's science and technology innovation center with global influence and accelerate the pace of building a world-class university with Chinese characteristics, Fudan University closely focuses on the national strategy to build Zhangjiang Science City and improve the concentration and display of science and innovation center. With the high attention and strong support of relevant national ministries and commissions and the Shanghai municipal Party committee and government, it actively connected with the construction of Shanghai Science and innovation center, and proposed to build Zhangjiang Fudan International Innovation Center in Zhangjiang Science City, so as to give full play to Fudan's comprehensive discipline and scientific and technological advantages, pool global strength, and then solve comprehensive major scientific problems and cutting-edge core technology problems.

- Fudan University Science Park

Fudan Science Park was established in 2000 with the support of the government. It is one of the first batch of National University Science and Technology Parks recognized by the Ministry of education. Closely relying on Fudan University, it adheres to taking enterprises as the main body and market-oriented, takes promoting the transformation of scientific and technological achievements, incubating high-tech enterprises, cultivating innovative and entrepreneurial talents, serving regional economic construction, and supporting industrial-technological progress as its own responsibility, promotes the combination of government, industry, University, research, Finance, and intermediary, and explores a road of independent innovation with Chinese characteristics.

Research institutes established by universities in cooperation with other regions can apply the research results of universities to other regions to facilitate the dissemination of knowledge and drive the development of these regions. In addition to Shanghai, a larger knowledge network and contact network have been established to facilitate exchanges and learning among all localities.

- Baoshan Fudan major innovation engineering platform

In order to promote the connection between discipline chain and industrial chain and create a good ecology of regional scientific and technological innovation, the Symposium on the construction of Baoshan Fudan major innovation engineering platform was held in Fudan University. The meeting further clarified the direction for the cooperation between Fudan University and Baoshan District schools. The two sides will further focus on the construction

of the engineering platform. While enhancing the ability of scientific and technological innovation, the two sides will build a public technology platform under the guidance of major projects, strengthen the transformation ability of scientific research achievements, and create technology to serve society. In the future, Fudan University will be more proactive in docking with the national strategy, serving local economic and social development, and helping Baoshan build the main position of the Shanghai Science and innovation center.

Since the signing of the framework agreement on deepening strategic cooperation between Baoshan and Fudan at the beginning of this year, the two sides have cooperated closely and deepened plans for many times around the transformation of scientific, technological achievements and industrialization projects, aiming to provide more powerful support and broader space for Fudan teachers and students to come to Baoshan for development. In the next step, it is hoped that the two sides will strengthen communication, speed up the construction of major innovation engineering platforms, and explore a new path of regional school cooperation.

- Anhui Fudan Science and Technology Park Innovation Center

Fuyang Fudan electronic information joint innovation research center is a research institution jointly established by the municipal government, Fudan University, and Fudan Science and technology park. The "double-base" operation mode of Shanghai and Fuyang is adopted, which is expected to help Fuyang speed up its integration into the Yangtze River Delta and drive the construction and development of Fuyang park through innovation.

- Research institution of Fudan University in Ningbo

The Institute is committed to promoting the industrialization of biomedicine, green technology and other scientific research achievements of Fudan University and promoting the adjustment of industrial structure in Ningbo. Hangzhou Bay New Area provides relevant policy supporting support, and relevant scientific research conditions are open to the Research Institute, so as to ensure the human investment, technical support and auxiliary support required for the research institute to complete various R & D projects. The school encourages subordinate industrial institutions to give priority to the development of Ningbo Hangzhou Bay New Area.

Spin-offs and entrepreneurship

Fudan forward: the first listed joint-stock company. Shanghai Fudan Forward Science and Technology Co., Ltd., was founded in November 1984 by a few young professors from Fudan University. In January 1993, the company’s stock was officially listed on the Shanghai Stock Exchange and became the first listed joint-stock company in mainland China. As one of the representative cases of the spinoffs of Fudan university, Fudan Forward has continued to forge its entrepreneurial spirit: “pursue the first-class; dare to be first; work hard and make contributions to the society” in the past decades.

Centre for Entrepreneurship and Venture Capital Research, Fudan University established in 2000. Fudan University has integrated its research resources and approved the establishment of the Centre for Entrepreneurship and Venture Capital Research at Fudan University. It provides research support for the continued development of university-derived entrepreneurship. It is also the first entrepreneurship research centre to be established in a university in China.

Fudan University Science Park: *one of the earliest national Science and technology Parks*. Founded in 2000, Fudan university Science park was jointly approved by the Ministry of Science and Technology and the Ministry of Education as one of the first national university science and technology parks in May 2001. As an important carrier for the extension of the university's originality to society and a platform for the coupling of university innovation elements and social innovation resources, the Park relies closely on Fudan University and takes the missions of science transformation, social service, intelligence convergence for a better future. Three core services are provided by the Park, including transformation of scientific achievement, financial supports, and business incubation. Shanghai Fudan Science and Technology Park Co., Ltd. is the operating vehicle of the Park of Fudan University being responsible for the construction and management of the Park. After long-term exploration, more than 800 companies are registered and around 200 companies having daily offices in the Park. Until now, the Park has about 1000 scientific and technological transformation achievements and 300 patents for inventions. One of the spinoffs include the Shanghai Fudan Microelectronics Group Company Limited., which is now a leading company specializing in the design and development of Application Specific Integrated Circuit (ASIC). In July 1998, this enterprise was founded by the State Key Laboratory of Special Purpose Integrated Circuits and Systems of Fudan University, Shanghai Commercial Investment Company and a group of entrepreneurs who dreamed of creating the best integrated circuit design company (chip design) in China.

Entrepreneuship fund. The Entrepreneurship Foundation Fund was established in January 2007 through a partnership between Fudan University and the Shanghai Foundation for Student Technology Entrepreneurship. It is open to young university students from the University and from home and abroad, and supports university students' entrepreneurial projects that are eligible for funding from the Angel Fund. As the business incubator of Fudan University, Shanghai Fudan Asset Management Co., Ltd (formerly known as the University Property Office) is entrusted by Fudan University and the Entrepreneurship Foundation to undertake the application acceptance, preliminary examination, funding, follow-up management services and withdrawal of the Angel Fund entrepreneurial projects. Relying on Fudan University and social resources, it provides university student entrepreneurial teams with venue and policy support, entrepreneurial mentors, project promotion and other entrepreneurship-related services. It has incubated and nurtured a number of entrepreneurial enterprises represented by Fuzhan Technology, Fuxiang Optics, Love Recycling.

Innovation and Entrepreneurship Base in the Science Park. In 2014, Fudan Science and Technology Park Smart Nursery and Fudan University Science and Technology Park Science and Technology Innovation Incubator were established to build a complete "pre-incubation-incubator-accelerator-industrialization base" model with the advantages of Fudan Park's overall industry and resources. The whole incubation model is based on the overall industrial and resource advantages of Fudan University Science Park. In addition to fully furnished space products, the base also provides value-added consultancy services in terms of policy, funding, personnel, training, channel development, finance, law, management and other aspects,

according to the different development stages of university students and social entrepreneurial teams. For example, the teams in the base could be granted with funding from the district government (e.g., Yangpu district in Shanghai) and above.

Entrepreneurship Alliance. The Fudan Venture Enterprise Alliance was officially established in 2011. The Fudan Entrepreneurship Alliance is an entrepreneurial platform that brings together Fudan entrepreneurs at different levels, Fudan entrepreneurial enterprises at different stages, and different types of entrepreneurial resources, and aims to provide help and care for more entrepreneurs.

Conclusions

Fudan university has formed a relatively comprehensive system for technology transfer. As discussed earlier, a leading group on intellectual property management and operation was set up forming a coordinated working mechanism that integrates scientific and technological innovation with intellectual property management, transfer and transformation of scientific and technological achievements and valued investment. Multiple documents have been issued regarding the measures for the scientific ant technological personnel ownership and provisional regulations for faculty leave and pay. Platforms have been built to actively promote the integration of industry and education, with the School of Microelectronics as the main construction body, to meet the strategic objectives of the development of the integrated circuit industry in the Yangtze River Delta and serve the national goals. Combining the development needs of local industries, Fudan University cooperates with Shandong and Heilongjiang province to build industrialisation platforms around major scientific research achievements such as mesoporous materials, and promote the development of university-university cooperation. Relying fully on traditional advantageous disciplines such as electronics and information, materials, chemistry, pharmacy and life sciences, the university has started to vigorously develop new engineering disciplines and build high-level research and transformation platforms. A number of channels such as joint laboratories and joint training of high-level talents have been initiated, creating a chain of innovation and transformation with the "pre-incubation" system to promote the transformation of scientific and technological achievements

3.3.18. Shanghai Jiao Tong University

Basic information

Founded in 1896, Shanghai Jiao Tong University (SJTU) is situated in Shanghai with the goal of cultivating talented professionals for the nation. The university enjoys national prestige and is a leading research-oriented and comprehensive university in China. Today, SJTU has become one of the world's top 100 universities (ranked 50th according to QS 2022) and a key university directly under the administration of the Ministry of Education (MOE) of the People's

Republic of China and jointly-managed by MOE and Shanghai Municipal Government.

As of December 2020, SJTU has 33 schools/departments, 13 affiliated hospitals, 2 affiliated medical research institutes, 23 directly affiliated units and 5 directly affiliated enterprises, with 25 members of the Chinese Academy of Sciences, and 23 members of the Chinese Academy of Engineering. Over 200 members of the Chinese Academy of Sciences and the Chinese Academy of Engineering are SJTU alumni. SJTU also ranked in the top 0.1% in Essential Science Indicators (ESI) in 7 research fields, including Engineering (top 0.01%), Materials Science, Chemistry, Clinical Medicine, Computer Science, Pharmacology & Toxicology, and Biology & Biochemistry.

SJTU enjoys an increasingly high scientific research level and technological innovation level. Up to 2019, SJTU led the country for the 11th consecutive year in terms of both the number of projects and the amount of funds received from the National Natural Science Foundation of China **(SJTU, 2020)**. In 2020, the number of SCI papers hit a historical high with a total number of 8,239. With 1 National Science and Technology Infrastructure, 8 State Key Laboratories, 5 National Engineering Research Centers, 2 National Engineering Laboratories, and many other joint centers and platforms, SJTU is extending its academic influence on the world.

SJTU, in its pursuit of being at the forefront of modern technology and meeting the strategic needs of national development, has strengthened cooperation between industry and academia by building partnerships with dozens of large enterprises in areas such as scientific research and talent development. SJTU set up Shanghai Zizhu Science-based Industrial Park, together with Zijiang Holdings and the Minhang District Government, which has attracted over 100 enterprise research centers in over 10 years, such as Microsoft, Intel and Wicresoft (a global digital transformation service provider, founded in 2002 by Microsoft and the Shanghai government). The establishment of Zizhu University Students & Teachers Entrepreneurship Center provides significant support for SJTU's Tech Innovation Programs and Innovative Talent Development. SJTU co-founded Shanghai Zizhu Advanced Industrial Technology Research Institute (AITRI) with Minhang District. As of now, AITRI has signed contracts with several large enterprises to establish advanced industry R&D centers.

Research funding and sources

The total amount of non-NNSF research funding in SJTU increased from 1.678 billion yuan in 2011 to 4.767 billion yuan in 2020. At current growth rates, it will exceed 5 billion yuan by 2021, a threefold increase from 2011. Even though the total amount of non-NNSF research funding is growing rapidly, the funds from NNSF still accounts for about 15~20 percent of that in recent years. In 2020, the number of projects approved by National Natural Science Foundation in SJTU reached 1,233, exceeding 1,000 for four consecutive years and ranking first in China for 11 consecutive years. The total funding from NNSF reached 821 million yuan.

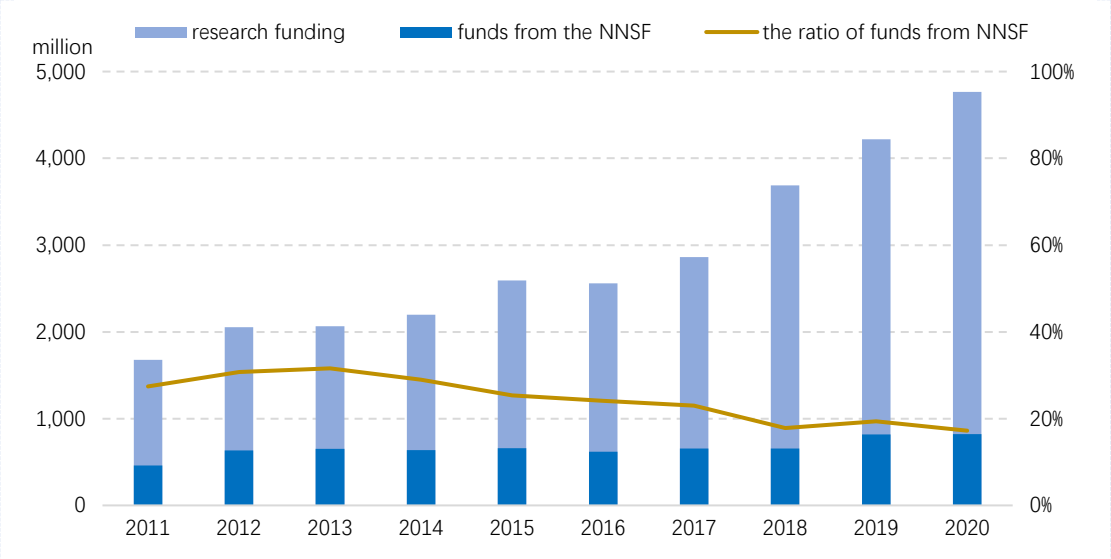


Figure 3-35. Total amount of non-NNSF research funding and total amount of funds from NNSF (National Natural Science Foundation) million as well as it's ratio (2010-2019)

Source: **SJTU's statistic report (2010-2019)**

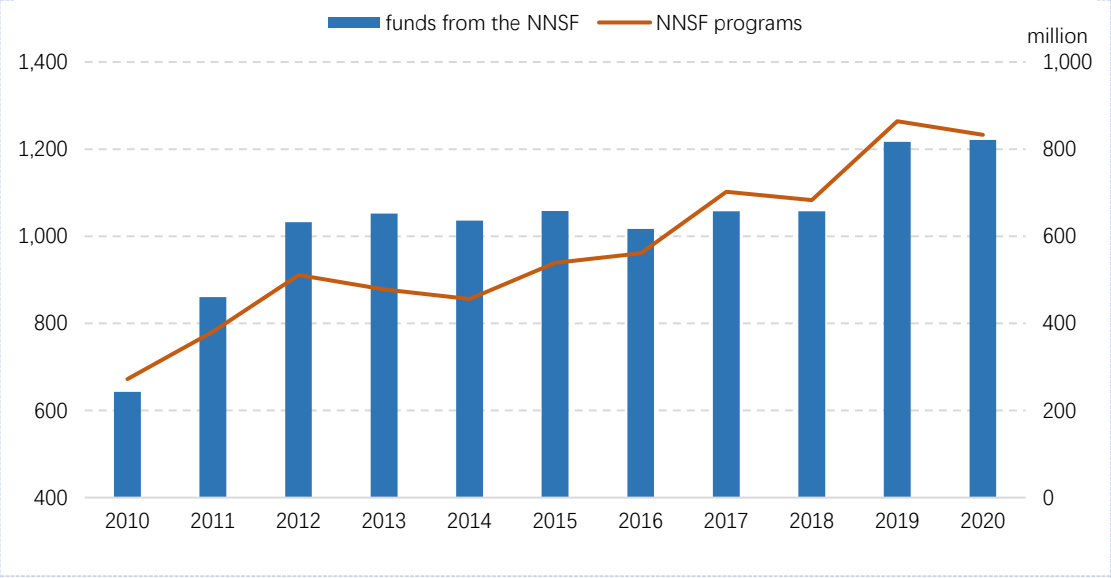


Figure 3-36. Total number of NNSF programs and total amount of funds from NNSF

Source: **SJTU's statistic report(2010-2019)**

University technology transfer office (UTTO)

Since the Law of the People's Republic of China on Promoting the Transformation of Science and Technology Achievements was revised in 2015, Shanghai Jiao Tong University has established and improved the university's scientific and technological achievements transformation system. In this system, both AITRI and Office of Research Management (RMO) play an important role. RMO is responsible for the application, the registration, and the archive of patents. The main functions of AITRI are the transfer of intellectual properties, including the transferring, the licensing as well as the investing, and the examination of relevant contracts.

Statistic of UTTO outcomes

Licensing

In 2015, SJTU established a working mechanism under the overall coordination of university leaders, with each department performing its own duties. Meanwhile, it also improved the working process of TT and incentive systems **(SJTU, 2015)**. Under the new working mechanism, AITRI integrated, evaluated and transferred intellectual properties that were previously scattered among different colleges. After that, the transformation of scientific and technological achievements has made a great leap forward under the work of AITRI. The number and the amount of IP transactions in 2017 had almost tripled than that of 2008.

In recent years, the statistical caliber of the data has also become more accurate, from IP to technology achievements. In 2019, the total number of transactions was 91, with total amount nearly 367 million yuan. Among them, 58 achievements were rights transferred, with an amount of 25.03 million yuan; The amount of 21 licensed achievements was nearly 240.6 million yuan; There are 12 investment projects valued at 101.56 million yuan **(SJTU, 2019)**.

From January to September 2021, the number of industrial contracts managed by TTO reached 95, with the total amount exceeding 545 million yuan **(SJTU, 2021)**.

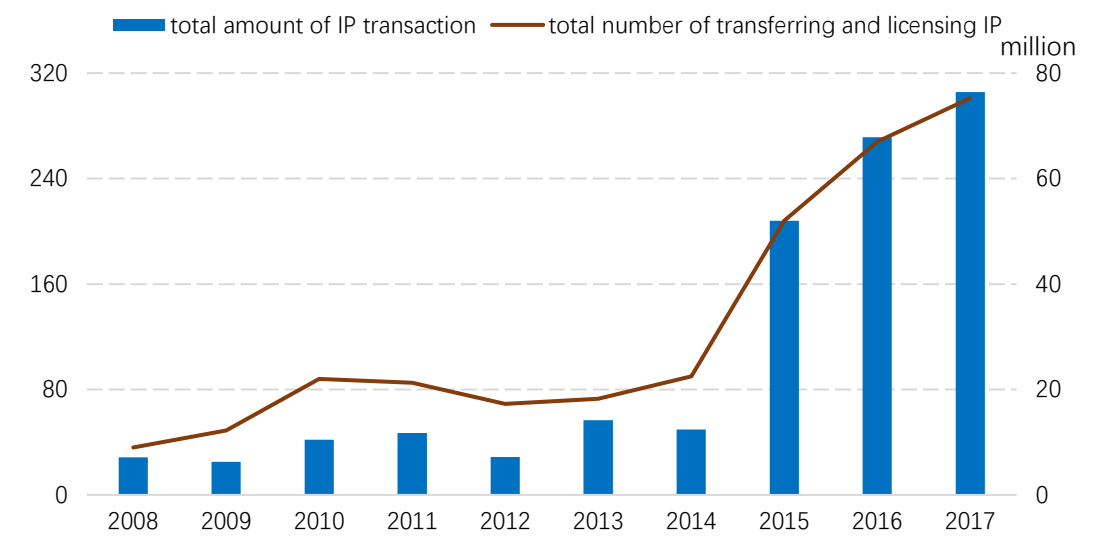


Figure 3-37. Total number and amount of IP transaction (2008-2017)

Source: "上海交大科技成果转移转化实践" **(Liu Yangang, 2018)**

Intellectual property

Patent and paper reserves are abundant in SJTU, which constitute the foundation of successful technology transformation.

From Figure 3-38, we know that there was an apparent upward trend in recent years, although total number of the new patent applications and granted was fluctuated from 2015 to 2018 in SJTU. As introduced by the official website, as of 2019, the number of total patents, granted patents[137] and valid patents[138] in SJTU are 25,773, 14,923, and 8,348 respectively **(SJTU, 2019)**.

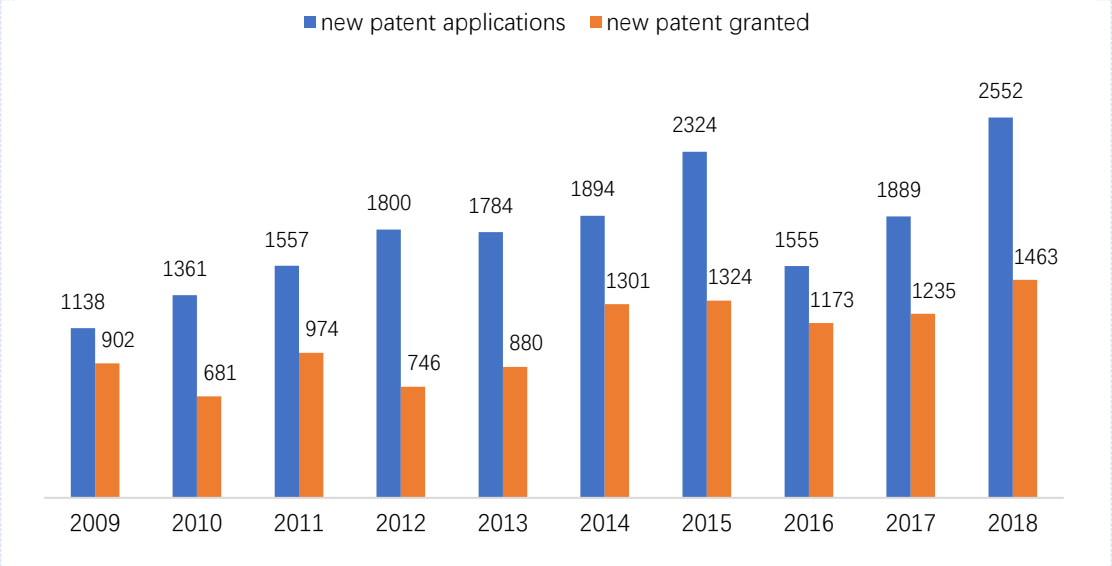
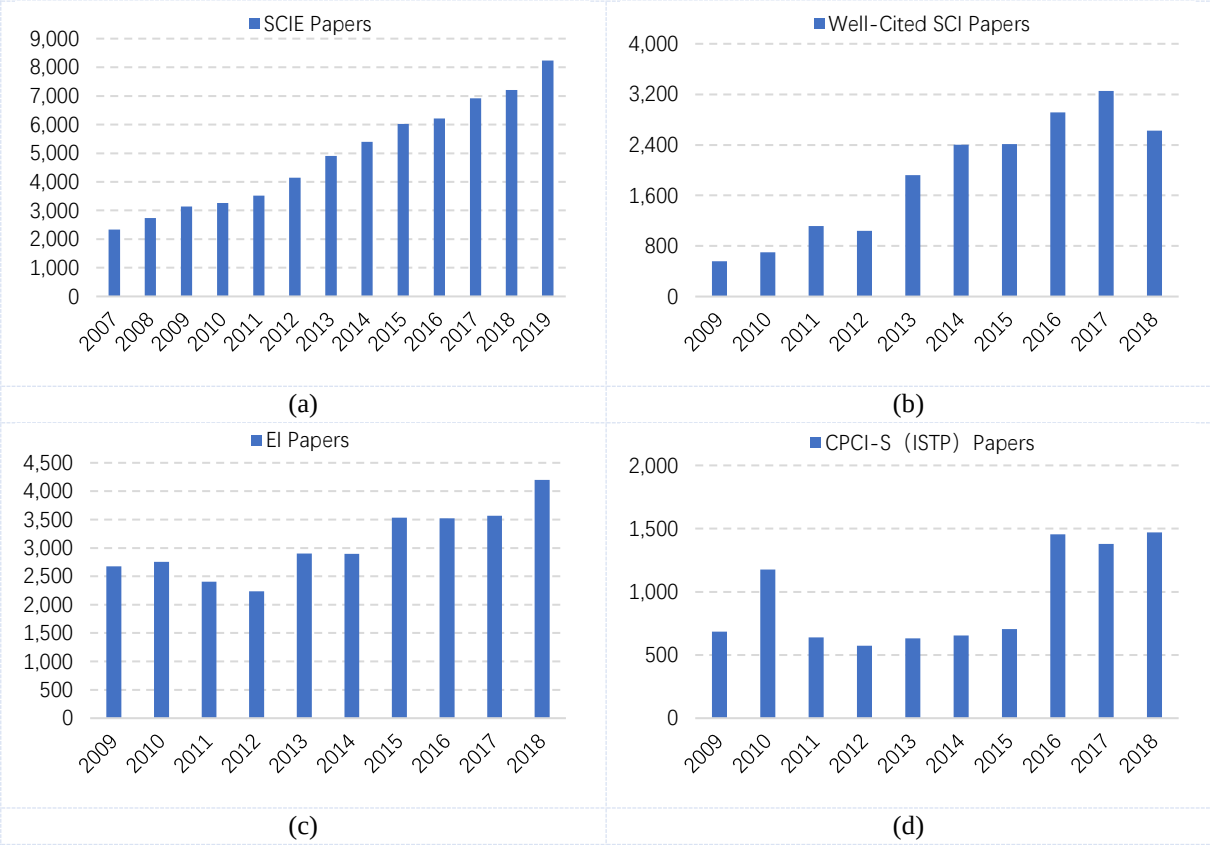
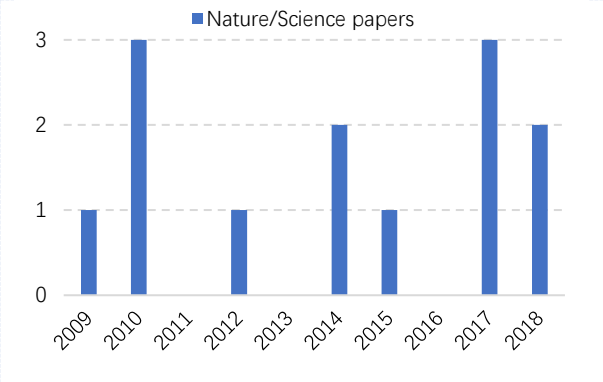


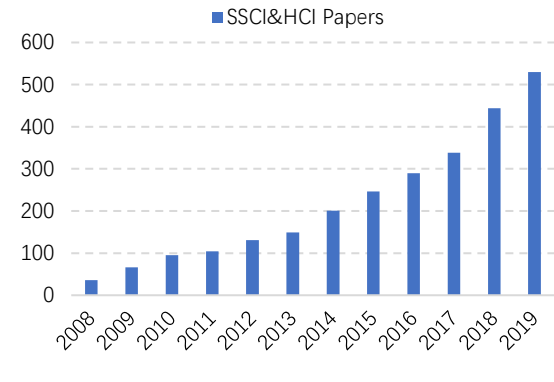
Figure 3-38. Total number of patens filed and granted by SJTU
Source: **SJTU's statistic report (2010-2019)**

The number of papers published by SJTU has always been increasing. Particularly, SCIE papers and SSCI&HCI papers maintain a steady growth year by year. Meanwhile EI papers have stayed above 3,000 and CPCI-S (ISTP) papers have stayed above 1,000 in recent three years.





(e)



(f)

Figure 3-39. Performance of scientific publications by SJTU. (a) total number of SCIE papers; (b) total number of well-Cited[139] SCI papers; (c) total number of EI papers; (d) total number of ISTP papers; (e) total number of Nature/Science papers; (f) total number of SSCI&HCI papers.

Source: **SJTU's statistic report (2010-2019)**

For improving technology transfer, office of intellectual property in AITRI is also currently operating an intellectual property information management platform in a website, where SJTU's tradable patents and relevant information are posted, to search for enterprises with cooperative intention. As of Nov 15 2021, 1336 patents are currently listed in AITRI's IP trading platform, and anyone who is interested in it can contact the office directly by visiting the website **(知识产权信息管理平台, sjtu.edu.cn)**.

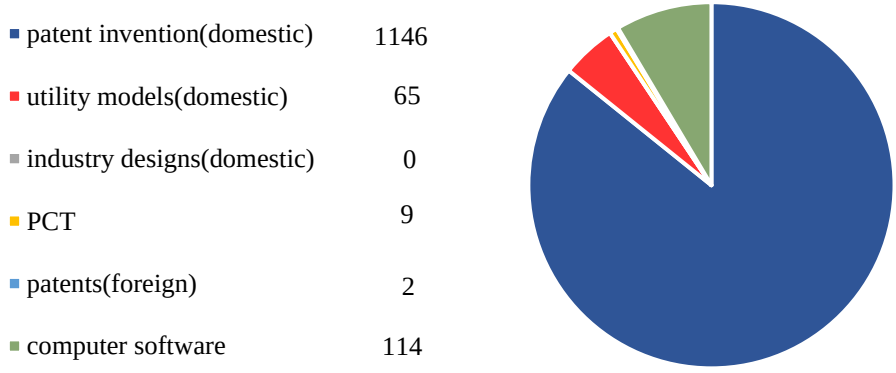


Figure 3-40. Total number of current tradable patens categorized by types

Source : **the website of Intellectual property information management platform of SJTU, 2021**

Spin-offs

After the Law of the People's Republic of China on Promoting the Transformation of Science and Technology Achievements was revised in 2015, SJTU looked at new ways of pricing and shareholding. In the same year, SJTU obtained approval from the Ministry of Education to establish the Shanghai Jiaoda Intellectual Property Management co., Ltd. (IPMC). Managed by AITRI, IPMC focuses on the pricing and investment of scientific and technological achievements and does not include any tangible asset management. It is a special channel for the disposal of intellectual property rights of SJTU and the shareholding agent of spin-offs. **(Wu Shouren, 2020)**.

In 2016, IPMC completed the investment agreement for 7 intellectual properties with a total registered amount of 396.7 million yuan, among which the ratio of technology shares is nearly a quarter, 107.7 million yuan. At the same time, the agreement requires the project company to pay no less than 1 million yuan of scientific research funds to the university every year after its establishment **(SJTU, 2016)**.

As an illustration, the research team of Professor Hainan Kong from Shanghai Jiao Tong University has obtained more than 30 national invention patents and a number of key core technologies in Erhai Lake, including lake ecological restoration, river management, non-point source pollution control and other fields. China Water Environment Group Limited, an affiliate of CITIC Group, and SJTU as well as Professor Kong signed a cooperation agreement, and set up jointly Shanggu Environmental Technology Co., Ltd, a registered capital of 100 million yuan. In the company, Professor Kong owns 12% **(Qichacha, 2021)** of the equity, and IPMC owns 8% **(Qichacha, 2021)** of the equity **(Hou Shuwen and Wangchun, 2019)**.

In another case stud, in 2017, Professor Wang Haowei of school of Materials of SJTU invented "in-sjtu aluminum matrix composites", including cast aluminum matrix composites and deformed aluminum matrix composites, which are new materials independently developed by the school during the tenth Five-year Plan period. Through joint investment, SJTU and Huaibei government, jointly set up Shanghai Jiao Tong University Anhui Research Institute of Ceramics and Aluminum New Materials Co. Ltd. to carry out industrial application and industrial design research related to ceramics and aluminum technology. In the company, Professor Wang owns 3% (**Qichacha, 2021**) of the equity and IPMC owns 0.3% (**Qichacha, 2021**) of the equity.

Up to this year, according to incomplete statistics, IPMC has held 7 subsidiary enterprises, invested in 42 enterprises, and held 45 sub-subsidiary enterprises by the method of pricing and investment (**Qichacha, 2021**).

Distribution of shares for patents, licensing, and spin-offs

SJTU attaches great importance to the rules and regulations of the transformation of scientific and technological achievements. Since 2015, SJTU has formulated a "1+3+6" system consisting of 10 documents in accordance with national laws and policies, including the Law of the People's Republic of China on Scientific and Technological Progress, the Patent Law of the People's Republic of China and the Law of the People's Republic of China on Promoting the Transfer of Scientific and Technological Achievements. With the continuous introduction of relevant national policies, SJTU is also constantly updating the existing system. The new document forms the "1+5+20" system and will be released in March 2021 after the latest revision, further releasing the vitality of the transformation of scientific and technological achievements of SJTU in many aspects.

Referring to Rules for the Administration of Pricing investment in Scientific and Technological Achievements (Trial Implementation), the income distribution system is more detailed. The 2016 document stated that profits from the commercialization of university research are to be divided among the university, the department and research teams in a ratio of 20%: 20%: 60%. In the latest revision of the document, there will be continuous quantitative criteria according

to different situations. In terms of cash income, the proportion of income distribution is 15%: 15%: 70% among the university, the department and research teams, respectively, for university-funded projects. The cash income distribution is 10%: 10%: 80% among the university, the department and research teams for self-funded research projects. For projects invested in the name of the school, usually the school has a stake of no less than 10% and the uniform proportion of equity income distribution is 20%: 20%: 60% among the university, the department and research teams. Generally, researchers can choose their own allocation ratio according to their own situation, reducing the time cost and cash flow pressure of maintenance costs on them.

Table 3-29. Income distribution of TT

	Expenses payer	SJTU	College	Research team
Cash Income	University	15%	15%	70%
	Research team	10%	10%	80%
Investment Income	University	20%	20%	60%

Source: SJTU, 2021

To attract talents and prepare for the further development of the transformation of scientific and technological achievements. SJTU is looking for advanced researchers in the field of technology transfer and intellectual property. The basic requirement is 5 years of relevant working experience in incubators or innovation centers and a doctoral/PhD degree. At the same time, in term of Implementation Rules for Postgraduate Personnel Training of Technology Transfer Program (Draft), SJTU has also launched a special postgraduate training program for technology transformation nationwide, which is expected to be officially launched in the autumn of 2022.

According to the Rules for the implementation of the pilot project to grant researchers the ownership or long-term right to use their scientific and technological achievements (Trial Implementation), as a pilot, SJTU has given researchers ownership or long-term right to use their intellectual properties. After the policy was issued, members of research teams could complete the transformation of scientific and technological achievements by themselves. The shares invested with scientific and technological achievements can be held by candidates approved by the university, college, and team through negotiation. This policy has largely solved the difficulties and obstacles in the management of state-owned assets, reduced the probability of equity disputes and increased the faculty's willingness to start their own business.

Table 3-30. Institutional systems of SJTU to guarantee technology transfer

"1+5+20" institutional system published in 2021
"1": • Opinions of Shanghai Jiao Tong University on promoting the transformation of Scientific and technological Achievements in the New Era **"5":** • Measures for the administration of off-campus part-time jobs of faculty and staff

- Measures for one-door service management of transformation of scientific and technological achievements (Trial Implementation)
- Measures for the organization and implementation of the transformation of scientific and technological achievements (Trial implementation)
- Measures for the administration of rewards and incentives for the transformation of scientific and technological achievements (Trial Implementation)
- Measures for the administration of intellectual property rights of scientific and technological achievements (Trial Implementation)

18 items of "20":

- Rules for the Implementation of expert Evaluation Meeting of Transformation Projects of Scientific and Technological Achievements (Trial Implementation)
- Rules for the Administration of Disposal and Evaluation of Scientific and Technological Achievements (Trial Implementation)
- Rules for the Implementation of Confirmation and Transformation of Proprietary Technology and Patent Application Right (Trial Implementation)
- Implementation Rules for Supervision, Assessment, and Incentive of Specific Technology Transfer Institutions (Trial implementation)
- Rules for the Administration of Specialists in transformation of Scientific and Technological Achievements (Trial Implementation)
- Rules for the Implementation of the Management of funds for Transforming Scientific and Technological Achievements (Trial Implementation)
- Rules for the Management of Intellectual Property Rights Management and Transformation Operation Fund (Trial Implementation)
- Rules for the Administration of Licensing scientific and Technological Achievements (Trial Implementation)
- Rules for the implementation of a series of senior professional and technical Positions in the transformation and popularization of scientific and technological achievements
- Rules for the Administration of the Transfer of Scientific and Technological Achievements
- Rules for the Implementation of examination and Management of The Transformation of Scientific and Technological Achievements of Entrepreneurial Enterprises by Researchers (Trial Implementation)
- Rules for the implementation of the pilot project to grant Researchers the ownership or long-term right to use their Scientific and technological Achievements (Trial Implementation)
- Rules for the Implementation of Recognition and Management of Proprietary Technology (Trial Implementation)
- Implementation Rules for Postgraduate Personnel Training of Technology Transfer Program (Draft)
- Implementation Rules for the Appointment of Senior Professional and technical Positions in intellectual Property and Technology Transfer Management Services
- Provisions on the Administration of Technology Transfer Institutions Serving the Transformation of Scientific and Technological Achievements of Schools (Trial Implementation)
- Rules for the Administration of the Implementation of Scientific and Technological Achievements (Trial Implementation)
- Rules for the Administration of Pricing investment in Scientific and Technological Achievements (Trial Implementation)

Source: http://aitri.sjtu.edu.cn

Entrepreneurship process (incubators, competitions, financial support)

Shanghai Jiao Tong University Science Park (Minhang Park) collaborates with RMO, AITRI and IPMC to jointly promote the transfer of scientific and technological achievements and incubation of scientific and technological entrepreneurship for teachers and students of SJTU. Minhang Park is a branch of Shanghai Jiao Tong University National Science Park, which was established in July 2019 and is located near the main campus of SJTU. Its main functions include providing makerspaces, technologies, and services for start-ups **(SJTU Science Park, 2021)**. As of December 30, 2020, there have been 181 enterprises settled in Minhang, 107 enterprises established by teachers, students and alumni, and 74 virtual registered enterprises, among them including 15 high-technology enterprises certificated by national government[140], 20 transfer projects of SJTU, and 7 items subsided by municipal government **(Wang Shuling, 2020)**.

Minhang Park provides a lot of financial support for enterprises. First, in terms of fiscal

subsidies, 50% of the rent for the first three years will be subsidized to enterprises established by research teams from scientific research institutions at home and abroad, and corporate value-added tax and individual income tax will also be reduced. Second, in terms of financing, the Minhang District Science and Technology Innovation Fund can provide up to 500,000 RMB interest-free loans, and Wujing-Jiaoda Functional Industry Fund can provide up to 10 million RMB equity financing. In addition, there are some low-interest loans. Third, if the enterprise can be listed successfully, there will be corresponding rewards, such as listed on SSE(Shanghai Security Exchange) STAR Market, as well as a one-time reward of up to 6 million yuan **(Minhang Park, 2021)**.

One successful example of such enterprises is Leading Optics (Shanghai) Co., Ltd. It is a representative high-tech enterprise incubated in Minhang Park. Founded by Ren Mingjun, an alumnus of SJTU, relying on the State Key Laboratory of Mechanical System and Vibration of SJTU, Leading Optics owns the cutting-edge technology of high-efficient machining for complex optical element and high-temperature ceramic material with close-loop process control. As an enterprise with technology transfer in the park, Ren Mingjun said that the enterprise had received high support from the university, the government, and the park in the early stage of settling in the park **(Wang Shuling, 2020)**. In this year, Leading Optics won the title of "2021 Minhang District Science and Technology Entrepreneurial New Enterprise". According to the reward polity of Minhang Park, Leading Optics can receive a one-time reward of 200,000 yuan. In March this year, Leading Optics received funding from the Minhang Science and Technology Innovation Fund and Shanghai Technology Entrepreneurship Foundation for Graduates(EFG), and a signing ceremony was held on May 24. In addition to financial support, in terms of science and technology, Leading Optics continued to deepen cooperation with SJTU, and jointly established the Ultra-precision Manufacturing Research Center **(EFG, 2021)**.

Organizational structure and major staff of TT office

Established in December 2009, Advanced Industrial Technology Research Institute (AITRI) is the department responsible for coordinating the transfer of scientific and technological achievements of the SJTU. The organizational structure of AITRI is divided into three layers (Figure 3-41).

The first layer is taken up by the leading group of university. The leading group has a total of 9 persons, led by Mao Junfa, vice president of SJTU. Members of the leading group come from relevant functional departments, colleges and directly affiliated institutions of the SJTU. The transfer leading group of university is the overall planning, coordination, deliberation, and decision-making body for the transfer of scientific and technological achievements. Major issues involving the transformation of scientific and technological achievements shall be reported to the Party Committee or the president’s Office of the SJTU for decision making after deliberation by the leading group.

The second layer is taken up by leaders of institute, including a director and two vice directors. They are responsible for the administration of internal and external affairs of the college. Jin Sun, the dean of AITRI, is a member of the leading group of SJTU. He got a Ph.D. degree of

engineering in SJTU in 2001. He teaches at school of mechanical and power engineering institute of automobile body design and manufacturing technology (BMTC), employed as associate professor in 2004, was a visiting scholar in the University of Michigan in the United States in 2005, and was appointed the deputy director of Shanghai Digital Automobile Body Engineering Key Laboratory. In 2010, he was promoted as a researcher and served as the assistant dean of the School of Mechanical and Power Engineering. In 2011, he was selected as an awardee of the New Century Talents Scheme of the Ministry of Education. In 2015, he worked as deputy dean of institute of science and technology development. In 2020, he begun to work as the dean of AITRI **(School of Mechanical Engineering, 2021)**.

The third layer is taken up by several offices, including office of science and technology cooperation, office of intellectual property, and office of technology transfer. Particularly, Office of technology transfer is responsible for detailed work about the transfer of technology achievements of SJTU. Its main functions include reviewing as well as managing the scientific and technological achievements of SJTU and carrying out the pilot reform tasks of the National Development and Reform Commission. In the office of intellectual property, there are 6 technology transfer employees. Liu Qunyan, the director of office of technology transfer, worked at Kingbird Law Firm, Henan Guoji Law Firm, Beijing Dentons Law Firm (Shanghai) and Shanghai Oriental Development Law Firm between 1996 and 2011. In 2014, he worked as general manager in IPMC of SJTU. In 2017, he got a Ph.D. degree of Law in the East China Normal University. In 2019, he began to work as the director of technology transfer office and dean assistant in AITRI. Dr. Liu's main research areas are science and technology management, technology transfer. Dr. Liu pioneered different ways of technology transfer, including "Easy Access IP", teachers' autonomous technology transformation. He was the first to put forward "variable interest entity" (VIE) model for the investment of scientific and technological achievements **(Linkedin, 2021)**. The VIE Model is also known as agreement control. Instead of controlling the actual operating company through equity ownership, the control of the actual operating company is realized through signing various agreements. For example, by VIE model, the SJTU can sign agreements with faculty members who start businesses to control the companies they set up, rather than the control of holding equity. This will be beneficial to obtain financing for these start-ups.

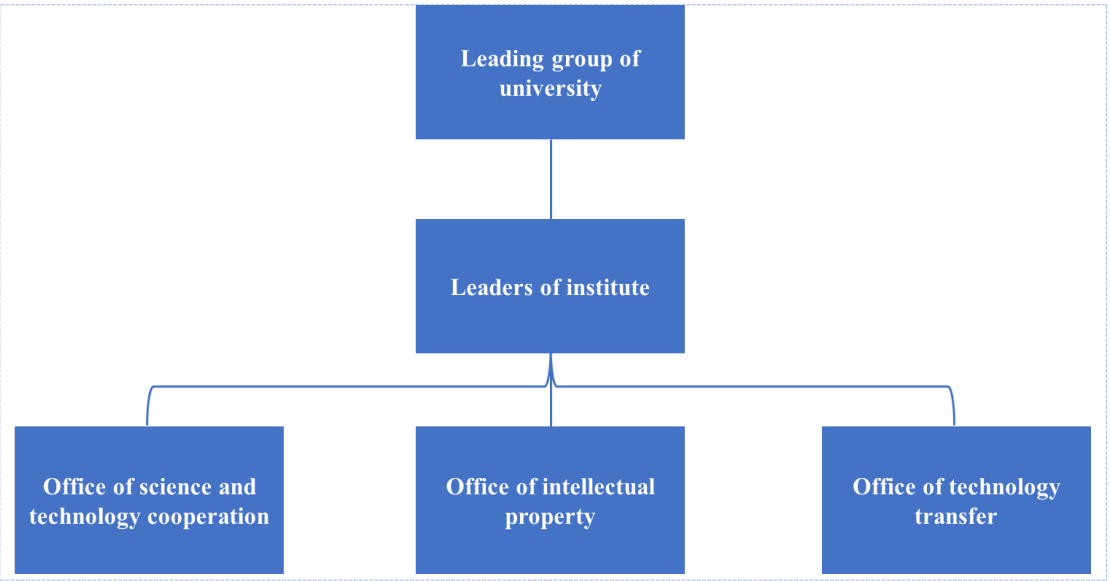


Figure 3-41. Structure of AITRI

Source: http://aitri.sjtu.edu.cn

UTTO for Medicine

In January 2019, under the cooperation between SJTU and Xuhui District Government, Molecular and Nanomedical Innovation and Transformation Center was launched. Focusing on the field of molecular nanomedicine and smart healthcare, the center is committed to guide the scientific research achievements of Shanghai Jiaotong University to serve local economic development, promote the transfer and transformation of molecular and nanomedical innovation, and accelerate the upgrading of the health industry in Xuhui District. The goal of the center is to build a new technology transformation functional platform representing the level of the university and provide a typical demonstration for Xuhui District to construct a global science and technology center in Shanghai.

The center is located in the Shanghai Juke Biotech Park, which is home to many biopharmaceutical enterprises. It covers an area of about 2600 square meters and has built a quality management certification and professional incubation service system. A private enterprise, Shanghai Baiyi Molecular and Nanomedical Innovation and Transformation Center is fully responsible for the operation and management of the center. The team members are all from research institutes or laboratories in SJTU, as well as pharmaceutical enterprises with rich entrepreneurial experience. After nearly 3 years of efforts, the center has incubated 6 industrialization projects and signed 2 technology transfer contracts.

Conclusion

Benefiting from its abundant academic resources and scientific research achievements, SJTU has experienced a significant growth of technology transfer over the past years, especially in the fields of engineering, chemistry, materials science, computer science and biomedical science. With the goal of being at the forefront of modern technology and meeting the strategic requirements of national development, SJTU identifies cooperation between industry and academy as a priority, and has established partnerships with dozens of large enterprises on the

aspects of discipline construction, scientific research, and talent cultivation.
SJTU started to allow intellectual property to be a new way of pricing and investing, when the school was approved by MOE to establish Shanghai Jiaoda Intellectual Property Management co., Ltd. (IPMC) in 2015. Staff in SJTU are encouraged to invest by cash, while they could have direct ownership of the company shares or let IPMC keep their shares. And IPMC is a special channel for the trading of intellectual property rights of SJTU and the shareholding agent of companies invested by scientific and technological achievements.
SJTU has set up several institutions to promote the transformation of scientific and technological achievements obtained by staffs and students, involving Shanghai Jiaoda Intellectual Property Management co., Ltd., Shanghai Jiaoda Technology Transfer Center Co., Ltd, Advanced Industrial Technology Research Institute, Shanghai Jiao Tong University Science Park, and various new-type R&D centers. All these agencies constitute an all-round, multi-level organization system for the transformation of scientific and technological achievements inside and outside SJTU. Besides, there are a group of specialists who can provide professional advisory services for less experienced staff, which include helping them look for cooperation, draft the contracts, deal with approval process, and acquire different resources. Now, SJTU constantly improves the existing system and has gradually formed a "1+5 +20" institutional system to "promote the transformation of scientific and technological achievements in the new period", which effectively guarantees its technology transfer work.

3.4 Conclusions and policy recommendations

3.4.1. Conclusion

Based on the ‘knowledge production’ role in Chapter 2 of the report, we ensure that the role is the basic mission and obligations of the university irrespective of regional hubs and universities. With the transition to a knowledge-based economy, these universities provide not only the creation, reproduction, exchange, and diffusion of knowledge (OECD, 2004) but also incubates the learning society that catalyses the creation of a knowledge-based economy (Goddard and Vallance, 2013). The pathways which are mainly teaching and research from universities to the region/society has recently been replaced entirely MOOCs (Massive Open Online Courses) due to the pandemic.

Global universities understand their role which encourages faculties and students to fulfil their duties of teaching and research. With regard of an institutional measure, every university strictly evaluates teaching and research in terms of the criteria for promotion or tenure of faculty. The universities measures teaching responsibility in terms of not only faculties’ participation in teaching workshops, seminars, laboratory sessions with students (Youtie and Shapira, 2008), as well as other forms of outside-the-course ‘lifelong interaction’ that they

engage with both university and non-university actors (Chatterton and Goddard, 2000; Ponds et al., 2009). In addition, the research achievement is measured as scholarly investigations, contribution to professional fields, receipts of grants, and fellowships; professional impact of their work; and their success in directing productive work by advanced students. However, these evaluations may vary slightly depending on the policy of universities even through their primary duty of the teaching and research. The policy on faculty evaluation of University of California incorporates quality of teaching; new ideas and original scholarly research; public service; and excellence in one's professional field of competency. On the other hands, University of Washington (UW) does not include the performance of knowledge transfer and place more weight on the evaluation of teaching and research. The case of some college in Seoul National University (SNU) evaluates place 25% volunteer work and 20% university-industry collaboration by reducing the proportion of teaching and research.

In relation to the 'technology transfer' role elaborated in Chapter 2, throughout the individual university write-ups, we also observe that patenting and licensing are shown to be not the only KT/TT indicators of interest for these universities. To a certain extent, these universities do as well emphasize other relevant categories, e.g. funding for spin-offs and/or start-ups, number of jobs created from these companies, income from collaborative and/or contract research, etc. The cases of Imperial College London (ICL) and KU Leuven demonstrably fit within these discussions, and specific to Tel Aviv University (TAU), the number of successful exits for companies founded by university alumni and researchers. Nevertheless, it is also evident that the universities we studied for this report continue to pay attention primarily to income-generating KT/TT indicators (Hughes and Kitson, 2012; Lambert Report, 2003; Middlehurst, 2004), reflecting the discussion by Rosli and Rossi (2016) on isomorphic pressure faced by higher education institutions to perform well by means of benchmarkable indicators.

Furthermore, the universities we studied in this report have significantly contributed to further regional development with respect to their localities, reflecting the findings by Power and Malmberg (2008) and Uyarra (2010) about the increasing expectation for these institutions to play a major role in developing their regional innovation systems (RIS). This is demontrated by KU Leuven through their significant contribution to the city of Leuven – and to a certain extent, Flemish-Brabant province – in terms of their research infrastructure, e.g. science parks and start-up incubators, or TAU given the significant roles of university alumni in founding high-technology companies based in the city of Tel Aviv. However, universities can only do so much in promoting regional innovation, as other types of innovation actors, followed by proactive linkages among them, are no less vital in driving the dynamic landscape of their innovation systems; in other words, higher-education institutions cannot be expected as the sole drivers of regional development (Uyarra, 2010). As an illustration, in the case of London, ICL is not the only primary actor driving the development of innovation hub; the city's success requires a dynamic configuration involving hundreds of universities and colleges, government agencies, health research institutes, companies, financing support through banks and VCs, etc. Similar pattern applies to other localities, such as Leuven (as shown by the roles of IMEC and VIB) and Tel Aviv (where networks of serial entrepreneurs and VCs also support innovation hub development).

With regard to the 'societal development' role, we found that university policies may influence the likelihood of faculty members engaging in societal engagement through their research (De Jong et al., 2015; Sivertsen and Meijer, 2020). This is demonstrated by KU Leuven's faculty tenure and performance assessment policies. Across all five dimensions taken into consideration, there is a strong element of linking their works to societal impacts, e.g. highlighting five most impressive journal articles in the research aspect, emphasis on promoting lifelong learning in teaching, involvement in non-profit work in the service-to-society component, personal aspiration of their works in 'bio-sketches', and problem-solving capabilities in the leadership dimension. ICL also exemplifies this role through their 'public service' component of their faculty tenure policy, in which evaluation committees take into consideration faculty members' participation in expert committees on advising governments on issues within their expertise. Overall, while many universities retain their emphasis on income-generating KT/TT categories, there is a tendency of gradually moving away from this approach, and holistically taking into account non-pecuniary indicators.

Moreover, the degree to which universities can participate in societal engagement cannot be solely determined by their policies alone; individual academics' own intrinsic motivation (Kreps, 1997; De Jong et al., 2015) are no less important. This is again well illustrated by KU Leuven in their faculty tenure and assessment policy. In the 'bio-sketch' component of the assessment framework, evaluation committee members closely examine individual faculty members' own future ambition, goals, and aspiration they would like to achieve through their research and teaching. Beyond the five dimensions highlighted in the preceding paragraph, evaluation committees also closely observe faculty members' communication with their students, colleagues, other university stakeholders, as well as non-university actors. Relatedly, KU Leuven is steadily moving away from individual assessment and broadening their focus by reviewing the dynamics of research team relationships and others' perception about the assessed faculty members.

Regarding the 'platform/network development' role, the university as platform is based on the network of connection with students through education, dissemination of research output by scholars in relevant fields through academic activities, provision of manpower and exchange of technologies and scientific insights with industry actors, and the provision of advice for government agencies and other public institutions. The number of connections of each university with the external organizations and the magnitude of the influence of each connection are the capabilities of the university facilitated through the university's platforming (Powell et al., 2005). At the same time. a new paradigm of innovation to move, exchange, and generate resources toward global I&T hub is introduced with the emergence of global networks, accessibility from the development of ICT, and the rise of a platform economy (Kenney and Zysman, 2016; Parente et al., 2018). In this respect, the platform/network development role of the university is expanded for knowledge transfer in the globalization to tap into innovation resources outside the hubs, which enables university's ecosystem to become I&T hub to build its significance beyond the regional and national levels.

Based on the platform/network development role as 'anchor tenants' for the growth of local communities of practice in a RIS, the universities aim at the platformization which expanded

to not only provide the roles of education and research (Etzkowitz and Leydesdorff 1997; Etzkowitz et al. 2000), but also to utilize the human, material, institutional, and financial educational resources of the local community for improving the global competitiveness and catalyzing further regional innovation (Mishra et al., 2020). The strategies of universities to adopt a business model/value chain of platform using the external networks have different levels and organizations. Every innovative university of the report as an intermediary entity adopting platform business models, aims at forming constantly connections with various actors outside of campus: forming networks with regional actors through knowledge/technology transfer; connection with actors of industry and market through spin-off activities and startup establishment; and communication with local communities and society through social development roles. In addition, the cases of Tsinghua University and Shenzhen University, where the entire RIS operates as a platform beyond organizations, institutions, and university policies are interesting. Under the leadership of Chinese government, each regional ecosystem can be transformed into the platform with multiple partnership models driven by regional universities which have been reinforcing its in-depth collaboration with these national strategic development regions. Table 3-31 illustrates our summary of write-ups on universities.

Table 3-31 Summary (1)

Units	Criteria	University of Washington	University of California at Berkeley	KU Leuven
University	Basic info	Founded in 1861, with campuses in Seattle, Tacoma, and Bothell Status: Publicly funded university 2021 QS rank: 72 Number of Students (BS, MS, PhD, professional degree) (2020): 59,381 Number of Faculties (2020): 4864 Number of staff (2020): 26,229	Established in 1868 Status: Publicly funded university 2021 QS rank: 4 Number of Students (BS, MS, PhD, professional degree) (2020): 42,347 Number of Faculties (2020): 2,935 Number of staff (2020): 8,723	Founded in 1425; 1834 (as Catholic University of Leuven); 1970 (after split into Dutch-speaking and French-speaking universities) Status: publicly funded Catholic university 2021 QS rank: 84 Number of faculty members: 1,680 Number of students: 58,045 Number of staff: 11,534
	Infrastructure	Makerspace, Co-Motion Labs	35 core facilities and shared resources for specialized technology and technical expertise	Arenberg Science Park and Haasrode Science Park; three additional science parks are being planned
	Governmnet-built Infrastructure	Washington Clean Energy Testbeds; UW Reality Lab; Washington Nanofabrication Facility (WNF).		International Microelectronics Center (IMEC) and Flanders Institute of Biotechnology (VIB)
	Programs to promote culture of innovation and entrepreneurship	N/A	Big Ideas@Berkeley, Berkeley-Haas Entrepreneurship Program, Bay Area NSF Innovation Corps, Pantas and Ting Sutardja Center for Entrepreneurship & Technology, Cleantech to Market (C2M)	KU Leuven KICK, an entrepreneurship program offering business plan consultation, start-up incubation, credit-based courses, business pitch competitions, and seed funding specifically geared for students
	Funding schemes	Research Funding - all sources (2020): 1,631,329,000 USD Funding from the Washington Technology Center, Washington Technology Foundation, and Washington Technology Alliance to enhance marketability of start-ups, office spaces, and opportunities to connect with industry firms	Sponsored Projects Office offeres several programs, e.g., SBIR/STTR (small business) grant; National Science Foundation or the National Institutes of Health	Funding schemes by Flemish regional government under VLAIO (Flanders Innovation and Entrepreneurship) and FWO; funding schemes by Belgian federal government under Innoviris; funding schemes by European Union (previously from Horizon 2020, recently from Horizon Europe); foreign funding schemes (notably from US National Institutes of Health/NIH)

	Promotion/tenure policies	N/A	UCB has adopted practices that encourage faculty engagement in entrepreneurial activities, particularly through the industrial leave policy, allowing academics who apply to take a leave of up to one year, or even more in the case of professoriate-level above assistant professor, to engage in commercial pursuit, in particular company formation. In addition, faculty can avail of the relief from teaching duty policy of up to a maximum of 50% over a semester, in order to engage in translational activities for inventions developed based on their research work in the university.	Five assessment dimensions (research, teaching, service to society, bio-sketch, leadership capacity) comprising up to 55 criteria in which faculty members - out of their own volition - can opt to be evaluated
	1 or 2 outstanding features or incentives or program or good practice	CoMotion's funding programs - Innovation Gap Fund; CoMotion DubPitch; WE-REACH; Commercialization Fellow Program	Berkeley Catalyst Fund (BCF) is a venture fund affiliated with the College of Chemistry, initiated under the leadership of former Dean Richard Mathies and current Dean Doug Clark.	Leuven Research and Development (LRD), which functions as the university's TTO as well as coordination unit for research activities at the department and faculty level, and which, in turn, is run by professors
	2-3 stellar inventions/spinoffs/faculty-inventors	Proprio (a spin-out that developed an innovative platform for machine learning and computer vision to improve surgical navigation; co-founded by UW faculty, post-graduate students, and alumni); PvP Biologics (a spin-out that developed an oral enzyme for the treatment of celiac disease; acquired by a Japanese pharmaceutical company which had funded the first phase of its clinical trial; co-founded by UW post-graduate students and faculty); A-Alpha Bio (a start-up that is developing drugs to treat respiratory and intestinal diseases; co-founded by two UW graduate researchers); Membrion (a spin-out that makes membranes that can convert some types of salty water into fresh water; founded by an UW lecturer)	20n, Inc. - computational systems that predict DNA design for novel industrial biotech and health applications; co-founded by Associate professor from the Molecular Biophysics & Integrated Bioimaging Division. Axent Bioscience, Inc. is a stem cell therapies company; co-founded by Professor of Chemical and Biomolecular Engineering. Nurix is pioneering rational drug design in the emerging field of protein regulation by targeting E2 conjugating enzymes and E3 ligases that control the Ubiquitin Proteasome System (UPS).	LayerWise (a spin-off commercializing additive manufacturing for medical implants) and reMYND (a company specializing in transgenic mice for research on Alzheimer's disease)

TTO/KTO	Basic info	▪ Organizational structure - UW's technology transfer system comprises both internal and external organizations. It has its own technology transfer office (Co-Motion) that provide innovation spaces, incubation programs, mentoring, and legal and business advice. ▪ *Co-Motion* Mission: "We partner with the UW community on their innovation journey, providing tools, connections, and acumen to transform ideas into economic and societal impact" Size: 49 employees (2021) - innovation managers and administrators with advanced learning in engineering, life sciences, and business.	▪ UCB's transfer office IPIRA (Intellectual Property & Industry Research Alliances), established in 2004, aims at promoting campus interactions with industry, innovation, and commercial uptake of inventions. IPIRA focuses on marketing university patents to the industry (technology push) as well as attracting private companies through industry partnerships (technology pull). ▪ Mission: "create multifaceted relationships and new modes of interaction with industry, to diversify research funding sources, support economic development through technology and knowledge transfer, including entrepreneurship – and was tasked with an initial goal of doubling corporate sponsored research, which was around $10M per year at the time". ▪ IPIRA has 2 offices - Industry Alliances Office (IAO) and Office of Technology Licensing (OTL) Size - 18 employees (2021) - OTL is at 8 total, the IAO at 6 total, plus 4 employees of IPIRA.	▪ Year established: 1972 ▪ Organization structure: consisting of Central Management Unit and LRD teams at the faculty and department levels, all run directly by professors, as well as innovation managers under the industrial research scheme (IOF) ▪ Number of staff (at the Central Management Unit): 87
	Basic profile of current TTO director or equivalent post	Director Co-motion and Vice-provost for innovations - François Baneyx - Professor of Chemical Engineering and an adjunct professor of bioengineering; co-founder UW spinoff; fellow of the American Association for the Advancement of Science and a member of the Washington State Academy of Sciences.	IPIRA is headed by an Assistant Vice-Chancellor for Intellectual Property and Industry Research Alliances, who is a member of the Knowledge Transfer Advisory Committee - Carol Mimura, Ph.D. Carol has served as a member of the Forum on Drug Discovery, Development, and Translation of the National Academies of Sciences Institute of Medicine, on the boards of the Children's Hospital Research Institute in Oakland, CA and BayBio, the regional voice of biotechnology in Northern California.	Current director: Professor Koenraad Debackere; profile: full professor at the School of Management, expert on university-industry linkages and firm innovation
	License income; IP Policies; Royalty distribution;	▪ Royalty of University (2020) - 8,071,000 USD ▪ 2184 license (2017-2021). License income: 1) deducting 20 percent from the licensing income to cover patent costs and other expenditures due to commercialization services provide CoMotion, 2) the remaining 80% of the	▪ Total active patents (2018): 1,535 ▪ Licensing revenue: $7.8M in FY15 and $9.9M in FY16.	"License income: approx. €200 million (as of 2018)

	Ownership distribution; Patents filing	proceeds from a license are shared equally among the inventors of the technology (26.67%), their departments and schools (26.67%), and the Provost (26.67%) ▪ UW allows students to own the IP of innovation solely developed by them as students or outside of any direct assistance from the university, unless they are under some kind of employment arrangement ▪ Patent rights - inventors assign their rights in the innovation to the UW ▪ 487 US patents issued (2017-2021) - success rate of patent applications by UW is between 30 and 40 percent. The majority of patents filed by UW were in the areas of pharmaceuticals and biotech and agriculture, forestry and food.		
	Spinoff	Incubated 126 start-ups (2006-2016)	1,272 startups were established (1968-2015); 622 are active (2015); 60 current UCB faculty have been involved in starting one or more companies	N/A
	1 or 2 stellar events/programs organized by the TTO	▪ Innovation Gap Fund ▪ CoMotion DubPitch ▪ WE-REACH ▪ Commercialization Fellow Program	N/A	IP policy: inventions based on university research are to be owned by university; joint patenting with industry is not preferred (as an alternative, the university is open to exclusive licensing arrangements); joint patenting with public research organizations is very encouraged (and in some conditions, mandated by Belgian law)
Startup incubator	Basic info	▪ Some activities with Startups are managed by Co-Motion Lab - multi-industry incubation environment for early-stage startups. Includes CoMotion Labs life sciences incubator; CoMotion Labs hardware incubator; CoMotion Labs technology incubator ▪ Buerk Center for Entrepreneurship serves the entire campus with exceptional academic programs and real-world experiences. Students	▪ Sutardja Center for Entrepreneurship (SCET) was founded in 2005 through an endowment gift from Pantas and Ting Sutardja to the College of Engineering to create a teaching center for entrepreneurship. Offeres courses, bootcamps, and hackathons for 1,700-1,800 students annually ▪ CITRIS Foundry is an accelerator for deep technology startup companies. Embedded in the	▪ Kortrijk Innovation and Incubation Center ▪ KU Leuven Innovation and Incubation Center (focus specifically on spin-off companies based on joint research between KU Leuven and IMEC) ▪ Leuven Bio-Incubator (focus specific on biotechnology-related spin-offs)

		and faculty who engage with the center make strong connections to the Seattle entrepreneurial community ▪ Jones + Foster Accelerator - 6-month program ▪ CDL-Seattle is located in Seattle (USA) at the Foster School of Business - nonprofit organization for massively scalable, seed-stage, science- and technology-based companies	Berkeley campus in Sutardja Dai Hall, established in 2013 ▪ LAUNCH, based in the Haas School of Business, is a startup accelerator and competition designed to transform early-stage startups into fundable companies ▪ SkyDeck, one of UC Berkeley's startup accelerators ▪ The House. The House is a startup institute built for Berkeley, and home to Berkeley's founders.	▪ Tienen Biogenerator (focus specific on spin-offs developing nutritious food for people and animals)
	Basic profile of current Startup Incubator director or equivalent post	N/A	N/A	N/A
	1 or 2 stellar events/programs organized by the TTO	N/A	N/A	N/A
University R&D support center	Basic info: year	UW offers a number of different makerspaces with tools and resources for students and faculty to build and prototype their idea.	N/A	▪ R&D support center 1: International Microelectronics Center (IMEC); year established: 1984; mission: performing applied research in the area of microelectronics; revenue: 640 million euros (as of 2019); number of researchers: approx. 4,000 ▪ R&D support center 2: Flanders Institute of Biotechnology (VIB); year established: 1995; mission: performing applied research in the area of biotechnology and life sciences
	Basic profile of current R&D support director or	N/A	N/A	▪ Current director of IMEC: Luc van den Hove; background: a long-time researcher at IMEC (since 1984), previously was

	equivalent post			Executive Vice President of IMEC, now President and CEO of IMEC since July 2009 ▪ Current director of VIB: Ajit Shetty; background: a business executive at Johnson and Johnson and chairperson of the board of directors at Janssen Pharmaceutica (a subsidiary of Johnson and Johnson), now chairperson of the board of directors at VIB
	1 or 2 stellar events/programs organized by the TTO	N/A	N/A	N/A
Summary/ conclusions		▪ UW received the largest federal funding for research among public universities; UW has also relied on the support of private organizations in Washington State ▪ Net licensing income is shared equally among the inventors, host department, and university	▪ UC has adopted a combination of centralized and distributed approaches to the development and management of its technology transfer program ▪ UC has also adopted a multi-dimensional metric for evaluating licensing performance, which enables a better appreciation of interactions between the university and industry firms, as well as the challenges that went into the negotiations during the licensing process.	▪ KU Leuven's unique organizational structure with regard to their knowledge/technology transfer, in the form of LRD ▪ Faculty performance assessment approach that is highly tailored and individualized in accordance with faculty members' track records and activities

Table 3-32 Summary (2)

Units	Criteria	**Imperial College London (ICL)**	**Tel Aviv University (TAU)**	**Seoul National University (SNU)**
University	Basic info	Year founded: 1907 Status: public research university 2021 QS rank: 8 Mumber of faculty members: 2,100; number of academic staff: 4,400; number of students: 19,400	Year founded: 1956 Status: publicly-funded research university 2021 QS rank: 255 Number of faculty members: 1,048 (as of 2020); number of students: 26,300 (as of 2017)	Year founded: 1946 Status: national university 2021 QS rank: 37 Number of faculty members: 2,131 (as of 2020); number of students: 27,813 (as of 2020)

	Infrastructure	White City Incubator	N/A	N/A
	Government-built Infrastructure	London Institute of Medical Sciences of Medical Research Council, National Heart and Lung Institute	Tel Aviv Sourasky Medical Center, Sheba Medical Center, Clalit Health Services	Seoul National University Hospital (SNUH), SNUH Bundang, Seoul Metropolitan Government (SMG)-SNU Boramae Medical Center
	Programs to promote culture of innovation and entrepreneurship	Imperial Enterprise Lab (launched by Imperial Enterprise), Imperial Entrepreneurs (launched by Imperial College Union, the university's student union), Imperial Venture Mentoring Service, Imperial College Union Social Enterprise, Imperial College Advanced Hackspace	StarTAU (by Ramot), Brainboost (by Sagol School of Neuroscience), Capsula (by Porter School of the Environment and Earth Sciences), BioMedTech (by Faculty of Medicine), Collier Institute of Venture (by School of Management), Center for Entrepreneurship and Innovation (by the university's leadership board)	SNU 10-10 Project, support program for creative leading researchers, support program for start-up commercialization, and seed funding specifically geared for students
	Funding schemes	▪ Internal funding schemes, e.g. The Jameel Fund, research funding schemes by UK government-funded agencies (EPSRC, ESRC, NERC, STFC, BBSRC), Global Challenges Research Fund, Joint Proof of Concept Fund, Imperial College COVID19 Research Fund, etc ▪ External funding schemes, e.g. Horizon Europe (administered by European Comission)	Funding schemes by Israel Science Foundation, Research Funds of Chief Scientists in Government Ministries, Israel Innovation Authority (formerly Office of the Chief Scientist), Bi-national and international funding schemes (e.g. US-Israel Binational Industrial R&D Foundation / BIRD, Israel-Europe Framework for EU Funding, Singapore-Israel Industrial R&D Foundation, Japan-Israel R&D Cooperation, German-Israeli Foundation, etc)	Funding schemes by the Ministry of Education and Korean Educational Development Institute, Funding schemes by National Research Foundation of Korea, research funding schemes by Korean government-funded schemes (MOEF, MOTIE, MSIT, etc.)
	Promotion/tenure policies	Four assessment dimensions (teaching/education, research, leadership and management, profession and practice); profession and practice specifically comprise of indicators relevant to KT/TT: medals for public service; consultancy; innovative input and feedback in projects; patenting and licensing; spin-off establishment; pioneering innovations of worldwide recognition; service as expert witness; leadership in respected bodies/peer-reviewed bodies	Unwritten rule': performance is almost entirely driven by research performance (around 75% weighting); another 20% is based on success in research funding performance; the other 5% is mainly based on 'nice-to-have' criteria (e.g. achievements in knowledge and/or technology transfer activities, serving in government/public service committees, etc)	Four assessment dimensions (40% research, 40% teaching, 10% service to society, 10% evaluation by the head of institution), different promotion/tenure policies depending on the colleges (e.g., 20% achievements in knowledge and/or technology transfer activities, 25% service to society in the graduate school of engineering practices)
	1 or 2 outstanding features or	Founders' Choice program, which offers two types of support: Founder-Driven Route (where spin-off founders receive basic assistance	Proliferation of innovation and entrepreneurship support initiatives beyond Ramot at the faculty/department level	Flexible 'one day per week' activities; new positions for professors who dedicated exclusively to industry-university cooperation

	incentives or program or good practice	services, with ICL taking at most 5% of the company's equity) and Jointly-Driven Route (where spin-off founders receive comprehensive services, but with ICL taking a higher amount of the company's equity, ranging from 15-30%)		
	2-3 stellar inventions/spinoffs/faculty-inventors	Ixico (a spin-off commercializing artificial intelligence/AI technologies for better recommendation of therapies relating to neurological and neurodegenerative diseases, e.g. Alzheimer's)	Waze (a satellite navigation software program that is acquired by Google for US$1 billion), Viber (a social media chat app that is acquired by Rakuten for US$900 million)	HyperConnect (a spin-off commercializing computer vision and video communication (WebRTC) for providing social networking service by connecting people using video source, e.g., Azar).
TTO/KTO	Basic info	▪ Year established: 1986 (as Imperial Innovations); 2018 (as Imperial Enterprise, after restructuring) ▪ Organization structure: consisting of 11 divisions) ▪ Number of staff: 130+	▪ Year established: 1973 ▪ Organization structure: consisting of a board of 14 members with various experiences as academics, VCs, serial entrepreneurs, government policymakers ▪ Number of employees: 12	▪ Year established: 2004 ▪ Organization structure: consisting of office of research affairs, R&D education center, department of policy affairs, department of research management, department of business affairs (IP management), and industrial-academic cooperation/technology holding company ▪ Number of staff: 126
	Basic profile of current TTO director or equivalent post	Current director: Simon Hepworth; profile: a PhD graduate of the University of Oxford, was a business executive at Ford and Visteon before joining the company	▪ Current CEO of Ramot: Keren Primor Cohen; profile: former Legal Counsel at Yeda R&D (the TTO of Weizmann Institute of Science) and former VP of Business Affairs at Ramot, having joined Ramot since 2007 ▪ Current Chairperson of Ramot (concurrently serving as Vice President of R&D): Professor Dan Peer; profile: expert on nanomedicine development for cancer treatment, scientific co-founder of 5 biotechnology firms, and currently director in various research centers within TAU (Laboratory of Precision Nano-Medicine, Center for Translational Medicine, Cancer Biology Research Center)	Current Chairperson of SNU R&DB Foundation (concurrently serving as Vice President for Research Affairs of SNU): Professor in Department of Mechanical Engineering, Multiscale Mechanics Design; profile: expert on fluid mechanics, and turbulence/CFD/Bio-mimetic engineering
	License income; IP Policies;	▪ License income: approx. £1.9 million (as of 2018)	▪ License income: N/A ▪ IP policy: inventions based on university research are to be owned by university; contingent on the nature of the circumstances, joint patent	▪ License income: approx. 5,217 million KRW (as of 2020) → fixed 40% profits to a licensor and 60% to SNU

	Royalty distribution; Ownership distribution; Patents filing	▪ IP policy: inventions based on university research are to be owned by university; joint patenting with industry is highly discouraged ▪ Royalty and ownership distribution: regressive (50% share goes to inventors for licensing income of £100,000 or below, and the other 50% goes to university; 40% share goes to inventors and 10% to inventors' departments for cumulative licensing income between above £100,000 and £1 million, and the other 50% goes to the university; 30% goes to inventors and 20% to inventors' departments for cumulative licensing income above £1 million, and the other 50% goes to university) ▪ Patents filing: 77 (as of 2018)	ownerships are allowed (when external organizations also contribute portions of their funding and/or resources into university invention efforts), with percentage of ownership determined based on amount of resources ▪ Royalty and ownership distribution: flat (40% of net licensing income is to be allocated to inventors, and the remaining 60% to be shared with the university) ▪ Patents filing: N/A	▪ IP policy: inventions created by faculty related to his/her current duties, using the research facilities and manpower of the school, research expenses support received from this school, a ministry of the government or any affiliated institutions, or a research outsourcing contract with a third party are to be owned by university; Any intellectual property that has been created by the faculty of the school in relation to their respective duties should be owned by the SNU R&DB Foundation ▪ Royalty and ownership distribution: regressive (100% share gose to inventors for licensing income of 20 million KRW or below; 80% share goes to inventors and 20% to SNU R&DB Foundation for cumulative licensing income between above 20 million KRW and 100 million KRW; 70% share goes to inventors and 30% to SNU R&DB Foundation for cumulative licensing income between above 100 million KRW and 500 million KRW; 50% share goes to inventors and 50% to SNU R&DB Foundation for cumulative licensing income between above 500 million KRW ▪ Patents filing: 1,117 (domestic), 495 (international) (as of 2020)
	Spinoff	▪ Number of new IP-based spin-offs established: 10 (as of 2018) ▪ Number of student-based start-ups established: 41 (as of 2018) ▪ Number of start-ups in university incubator: 19 ▪ Number of active incubator graduate companies: 29 ▪ Cumulative number of IP-based spin-offs still active: 79	N/A	N/A

		▪ Investment funding for IP-based spin-offs: £87.5 million (as of 2018) ▪ Investment funding for student-based start-ups: £17.6 million (as of 2018)		
	1 or 2 stellar events/programs organized by the TTO	N/A	N/A	N/A
Startup incubator	Basic info	White City Incubator; year established: 2016	N/A	Main start-up incubation center and four existing incubators in four department ▪ CALS (College of Agriculture and Life Sciences) Bio-Venture Valley ▪ New Dental Technology Business Incubator ▪ SNU Biotechnology Incubating Center (Golden Helix) ▪ Artificial Intelligence Institute Center for Industry Collaboration (CIC)
	Basic profile of current Startup Incubator director or equivalent post	N/A	N/A	Current Chairperson of SNU Entrepreneurship Center: Professor in Department of Electrical and Computer Engineering; profile: expert on display and thin-film device, and flexible printed device and circuit
	1 or 2 stellar events/programs organized by the TTO	N/A	N/A	▪ One-stop business consulting (mentoring) ▪ SNU-Gwanak Tech Valley Audition (an entrepreneurship competition program) ▪ Global acceleration program for global start-up incubation ▪ SNU Startup Camp for students
University R&D support center	Basic info: year	N/A	N/A	▪ SNU R&DB Center play a role of R&D support
	Basic profile of current R&D support	N/A	N/A	▪ N/A

	director or equivalent post			
	1 or 2 stellar events/programs organized by the TTO	N/A	N/A	N/A
Summary/ conclusions		▪ Learning from ICL's experience with Imperial Innovations: it would be a good idea not to publicly list a university technology transfer company in a stock exchange given the uncertainties over long-term returns from investments in novel technologies utilizing university research ▪ ICL's explicit recognition of faculty achievements in KT/TT activities in their tenure policy is worth considering	▪ A widespread proliferation of innovation and entrepreneurship programs beyond the scope of Ramot (organized directly by the university's faculties and schools) ▪ TAU's broad contribution to Tel Aviv and Israel's innovation systems despite the restrictive faculty performance assessment policy (with innovation and entrepreneurship largely contributed by students and alumni)	▪ 1) SNU's unique centralized organizational structure with regard to their knowledge/technology transfer, R&D support, and start-up incubation 2) Learning from SNU's experiment with the flexible policy of 'one day per week' activities and recruitment of faculties focusing on industry-university cooperation

Table 3-33 Summary (3)

Units	Criteria	Tsinghua University	Shanghai Jiaotong University	National University of Singapore
University	Basic info	1911 founded, public, 2021 QS：15th; 15,772 faculties (3641 teachers,9598 staffs); 53,302 students	Established in 1896 Public QS 2022 = 50 Number of Students (BS, MS, PhD, professional degree)(2020) - 44,076 Number of Faculties (2020) - 3,236	Founded in 1905 Status: Publicly funded university 2021 QS rank: 11 Number of Students (BS, MS, PhD, professional degree) (2020): 30,312 Number of Faculties (2020): 4,288 Number of staff (2020): 12,018
	Infrastructure	Specific: Office of Technology Transfer, TusPark, i-Space, X-lab; Others: Tsinghua Holdings Co., Ltd.,National Engineering Research Centers, University-region joint research insititutes, University-enterprise joint research insititutes	Shanghai Jiao Tong University Science Park, including 10 sub-parks in the Yangtze River Delta region	Incubation center; corporate laboratories; 30 university-level research institutes and centers
	Government-built Infrastructure	TusPark，i-Space		Cancer Science Institute of Singapore (CSI Singapore), Center for Quantum Technologies (CQT), Mechanobiology Institution (MBI), and Singapore Center for Environmental Life Sciences Engineering (SCELSE)
	Programs to promote culture of innovation and entrepreneurship	Uni Era, University-enterprise Collaborative Innovation Plan, Tsinghua University President's Innovation Challenge, Tsinghua University Student's Innovation Ability Enhancement Project, innovate48 (in48), x-Cute Entrepreneurship Learning Camp, 2021 Tsinghua x-lab Kunshan Huaqiao "Smart Future" Innovation and Entrepreneurship Competition,Youth Education Chain League		▪ Innovfest; NUS Overseas Colleges; Lean Launchpad Singapore; Modern Aging ▪ Programme; NUS Enterprise summer program; NUS MSc venture creation program; NUS Technology Access Program

	Funding schemes		Research Funding - all sources (2020) - 4,767,000,000 CNY Funding from the National Nature Science Foundation (2020) - 821,000,000 CNY Education Development Foundation- sponsored by alumni (2020)-1700,000,000	Startup SG Founder; Lotus-NUS Fund; Technology Acceleration Programme; NUS Start-Up Runaway
	Promotion/tenure policies		1) Rules for the Administration of Pricing investment in Scientific and Technological Achievements (Trial Implementation) 2) According to the Rules for the implementation of the pilot project to grant researchers the ownership or long-term right to use their scientific and technological achievements (Trial Implementation), as a pilot, SJTU has given researchers ownership or long-term right to use their scientific and technological achievements	Assistant Professors are appointed on term contracts, while Associate Professors and Professors may be appointed either with tenure or on term contract. NUS introduced a teaching - only career pathway in 2008, which was reframed as an 'educator track' in 2015. The 2015 reforms sought to reinforce the status of the educator track, through improving the incentives for academics following this pathway, including enabling the progression to Full Professor with tenure.
	1 or 2 outstanding features or incentives or program or good practice	Office of Technology Transfer	SJTU and Huaibei government, jointly set up "Shanghai Jiao Tong University Anhui Research Institute of Ceramics and Aluminum New Materials" to carry out industrial application and industrial design research related to ceramics and aluminum technology	Technology Acceleration Programme (TAP) is a decentralised funding given by Ministry of Education (MOE) to Institutes of Higher Leaning (IHL) to achieve 4 focused areas of RIE 2020 Master-plan. The excellent teams can receive more than S $100,000 grants to enlarge their businesses.
	2-3 stellar inventions/spinoffs/faculty-inventors	Ultra-low power near-sensing AI chip(by TTO),digital energy exchange system (by TTO)	Leading Optics (Shanghai) Co., Ltd. (a representative high-tech enterprise incubated in Minhang Park, founded by Ren Mingjun, an alumnus of SJTU)	UNUM Therapeutics focuses on immunotherapy biotech which raised more than SGD 100 million since 2014; MEDAD Technologies focuses on adsorption desalination technology which won of BlueTech Award at 2014 SIWW; AYOXXA Leveraging success in proteomics focuses on microarray technology and POC

				recipient which closed more than 11 million Euros in financing; Clearbridge BioMedics Biomedical is an engineering spin-off which raised SGD 9 million in Sereis B 2013.
TTO/KTO	Basic info	Office of Technology Transfer, founded on June 6, 2014, is the supporting institution of Tsinghua University. It is responsible for the transformation of scientific and technological achievements and the management of intellectual property rights such as patent rights, Copyrights and technical secrets. Institute of technology transfer's mission is "promote technology transfer, service national strategy, promote the economic development, promote social well-being" and its goal is creating a world-class university technology transfer agency and enhancing the service, innovation, transformation forces and influence.	SJTU's transfer office AITRI (Advanced Industrial Technology Research Institute), established in 2009, is responsible for the transformation of scientific and technological achievements of SJTU. It main functions include IP management, technology cooperation, and transformation audit. vision: in the future, the institute will become a one-door, sunny, and all-embracing ecosystem of technology transfer, and become a connector between emerging industries and high-end technologies, an accelerator for accelerating the industrialization of new and high technologies, a booster for the transformation and upgrading of traditional industries and an incubator for the cultivation of strategic emerging industries. AITRI has 3 offices -office of technology cooperation, office of intellectual property, and office of technology transfer Size - 26 employees - leading group of university is at 9 total, leaders of the institute at 3 total, plus 15 employees of offices.	Organizational structure - NUS Enterprises lead 6 organizations: NUS ILO Office, NEC, NOC, NEX, NUP, NTHPL. Co-Motion Mission: promotes entrepreneurship and cultivates global mind-sets and talents
	Basic profile of current TTO director or equivalent post	Dean Wang Yan Vice Dean Li Bin	Jin Sun, the dean of ARTRI, is a member of the leading group of SJTU. He got PH.D degree of engineering in SJTU in 2001. He teaches at school of mechanical and power engineering institute of automobile body design and manufacturing technology (BMTC), employed as associate professor in 2004, 2005 in the United States at the university of Michigan, visiting scholar, 2006, the Shanghai digital automobile body engineering, deputy director of key	Professor Freddy Boey pioneered the use of functional biomaterials for medical devices in Singapore. He has filed 118 patents and founded several spin-offs. He previously served as director on the boards of the Government Technology Agency of Singapore (GovTech) and Defense Science Organization.

			laboratory. In 2010, he was promoted as a researcher and served as the assistant dean of the School of Mechanical and Power Engineering. In 2011, he was selected as the New Century Talents of the Ministry of Education. In 2015, he worked as deputy dean of institute of science and technology development. In 2020, he begun to work as the dean of ARTRI. Liu Qunyan, the director of office of technology transfer, worked at Kingbird Law Firm, Henan Guoji Law Firm, Beijing Dentons Law Firm (Shanghai) and Shanghai Oriental Development Law Firm between 1996 and 2011. In 2014, he worked as general manager in IPMC of SJTU. In 2017, he got PH.D degree of Law in the East China Normal University. In 2019, he begun to work as the director of technology transfer office and dean assistant in ARTRI. Dr. Liu's main research areas are science and technology management, technology transfer. Dr. Liu pioneered different ways of technology transfer, including "Easy Access IP", teachers' autonomous technology transformation. He was the first to put forward "variable interest entity" (VIE) model for the investment of scientific and technological achievements.	
	License income; IP Policies; Royalty distribution; Ownership distribution; Patents filing	Total revenue of technology transfer (patents, licensings, spinoffs) in 2019 - 62 mln USD (more than Stanford U). Royalty distribution for patents and license - 70% for research team; 15% - University; 15% - college/department. Some directions, like Automotive and Electronics, 5-10% goes to technology transfer intermediaries (the goal is to motivate office). Tech licensing - 368 (2017); 769 (2018); 718 (2020) - leader in China	Total number of patents granted (2019)-14,923 Total number of valid patents (2019) - 8,348 Transfer (2019): 58 items; 25.03M CNY License (2019): 21 items; 240.6M CNY Investment as equity (2019): 12 items; 101.56M CNY If the maintenance fee is paid by the school, the distribution ratio of cash income is 15%: 15%: 70%; If it is maintained by the self-raised funds of the person who completed the achievement, the	▪ Ownership distribution: unless otherwise expressly specified in the policies, all rights, title and interest in IP discovered, created or developed in the course or furtherance of university research shall vest in and belong to NUS. ▪ Revenue distribution: inventor-50%, faculty-30%, university-20%. ▪ Patents filing: 304 invention disclosures, 540 patent applications, 119 patents grated by 2018.

			proportion of cash income shall be 10%: 10%: 80%; For those who have completed the achievement and are disposed of uniformly by the school, the distribution ratio of cash income is 30%: 10%: 60%; For the transformation project that invests scientific and technological achievements at a price in the name of the school, the proportion of equity income distribution is 20%: 20%: 60%.(university:college: research team)	
	Spinoff	33 (2017); 50 (2018); 43 (2019); 62 (2020).	The IPMC (Shanghai Jiaoda Intellectual Property Management Company) holds shares on behalf of the school. Now, the IPMC has held 7 enterprises, invested in 42 enterprises, and held indirectly 45 companies.	National Cybersecurity R&D Laboratory (NCL); Singapore Data Science Consortium (SDSC); AI Singapore (AISG)
	1 or 2 stellar events/programs organized by the TTO	Ultra-low power near-sensing AI chip——Nanjing Meishen Intelligent Technology Co., LTD；A key technology of digital energy exchange system	The Joint Research Institute of Huawei and SJTU, established on July 22, 2021	▪ TAKE-NUS ▪ BLOCK71 Jakarta TechID
Startup incubator	Basic info		NeoBay-Global Innovation Community(NGIC) was founded in 2015 by Shanghai Minhang District People's Government, Shanghai Real Estate Group and Shanghai Jiao Tong University. NGIC covers entrepreneurship and business incubation in medical robots, artificial functions, Marine equipment, new materials and other related fields. By the end of 2019, the total number of NGIC incubation projects has exceeded 630, the total number of enterprises has exceeded 470, the total amount of project financing has exceeded 1.2 billion yuan, there are more than 100 entrepreneurial mentors, 91 entrepreneurial mentors, 48 legal advisers. Shanghai Jiao Tong University Science Park(Minghang Park), School of Entrepreneurship & Innovation (SEI) SJTU, and Intellectual property	▪ NUS Graduate Research Innovation Program provide step-by-step guidance to NUS Postgraduate students and researchers to cultivate deep tech entrepreneurs to transform the university's world-class research into their own deep technology start-ups ▪ BLOCK71 is a technology-focused ecosystem builder and global connector which catalyzes and aggregates the start-up community

			Managemnt Company(IPMC) of SJTU all embed in NGIC. SEI is responsible for the guidance and incubation of student entrepreneurship programs. Minhang Park and IPMC are respectively responsible for business incubation and patent cooperation after the transfer of scientific and technological achievements.	
	Basic profile of current Startup Incubator director or equivalent post		1) CAO Zhaomin, Chairman of Shanghai Jiao Tong University Science Park 2) Du Songning, Party branch secretary & General Manager	N/A
	1 or 2 stellar events/programs organized by the TTO			NUS Graduate Research Innovation Program (NUS GRIP); MVP Studio; JUMPstart; BLOCK71
University R&D support center	Basic info: year			N/A
	Basic profile of current R&D support director or equivalent post			N/A
	1 or 2 stellar events/programs organized by the TTO			N/A
Summary/ conclusions		Since 2020 - encourage to create more spinoffs (not licensing).	SJTU has set up several institutions to promote the transformation of scientific and technological achievements obtained by staffs and students,	▪ NUS received funding from national RIE plan

			involving Shanghai Jiaoda Intellectual Property Management co., Ltd., Shanghai Jiaoda Technology Transfer Center Co., Ltd, Advanced Industrial Technology Research Institute, Shanghai Jiao Tong University Science Park, and various new-type R&D centers. All these agencies constitute an all-round, multi-level organization system for the transformation of scientific and technological achievements inside and outside SJTU	▪ NUS established a multi-functional department ▪ NUS Enterprise to be in charge of every aspects of knowledge globalization and commercialization

Table 3-34 Summary (4)

Units	**Criteria**	**The University of Tokyo**	**Korea Advanced Institute of Science and Technology (KAIST)**	
University	Basic info	▪ Founded in 1877 Status: Publicly funded university 2021 QS rank: 24th Number of Students (BS, MS, PhD, professional degree) (2020): 28,806 Number of Faculties (2020): 3,225 Number of staff (2020): 8,131	Founded in 1971, with campuses in Daedeok Innopolis, Daejeon, South Korea Status: Publicly funded university 2021 QS rank: 39 Number of Students (BS, MS, PhD, professional degree) (2021): 10,793 Number of Departments (2021): 27 Number of staff (2021): 1,590	
	Infrastructure	The Division of University Corporate Relations in University of Tokyo Research Center for Advanced Science and Technology of University of Tokyo Institute for Open Innovation	KAIST Institute, Cross-Generation Collaborative Labs, Institute of Technology Value Creation	
	Government-built Infrastructure	N/A	▪ KAIST Laboratory Animal Resource Center (KAIST LARC) ▪ Institute for Security Conversence (ISC) ▪ KAIST Analysis Center for Research Advancement (KARA) ▪ KAIST Advisors on Materials and Parts (KAMP)	

	Programs to promote culture of innovation and entrepreneurship	Commencement of Collaborative Research/Entrusted Research The University Corporate Relations Proposal (UCR Proposal) Science and Technology Exchange Forum University Corporate Relations Network Management Office, Institute for Open Innovation uTIE Membership·	Startup KAIST K-School	
	Funding schemes	The Graduate School of Science's research efforts, which include joint research with other institutions, are mostly financed by Japanese government ministries, domestic science-related foundations, and other universities. MEXT (Ministry of Education, Culture, Sports, Science and Technology) METI (Ministry of Economy, Trade and Industry) MAFF (Ministry of Agriculture, Forestry and Fisheries) MLIT (Ministry of Land, Infrastructure, Transport and Tourism) MIC (Ministry of Internal Affairs and Communications) Ministry of Environment MHLW (Ministry of Health, Labour and Welfare) The University of Tokyo Edge Capital Partners Co., Ltd. (UTEC) TODAI TLO, Ltd	Total budget of US$765 million in 2013, of which US$459 million was from research contracts.	

	Promotion/tenure policies	N/A	According to KAIST's tenure policies, faculty who want to apply for or be appointed to the tenure track must not only perform well in teaching, but also make important contributions to scientific research and industry-university collaboration.	
	1 or 2 outstanding features or incentives or program or good practice	N/A	N/A	
	2-3 stellar inventions/spinoffs/faculty-inventors	N/A	▪ Soon-dal Choi: A scientist who made great contribution to South Korea's satellite-building development He is the founder of KAIST Satellite Technology Research Center and lead a collaboration with students from KAIST and University of Surrey to successfully engineer the first Korean satellite, KITSAT-1, also named "Our Star".[4] The satellite was successfully launched from Guiana Space Centre in 1992. ▪ Chang Hee Nam: A physicist; developed attosecond pulse generation and compression technology ▪ Eunseong Kim: a South Korean physicist. He is an experimental low temperature physicist. Along with his advisor Moses H. W. Chan, he saw the first phenomena which were interpreted as super solid behavior. In 2008, Kim was awarded the Lee Osheroff Richardson North American Science Prize, from Oxford Instruments for his contributions to the understanding of solid helium.	
TTO/KTO	Basic info	DUCR is currently composed of four sub departments: Office of Start-up and entrepreneurship education, Institute for open	Organizational structure - KAIST's technology transfer system includes both internal and external organizations. It has a human resources department, a committee/regulatory office, a budget office, a public	

		innovation, office of strategic research alliance and office of intellectual property management	relations/cooperation office and a technology value creation institute. ▪ *KAIST Vision 2031 Technology Commercialization Innovation* *Our vision is to suggest solutions to issues faced by our country and humanity and to create sustainable global value creation*	
	Basic profile of current TTO director or equivalent post	Toshiya Watanabe is conducting intensive study on “Intellectual Property Policy and Management” for innovation strategy, profiting from various organizational management resources as well as management of uncertain technology by 1) Empirical analysis using statistical data and/or questionnaire survey, 2) Case study 3) Project study collaborating with companies, government and international organizations.	▪ Chief University-industry Collaboration Professor) -Jongsung-Bae- KAIST Industrial Liaison Program & G-CORE Project output promotion ▪ Chief University-industry Collaboration Professor - Moon Jong Seo-Technology Transfer ▪ Chief University-industry Collaboration Professor- Hee Tae Kim-Technology Transfer	
	License income; IP Policies; Royalty distribution; Ownership distribution; Patents filing	▪ Promote licensing activities in collaboration with joint applicants, TLO, etc., so that inventions and others assigned to the University would be utilized in ways that maximize their social effects. ▪ With respect to the licensing technologies, focus on the potentials for application and business development in society together with the prompt feasibility thereof. ▪ Pay attention not to be utilized for purposes violating public order and morals. ▪ Pay attention not to produce any third party who is inflicted inappropriate damage due to the license activities. ▪ Take into account of the licensees’ social credibility and compliance situations.	▪ Introduction to R&D Incubation Support Projects (South East Korea Power Co., Ltd.) - Target: SMEs wishing to realise initial R&D related to power generation equipment and materials -What: Incubation of R&D by KAIST laboratories to support SMEs wishing to localise and develop new products - Scale of support: Project cost (approx. 30 million won/company), number of companies (approx. 10 companies per year)	

		▪ Pay attention not to hinder research activities due to the licensing activities. For this purpose, respect the concepts stated in the University of Tokyo Research License Treatment Guideline (established on August 5, 2008) and the University of Tokyo Research Tool Patents Treatment Guideline (established on February 8, 2008). ▪ 28 % to the inventors; 21 % to the inventors' university department; 21 % to the university itself; 30 % to Todai TLO		
	Spinoff	N/A	Total Patent Applications 14,681 (2006-2020)	
	1 or 2 stellar events/programs organized by the TTO	N/A	▪ K-Global ▪ Korea South-East Power Co. Ltd. R&D Incubation Support Project ▪ Industrial Liaison Program	
Startup incubator	Basic info	▪ UTokyo's incubator is formed by 4 parts: The University of Tokyo Entrepreneur Plaza, DUCR Incubation Room, Incubation Rooms on Komaba Campus, Entrepreneur Plaza Shared Incubation Room ▪ The University of Tokyo Entrepreneur Plaza: The Entrepreneur Plaza is the largest facility among the four facilities and was opened on Hongo Campus in 2007 housing a total of 29 rooms with roughly 58m² of space each. 20 of these rooms that are located on the 4th - 7th floors can be used as an office but can also be used as a wet laboratory capable of conducting P2 level biotechnology experiments. ▪ Incubation Rooms on Komaba Campus Starting in 2009, having offices of around 27m² as well as around 68m² in the Collaborative Research Building located on the Komaba II	▪ Startup KAIST was officially launched on April 7th, 2014, with the slogan "Stop Thinking, Start Doing." ▪ Startup KAIST is a movement led by KAIST for the revitalization of startups for the success of the national missions to create jobs and develop the engines of economic growth. Startup KAIST has three objectives to complete: invigorating the entrepreneurial spirit on campus, establishing an ecosystem in which startups can thrive, and helping startups to go global.	

		Campus as incubation rooms for startup companies and entrepreneurs. ▪ The University of Tokyo Entrepreneur Plaza Shared Incubation Room Since 2012, we operate a room in the University of Tokyo Entrepreneur Plaza as a shared office where entrepreneurs and startup companies can start a business by using a desk in the shared office. ▪ DUCR Incubation Room: The Office of Innovation and Entrepreneurship of the Division of University Corporate Relations (DUCR) seeks to achieve creative university-industry collaborations in order to implement the University's research outcomes into society and attain high-impact innovation.		
	Basic profile of current Startup Incubator director or equivalent post	N/A	Young Tae, Kim PhD--Associate Vice President of Institute for Startup KAIST--Director of K-School	
	1 or 2 stellar events/programs organized by the TTO	N/A	▪ K-School is home to the Startup Village, an entrepreneurial platform that supports all stages from idea development to the launch of startups. More specifically, the five stages are: strengthening of creativity → ideation → prototype development & R&D → incubating → startup launch. ▪ Idea Factory is a collaborative prototyping space available to all departments of KAIST. Include a variety of prototyping seminars, programs, and mentoring systems to bring forth student's creative ideas.	

University R&D support center	Basic info: year	Founded in 1996.5. The Center for Research and Development of Higher Education is working on improving the quality of education related to the University of Tokyo as a whole and supporting activities for that purpose.	▪ The KAIST Institutes (KI) was established in 2006 to foster interdisciplinary research at KAIST. ▪ Primary mission is to solve critical problems for the future of the humankind ; Develop new growth engines for the Korean economy. ▪ KI consists of six institutes and three centers: KI for BioCentury, KI for Information Technology Convergence, KI for Robotics, KI for NanoCentury, KI for Health Science and Technology, KI for Artificial Intelligence, Saudi Aramco-KAIST CO2 Management Center, Fourth Industrial Revolution Intelligence Center, and Center for Epidemic Preparedness. ▪ In KI, ~270 faculty members and ~300 researchers and students are currently engaged in various interdisciplinary research programs.	
	Basic profile of current R&D support director or equivalent post	N/A	N/A	
	1 or 2 stellar events/programs organized by the TTO	N/A	ISC was established for the purpose of developing innovative fundamental technology in the fields of security and national defense. Innovative R&D dedicated to cyber security, space systems, defense technology, autonomous systems, energy, materials, sensors, and quantum systems.	
Summary/ conclusions		▪ UTokyo received funding from Japanese National ministries and private owned fundings ▪ UTokyo will steadily advance these interlinked initiatives of creating knowledge, nurturing people and establishing a place of learning	As Korea's leading public university specializing in science and technology, KAIST receives research funding from the government and support from private organizations to support research and entrepreneurial innovation.	

3.4.2. Policy implications

Key message 1: Government and universities in Hong Kong should review how to further strengthen collaboration in building a vibrant innovation ecosystem - universities are vital, but not the only, contributors to the development of innovation hubs

Our case studies of selected universities demonstrate the pivotal role of universities in advancing the development of their respective innovation systems, as demonstrated by the case of KU Leuven in relation to the city of Leuven (and the Walloon-Brabant province, to some extent) in Belgium, or Tel Aviv University with respect to their longstanding linkages with the city of Tel Aviv in Israel. Nevertheless, universities are neither the only – nor the ones with core expectation – to primarily drive the development of innovation hubs within their localities. Similar to an ecosystem model, a thriving innovation hub comprises a configuration of diverse organizations with various types of expertise and missions, with rich complementarities and inter-organizational linkages. These can be exemplified from the strategic roles of government research centers in Leuven (such as IMEC and VIB), as well as networks of venture capital (VC) firms and serial entrepreneurs in Tel Aviv, in driving the development of the hubs beyond the universities alone.

Key message 2: Universities in Hong Kong should further promote the engagement of various innovation actors in knowledge transfer - universities' success in promoting innovation and entrepreneurship may have more to do with holistic inclusion of stakeholders than supportive faculty policies alone

Our in-depth profiling of the selected innovative universities also highlights a varying degree of inclusion of excellence in knowledge/technology transfer activities in their faculty tenure and performance evaluation policies. On one hand, certain universities openly encourage their faculty members to be involved in outside practices (e.g. KU Leuven), and for those who do not, there would be – at minimum – an inclusion of their activities and/or related achievements into performance assessment exercises (e.g. Imperial College London). On the other hand, there were also instances of major innovative universities that are fairly restrictive with respect to faculty members' engagement in KT/TT activities (e.g. Tel Aviv University). Interpreting these diverse findings, supported by our interviews and document analysis, we found that other university stakeholders, especially students, alumni, researchers, and KTO/TTO staff, are of considerable importance in shaping innovation and entrepreneurship ecosystems of these organizations. In other words, a holistic perspective has to be adopted to further incentivize their participation in these areas.

Key message 3: Universities in Hong Kong should provide pre-full licensing agreements to incentivize firms to license university inventions

In many places, one of the barriers to finding firms that can license university inventions relates to the absorptive capacity of firms. Firms may lack the resources, the skills or familiarity with regard to universities' inventions. Universities have been helping firms in capacity building through joint R&D agreements. In some of the top universities we studied (e.g., University of

California Berkeley), we observed that they offered a variety of licensing products prior to the signing of full licenses, such as letter of intent, option agreement or evaluation agreement. These licensing products will allow firms to have access to specific information about a technology, and to test and conduct feasibility studies. The adoption of this strategy for marketing IPs and for incentivizing firms to license university inventions, we argue, has the potential of enhancing universities' licensing performance. In addition, we suggest the inclusion basic figures on the number of these types of licensing agreements in the annual knowledge transfer reports, as a way of giving due recognition to the efforts that have gone into the process whether or not it has led to the signing of full licenses. Such recognition of efforts can be a significant motivating factor to technology transfer officials as well as university inventors.

Key message 4: Through investment and education, Hong Kong should continue nurturing highly skilled and highly trained innovation managers

We suggest that Hong Kong should prepare and attract more highly skilled and highly trained people to work as innovation managers in the technology transfer offices of universities. We have found that in some universities we have studied (e.g., KU Leuven and University of Washington Seattle) that their individual technology transfer offices have a large team of innovation managers, each of whom manage a portfolio of many projects and companies related to their universities' faculty, students, and alumni. It is advantageous for innovation managers to have advanced learning in specific STEM-related disciplines as well as Business or Marketing fields to enhance their effectiveness in providing adequate help to university researchers (e.g., aligning their research to benefit industry needs, pitching their ideas to investors, and connecting them with VCs) and thus, motivate faculty (as well as students and alumni) to engage in knowledge transfer exchanges. Innovation managers also play an important role in building close linkages between university scientists and researchers and the knowledge transfer office. The work of innovation managers can enhance the commercialization of university inventions and let success stories foster the 'I also can' attitude among faculty and students, which can contribute to improvement of the overall innovation performance of universities.

Key message 5: Universities in Hong Kong should review ways to better incorporate researchers' concerns into university polices - The academic contribution to industry is largely restricted due to the lack of university policy support and researchers' proximity to the industry.

Our analysis based on the survey data covering 16 universities in 5 regions suggest that there are some gaps between the current policies and the researchers' needs. To promote the university's contribution to the industry, it is necessary to design more effective policies by taking researchers' concerns and needs into consideration. Firstly, compared with domestic government funding received by the researchers, the industry funding has a relatively small percentage. And previous study shows that inventions produced from industry funding are more likely to diffuse than other funding. Thus, it is important to change the current funding structure by encouraging the researchers to apply for more industry funding. Second, very small percentage of respondents think the knowledge transfer activities contribute to the industry,

while most of them only regards these activities as opportunities to seek funding from the government research funding agencies. After taking the university policies and support into consideration, our findings imply that policy on the sharing of royalty income and engage in knowledge transfer related work are not satisfied among the respondents. Additionally, there are also big concern towards invention disclosure because faculty members think their efforts are not rewarded and other people may steal their ideas. Overall, it is necessary to design effective university policies to support knowledge transfer activities, motivate researchers and improve researchers' proximity to the industry.

Key message 6: Beyond the traditional roles such as teaching and education, Hong Kong should consider introducing institutional experiments in terms of the appointment policies of faculties.

The basic role of faculties is to contribute to the development of regions and countries by producing knowledge and nurturing talented students. Despite the changes of the times, the unique role of universities continued to give an emphasis on teaching and research. However, the rapid development of science and technology, changes in the industrial system, and convergence of disciplines across academic boundaries require more changes in the employment systems of faculties. Firstly, one of the universities we studied (i.e., Seoul National University) introduced a system of appointment to faculty positions that focus on the university-industry cooperation. Since candidates for this position are required to have more than 10 years of industry experience, we can interpret that the university has the intention to utilize their personal networks and connections in promoting university and industry cooperation. In addition, despite their positions as professors, they do not have any teaching and/or research obligations, which allows them only to focus on the university-industry cooperation. Secondly, an institutional experiment to break away from the traditional 'one day per week' policy can be introduced. By changing the existing policy, the restriction of outside activities of existing full-time professors is allowed to be more than 8 hours. In addition, prominent talents from global big tech companies can concurrently hold faculty positions at Seoul National University. Therefore, Hong Kong can consider this change in order to promote university-industry collaboration and attract prominent experts to the universities of Hong Kong.

4 Task 3 – Comparative Analysis of Global Innovation Hubs

4.1 Introduction

In the first two tasks of this project, we have engaged in in-depth case studies of five selected Hong Kong universities and 18 universities around the world based on the existing premise that universities have a potential to contribute to regional and economic development of their localities through multiple roles (Etzkowitz, 2012; Uyarra, 2010). In the third task, we seek to broaden the scope of analysis beyond universities, and examines the localities where these universities are located from a historical and evolutionary point of view.

Universities have also been highlighted as some of the core, strategic actors that are pivotal for RIS development (Cooke et al., 1997; Cooke, 2001), enhancing the tripartite Triple-Helix (university-industry-government) linkages (Etzkowitz and Leydesdorff, 2000), as well as rejuvenation in regions with maturing/declining industries (Safford, 2003). For regions struggling with declining industries, in particular, universities can be highly vital in revitalization when they embed themselves with local knowledge networks, and help promoting the emergence of new entrepreneurial communities in emerging industries (Benneworth and Charles, 2005; Safford, 2003). Universities' roles are even more significant when knowledge bases in the emerging industries are closely relevant to those of the preceding sectors, i.e. polymer innovation-based industries with knowledge base from the maturing tire industry (Boschma, 2015; Safford, 2003). However, can universities always be expected to play a leading role in regional development? Some scholars have – theoretically and empirically – argued and demonstrated that the reality is more complex and intricate than the proposition above constantly assumes. In an extensive, critical review of the past literature on universities' regional roles, Uyarra (2010) argued that university-RIS relationships are not necessarily straightforward, and at best, their impact on regional development has been relatively mixed.

As we proceed in the remainder of the report in profiling selected innovation hubs across the globe, we will demonstrate that while no one-size-fits-all grand narrative exists among these case studies, there are common threads that can provide useful, and relevant, lessons for Hong Kong to consider, particularly in innovation policy-making processes. Given the nature of this SPPR project, we also seek to explore the potential scope of contribution for universities – as well as their limits – in the innovation hub development processes. Moreover, due to the endemic nature of each of these studied hubs, we further provide explanation on the no-less vital roles played by other types of innovation actors, following Uyarra et al. (2017). The following sections provide an in-depth, comprehensive study of each of the eleven selected, globally renown innovation hubs: Hong Kong, Shenzhen, Shanghai, Beijing, Tokyo, Seoul, Singapore, Tel Aviv, London, Seattle, and Silicon Valley. In each of the 11 hubs, we will also draw on the existing universities that we have covered in Task 1 and Task 2 reports.

Table 4-1 Global Innovation Hubs Selected for the Analysis in Task 3

Name of hub	Pairing university selected in Task 2
Hong Kong	City University of Hong Kong (CityU) Chinese University of Hong Kong (CUHK) The University of Hong Kong (HKU) The Hong Kong University of Science and Technology (HKUST) Hong Kong Polytechnic University (PolyU)
Shenzhen	Southern University of Science and Technology (SUSTech) Shenzhen University (SZU)
Shanghai	Fudan University Shanghai Jiao Tong University (SJTU)
Beijing	Tsinghua University
Tokyo	University of Tokyo (Todai)
Seoul	Seoul National University (SNU)
Singapore	National University of Singapore (NUS)
Tel Aviv	Tel Aviv University (TAU)
London	Imperial College London (ICL)
Seattle	University of Washington (UW)
Silicon Valley	University of California – Berkeley (UC Berkeley)

Three types of analyses will be employed to inform findings regarding each of these hubs: 1) network analysis; 2) analysis of university-industry collaboration based on selected universities in Task 2, and; 3) identification of investment activities in high-technology firms by locally-based investors and venture capital (VC) funds. Before we proceed with our elaboration for each of the three methods – which we will uniformly apply across all 11 innovation-hub cases, we will first provide our theoretical justification for our selection of these analytical approaches.

4.2 Rationales for selection of analytical approaches in this work

Network analysis has been introduced as a promising path to better understand the dynamics and evolution of economic geography of localities of interest (**Ter Wal and Boschma, 2009**). One major limitation of the existing network analysis-themed works has been their tendency to study events at a single point in time, rather than observe their changes across multiple time periods. By adopting a dynamic approach, network analysis can provide a better, and more systematic, breakdown of how different actors in an innovation system build their ties, as well as examine which actors would subsequently play a major role in shaping the innovation system in turn (**Ter Wal and Boschma, 2009; Spigel and Harrison, 2018**). Simultaneously, network analysis represents a promising avenue for reconciling the recent ecosystem-oriented literature with its conceptual antecedents (NIS/RIS, cluster, industrial district-related academic

works) by emphasizing that not all local/regional stakeholders experience and interpret their ecosystem in the similar dimensions (**Casper, 2007; Spigel and Harrison, 2018**). Rather, the degree to which these regional actors contribute to the development of the localities depends considerably on the nature of relationships they have with their surrounding regions and the institutional set-up, which brings us again to the argument pointed out by **Uyarra et al. (2017)**. Network analysis – if performed in a dynamic setting – also enables us to observe the effects of failed organizations/businesses on the resilience of the localities, whether positive (in the form of externalities) or negative (in the form of 'ecosystem collapse') (**Brown and Mason, 2017; Spigel and Vinodrai, 2020**).

However, sole reliance on patent data to capture inter-organizational knowledge flows and spillovers, as well as career mobility linkages, may overlook other types of knowledge interaction and exchange among ecosystem actors that do not involve technology development (**Nelson, 2009**). As an illustration, less than 5% of all patents worldwide involve co-patenting practices (whereby two, or more, organizations have joint ownership rights over a patent), and when this figure includes multi-applicant co-inventorships (instances where an inventor has patents assigned to two, or more, organizations), the figure rises to only somewhere around 20% (**Laforgia and Lissoni, 2009; Ter Wal and Boschma, 2009**). Given that the core theme of the SPPR project has been about the role of universities with respect to the development of innovation hubs, and our particular emphasis on university-industry collaboration, we also consider the proposition that both actors work closely in the realm of scientific research and knowledge exchange. University-industry joint publications – which, for the sake of convenience, we will refer to them in the rest of the report as 'U-I co-publications' – have been touted as one promising avenue in tracing the degree of knowledge co-production among these actors (**Tijssen et al., 2009**). With the growing convergence in scientific and commercial values among academic and industry scientists (**Vallas and Kleinman, 2008**), followed by a recent phenomenon in which incumbent corporations increasingly resort to knowledge exchange and/or acquisition with universities, research institutes, or niche-technology start-ups rather than solely their own in-house R&D labs (**Arora, Belenzon, Patacconi, 2018; Zahra, Kaul, Bolivar-Ramos, 2018**), the trend of U-I co-publications can be expected to expand substantially in the future. Analyzing scientific knowledge collaboration through this indicator may, to a certain degree, compensate for the limitation of patent data analysis that primarily pays attention to technical knowledge (**Nelson, 2009**). Moreover, the open-source nature of academic publication databases enables the use of U-I co-publications to be benchmarked universally across different parts of the world (**Tijssen et al., 2009**).

However, again, the use of patent and publication data can only by and large cover the science and technology dimensions of innovation ecosystems, while overlooking the dynamics of technology companies that do not necessarily engage in publishing and patenting practices. One example would be mobile app developers that build best-selling mobile games, e-commerce platforms, or ride-hailing services. While some companies in such sector may own patents, their portfolio – in comparison to those of established, science-based enterprises – is considerably limited, and may result in disproportionately low centrality scores when included in network analysis, despite their significant impact on consumers' daily lives. One useful avenue to identify the presence of such enterprises would be to investigate the degree to which

they have received the attention of financiers and venture capitalists (VCs). Such reasoning necessitates us to include the third analysis, which relates to the identification of investment activities by investors in co-located technology firms. In this regard, we follow **Sorenson and Stuart (2001)**, whose groundbreaking work demonstrates that VCs, and their co-investment syndicate networks, are significantly more likely to invest in technology start-ups located within their geographical vicinity. Simultaneously, the third analysis is motivated by the recent observation that VCs are increasingly investing in technology start-ups overseas, often in response to either intensified competition with other VCs or the growing attraction of emerging economies, which are often facilitated by immigrant entrepreneurs (**Balachandran and Hernandez, 2021**); in this regard, we seek to observe the extent to which local VCs are still investing in technology companies within their localities.

Still, even with our best efforts through the three comprehensive, distinctive analyses, we are cognizant of existing limitations with our study. In this regard, we have not taken into full consideration other types of intangible-value innovation, such as business model innovation, service innovation, or the recently emerging discourse on social innovation and entrepreneurship (c.f. **Bayuo, Chaminade, Goransson, 2020; Thompson, Purdy, Ventresca, 2018**). The nature of organizations' business models, and its evolution, in particular, is substantially linked to the resilience of entrepreneurial ecosystems (**Roundy, Brockman, Bradshaw, 2017**). We also have not taken into consideration the possibilities of innovation arising from open-source communities, as well as other crowdsourcing-related platforms, e.g. open innovation contests by incumbent corporations to source the best ideas on technologies and/or business models (**West and Lakhani, 2008**). In order to address these limitations as much as possible, we include – on each of the 11 hub-related case studies – several mini-boxes that highlight some of these types of innovation, as well as other indirectly vital driving factors beyond the role of universities that we have mentioned in the previous pages. These mini-boxes, we hope, will partly compensate for such limitations.

Afterwards, we provide elaboration on the methods and data sources we utilized in conducting our three analyses for each of the hubs. In the first analysis, we made use of USPTO PatentsView dataset, covering 1983-2018 period, equivalent to a total of 36 years. Such extensive timeframe – which surpasses the analytical timeframe as agreed for the SPPR project (2009-2018 period) – enables us to observe the long-term evolution of these innovation ecosystems, in terms of the composition of organizational actors with the highest number of patents, shifts in the types of most actively-engaged actors over time, as well as the nature of their linkages. Following **Fleming and Frenken (2007)**, **Fleming, King III, and Juda (2007)** and **Ter Wal and Boschma (2009)**, we split our time frame into multiple periods of analysis – and given our data – into 6 different six-year periods (1983-1988, 1989-1994, 1995-2000, 2001-2006, 2007-2012, and 2013-2018) on the basis of filing years of these patents. Having engaged in data cleaning efforts – by either excluding patents with no organizational assignees or incomplete information, as well as streamlining the names of assignee organizations – we first listed out the top-10 innovators for the entire 1983-2018 period, before proceeding to replicate our analysis across each of the six-year periods.

Throughout the entire analyses, we will take into consideration two network properties for our

interest: degree centrality and betweenness centrality (**Freeman, 1977**), with the latter used more frequently than the former. Before we proceed to explain about these centrality measures, nonetheless, we first will have to explain how we obtain such measures in the first place. In this regard, we rely on inter-organizational linkages drawn from the basis of inventors patenting on behalf of two, or more, applicant organizations, following **Cantner and Graf (2006)** and **Graf and Henning (2009)**. Inventors were, in turn, identified on the basis of their unique identification numbers, for which USPTO PatentsView dataset has provided after the creators performed extensive disambiguation efforts on inventor names.

With regard to the analysis of publication data, we obtained our subsets of data based on the 23 universities we have covered for both Task 1 and Task 2 reports, covering a 10-year period from January 1, 2009 to December 31, 2018 (on the basis of publication dates for these academic works, which are peer-reviewed journal articles). For the publications specifically, we referred to Lens.org to collect our data. Lens.org offers a huge advantage over existing databases as the website serves as an open-source repository for both publications (in which over 240 million of them are being stored) and patents (covering an aggregate of 130 million such documents), as well as patent-paper citation linkages (**Jefferson et al., 2018**). In addition, Lens.org allows us to export search results – free of charge – in a larger observation size (capped at a maximum of 50,000 for each search request, compared to 500 for Web of Science / WoS), with an unlimited number of requests granted for each user signing up for the website services.

While we only provided brief overview regarding these data in the first two reports, here we will delve deeper into the scientific research landscape of these universities and their broader relationships with the surrounding innovation systems, with a particular interest in scientific knowledge exchange involving corporate researchers. Following **Tijssen et al. (2009)**, we proxy for the presence of such knowledge exchange through the existence of peer-reviewed journal articles co-authored by university and industry scientists, which we simply abbreviate as 'U-I co-publications'. We labeled an article as a co-publication through in-depth reviews of the institutional affiliation of the co-authors, using a combination of text-mining methods, manual checks, and visits to company websites, following **Powell et al. (2016)**.

In each of the 11 hubs, we will draw on the existing universities that we have covered in Task 1 and Task 2 reports. We are specifically interested in identifying with which enterprises scientists and faculty members from these universities have been repeatedly involved in collaborative research. Given the potentially wide geographical spread of these enterprises (**Jefferson et al., 2018**), we categorize these enterprises into three types as follows: 1) local; 2) domestic non-local, and; 3) foreign. Our consideration in delineating the 'local' and 'domestic non-local' boundaries was not driven by a strict geographical threshold, as **Tijssen et al. (2009)** have shown using several cut-off points (e.g. 100 miles, 1,000 miles, etc), but rather by taking into account the institutional, geographical, and social contexts of each hub we are covering, given the diverse conditions of different national jurisdictions. As we go through each of the listed hubs, we will explain in more details how we delineate the 'local' and 'domestic non-local' categories. Singapore, specifically, is an exception (given its status as a city-state); here, we decided to merge these two categories. Foreign firms, in this regard, refer to enterprises

located outside the national jurisdictions of these hubs. Afterwards, we seek to identify the top 10 collaborating firms with each of these universities on the basis of three geographical categories above.

Beyond identifying the most frequent industry collaborators from those three distinctive categories, we engage in additional investigation to identify subsets of locally-based collaborating firms that happen to be university-based spin-offs. Our motivation, beyond highlighting the roles of such institutions in their surrounding innovation ecosystems, is to provide evidence of generalization posited by **Murray (2002)** on the persistent tendencies of such spin-offs to continue engaging in knowledge exchange with the founding researchers and/or their laboratories, even long after they have transformed into independent companies. Once again, following **Powell et al. (2016)**, after we identified names of collaborating entities through analysis of institutional affiliation, we engaged in comprehensive 'site visits' of these company websites to ascertain the educational and professional backgrounds of company founders, senior leaders (mainly CEO and chairpersons), as well as their chief scientists. A company is labeled as a spin-off whenever any of these individuals had prior education, research, and/or work background in universities, whether as research students, PhDs, MBA, postdoctoral researchers, or faculty members. In most universities throughout the hubs covered in this report, we were able to successfully identify such companies, albeit with a considerable degree of variation. One limitation from our approach is that we may exclude spin-offs with no co-publications with universities, but nevertheless originated from academic research in those institutions. Relatedly, some of these enterprises may have also been no longer existent for a variety of reasons.

Coverage of investment data – complementing patent- and publication-based analysis – allows us to further identify technology companies that, while engaging in little to no inventive and/or scientific research activities, have nevertheless contributed significantly to the surrounding innovation ecosystems (e.g. ride-hailing services, mobile applications, etc). We are specifically interested in following the approaches by **Sorenson and Stuart (2001)** in terms of assessing the extent to which investors have paid attention – and subsequently supported – co-located technology firms, a strategic indicator of 'resource regeneration' by successful entrepreneurs in encouraging the formation of next-generation enterprises (**Stam and Spigel, 2016**).

In this regard, we collected data from Crunchbase, a subscriber-only database of over 1 million technology companies across the globe. Unlike our previous two proposed approaches on both the patent and publication data, we impose no limits on the period of analysis, but rather observe the entire, aggregate financing records of these investors. Given the existing space limitation, and our interest in the most influential investors, we purposefully limited our attention to the top 25, ordered on the basis of their cumulative number of investments. As a proxy for 'resource regeneration', we follow **Sorenson and Stuart (2001)** by identifying the proportion in which these financiers' investment activities are allocated towards technology firms co-located within their vicinity. Contingent on the unique situations of each hub, whenever circumstances permit, we will also provide basic description on the nature of some of these top-25 investors for each hub (e.g. whether they are government-funded VCs, university-run VCs, corporate VC funds, investors-cum-incubators, accelerators, etc).

To further validate results from these three analyses, we also perform a comprehensive industry survey targeted towards enterprises based in these 11 hubs. Incentives and barriers related to university-industry collaboration are explored, and the generated results will supplement our previous suggestions for ways to improve U-I collaboration.

4.3 Survey Analysis

4.3.1. Survey design and data collection

In this survey, we pay attention to how– and in what ways – university-industry collaboration, could generate impacts for the collaborating enterprises and focus on the factors that influence entrepreneurs' activities in the hubs as well as factors concerning funding, mentorship opportunities, and market linkages. To capture industry perspectives on university-industry collaboration, a questionnaire survey was sent to enterprises located in the 11 selected innovation hubs following the procedures carried out in Task 2. Broadly, the questionnaire seeks information on the barriers and incentives affecting the university-industry collaboration, and the potential measures to improve it.

The preparation of the questionnaire also took several months, from December 2021 until February 2022, and included the analysis of the existing survey instruments and several internal discussions with project advisors. The final version of the survey includes five sections. The first section of the questionnaire gathers general information of the firms. The second section of the survey is related to the enterprises' experiences on collaboration with universities. The third section asked about the enterprises' motivation to engage in the collaboration, followed by the questions on the incentives and barriers in the fourth section. The fourth section is dedicated to suggestions for improving university-industry interactions. The final section is optional and includes one open question about any additional information that was not covered by the questionnaire.

As what we did in Task 2, before the survey distribution, the team extracted email addresses from companies that have been identified from both Crunchbase, as well as company names extracted from co-publication and co-patent data obtained from the 17 universities listed in Task 2. A total number of 17, 895 emails were sent to the identified company or individual addresses in the selected hubs. The survey was administered in March-August 2022. Respondents received a request through email to complete an online questionnaire through the Qualtrics with the deadline stated. We sent the survey invitations in batches for better management of the process, with the first batch sent to mainland cities in March and April and the remaining hubs in the second batch. To improve the response rate, a follow up email was sent after 2 weeks with the reminder to fill in the survey for those who still did not do this. Finally, 776 responses were received in total and after excluding incomplete responses, our final sample includes 722 responses (4% of the usable population).

4.3.2. Survey results

Table 4-2 shows the characteristics of respondent companies. Firms are also asked about whether they have interacted with universities in the past five years and more than 60% of the firms stated which had interacted with universities.

Table 4-2 Characteristics of respondent companies

	With UIC		Without UIC		
	Frequency	Share (%)	Frequency	Share (%)	All (frequency)
No. of employees					
0-100	261	65.2	139	34.8	400
101-250	97	81.5	22	18.5	119
251-500	82	80.4	20	19.6	102
501-1000	34	70.8	14	29.2	48
>1000	39	73.6	14	26.4	53
Sector					
Bio-medical Technology	102	82.9	21	17.1	123
Comprehensive industry	20	64.5	11	35.5	31
Electronics	29	72.5	11	27.5	40
Finance and insurance	43	63.2	25	36.8	68
Green Technology	15	48.4	16	51.6	31
ICT	22	59.5	15	40.5	37
Information technologies	137	71.4	55	28.6	192
Manufacturing	77	75.5	25	24.5	102
Material and precision engineering	11	84.6	2	15.4	13
Others	54	63.5	31	36.5	85

University-industry collaboration channels

The respondents were asked to select the channels that their company used to identify academic partners in university-industry collaboration. Informal relationship seems to be the most frequent interaction way as identified by the respondents (23.82%), followed by the meetings on professional associations or industry associations (21.47%) and online platform (20.22%). Companies would also seek opportunities and potential collaborators through conference participation and universities' websites, with the latter one often used by the enterprises in mainland cities.

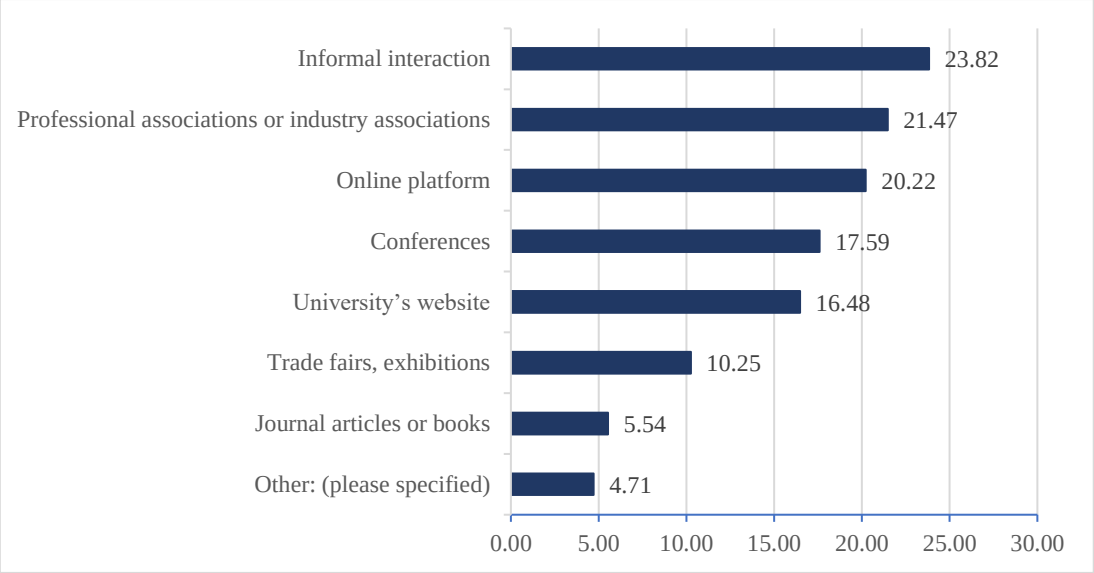


Figure 4-1. Percentage of University-industry collaboration channels

Experiences on Collaboration with Universities

Respondents were asked to indicate at what stage they would like to collaborate with universities. Among the four options shown below, activities related to applied research was favoured by the enterprises, followed by the technology development stage. Relatively, enterprises may less consider the interaction with universities in marketing stage or production stage.

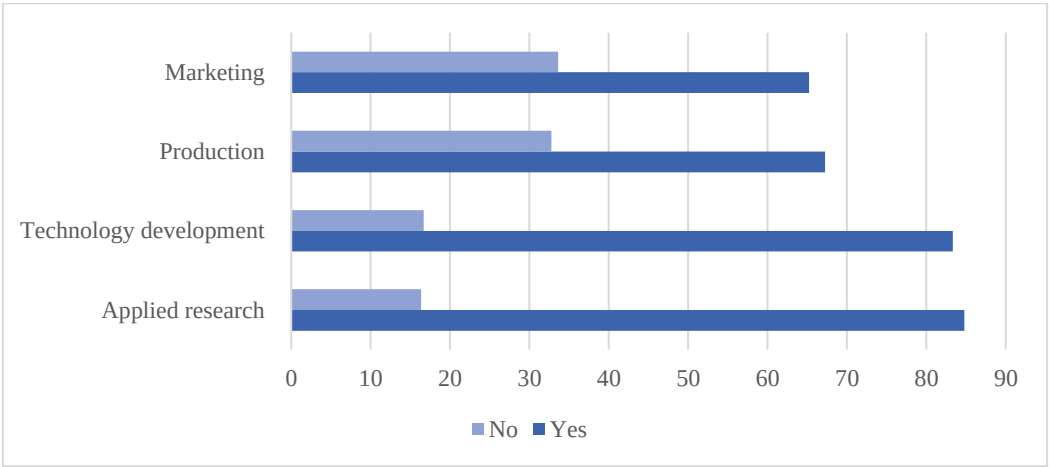


Figure 4-2 Respondents answering which stage they would prefer to collaborate with.

Motivation to collaborate with universities

The respondents were asked to select the reasons why they chose to collaborate with universities. As shown in Figure 4-3, one of the main factors they considered was to create innovative products, technologies, and markets, followed by the motivation to strengthen the companies' R&D capabilities by learning new research techniques from university researchers. Enterprises also expressed their interests in accessing faculties in the universities who created

cutting-edge technologies with huge commercialisation potentials. Relatively, less interests were stated by the respondents regarding the access towards the exclusive licensing for patents.

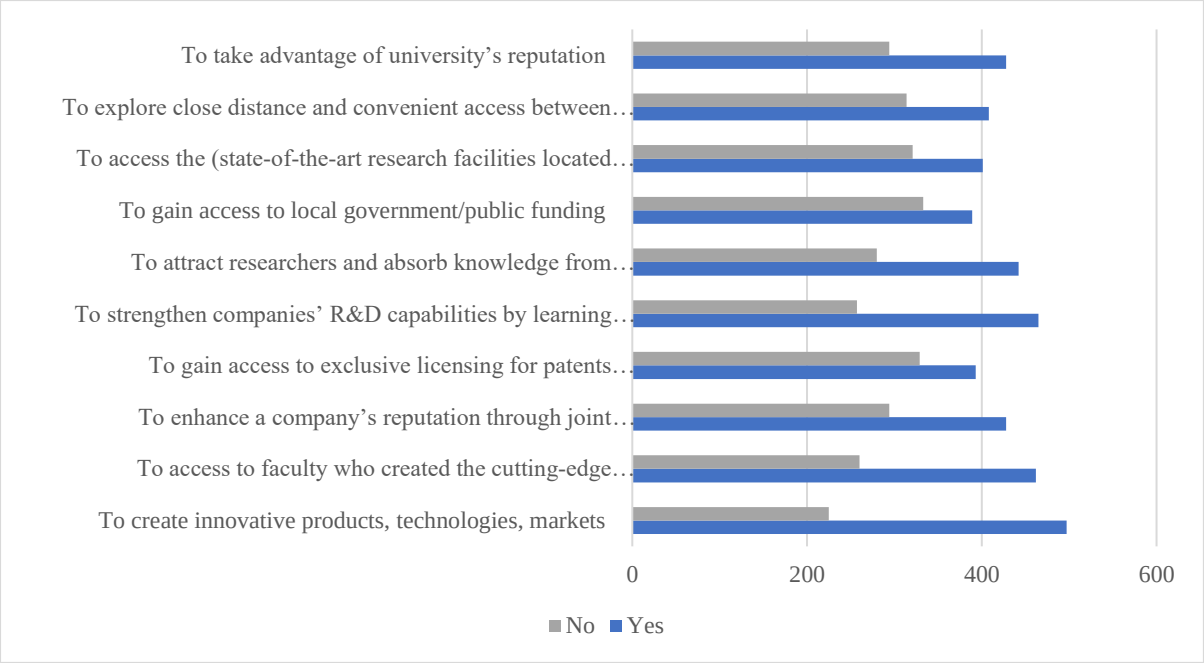


Figure 4-3 Motivations to collaborate with universities

We also asked the respondents to weigh the importance of four factors that could enhance their companies' incentives to collaborate with universities, as shown in Figure 4-4. We use a five-scale measurement of agreement in our survey: 0-not at all important; 1-slightly important; 2-moderately important; 3-very important; 4-extremely important satisfied. The results indicate that clear university intellectual property policies and universities with comprehensive research facilities and joint research labs might be two important factors companies consider. Some respondents also considered universities with outstanding researchers and high international ranking as one potential factor, while a same proportion of the respondents indicated that this may not be an important factor when collaborating with universities.

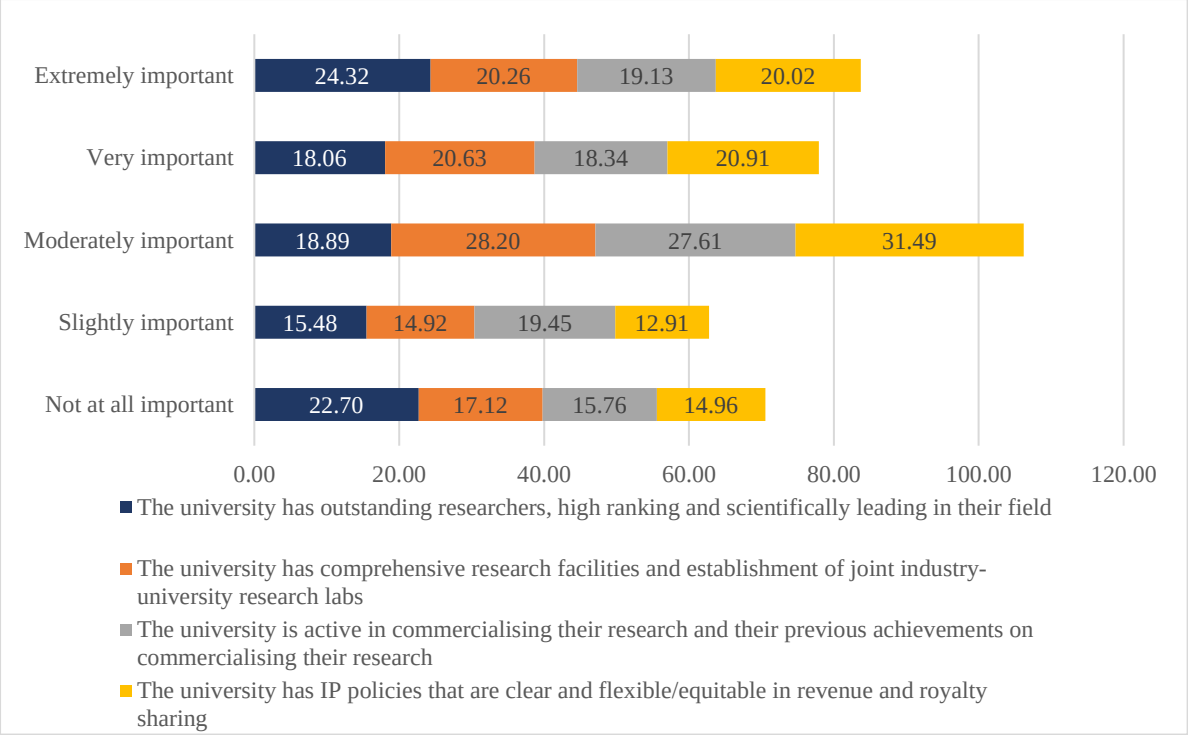


Figure 4-4 Industry's perceptions of factors driving university-industry collaboration

Barriers

Respondents were asked to evaluate their perspectives on barriers to collaboration with universities. Figure 4-5 shows the weighting scores on a five-scale measurement, ranging from 0 (no obstacles) to 5 (major obstacles). Among all different barriers, more than 70% of the respondents think these belong to small or no barriers. Similar to what we identified in task 2 survey, the biggest barriers, comparatively, still appear to be different views and objectives between industry and academia. Different working habits and expectations, as mentioned by some respondents, could cause additional conflicts and issues during the negotiation or collaboration processes. Importantly, lack of individuals or intermediary organisations that were both capable of conducting R&D activities and managing knowledge exchange channels were also considered as one of the barriers for engagement with universities.

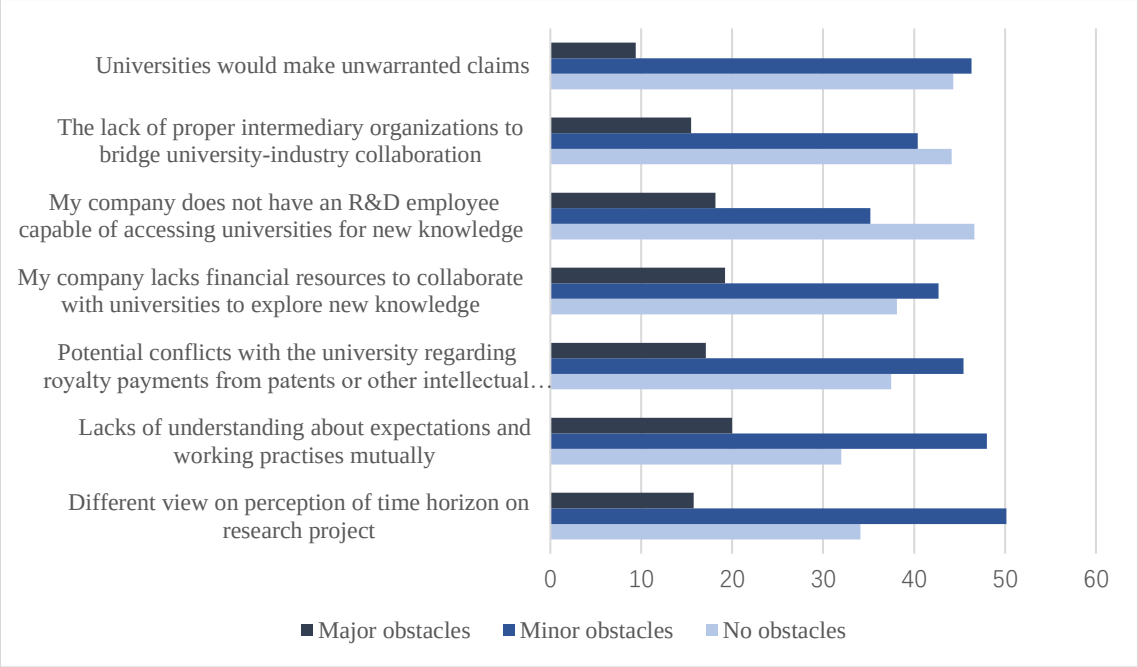


Figure 4-5 Barriers for engagement with universities

Industry perceptions of measures to improve UIC

Table 4-3 provides the information on respondents' opinions of the potential measures to improve collaboration with industry. A five-scale six-scale measurement of agreement was used: in our survey: 1-Strongly disagree; 2-Somewhat disagree; 3-Neither agree nor disagree; 4-Somewhat agree; 5- Strongly agree. The average number of their answers were calculated. Measures with the highest average score include the improvement of informal channels and provision of tax incentives for companies to collaborate with universities. Industry-sponsored degree programs should also be promoted, as indicated from the relative high score and also the additional comments left by some of the respondents. When asked about other potential suggestions for improving university-industry collaboration, some survey respondents mentioned that more opportunities should be created to facilitate the exchange of researchers and entrepreneurs. Meanwhile, clear intellectual property rules and ownership measures should be made, as stated by one of the respondents regarding the open UIC projects.

Table 4-3 Perspectives on suggestions for improving UIC

	Mean	Std
Enhance the access to laboratory facilities and other infrastructure at universities	2.3	1.4
Improve the exchange of information between universities and industry	2.6	1.4
Foster the university and industry collaboration via informal meetings, talks, communications	2.6	1.4
Establish industry-sponsored degree programs	2.5	1.3
Provide tax incentives for companies collaborating with universities	2.6	1.3

Set up industrial/science parks closer to university campuses	2.5	1.3
Encourage academic representation in industrial committees / chambers / board meetings	2.4	1.3

4.4 Case studies: 11 innovation hubs

4.4.1. Hong Kong

4.4.1.1.Introduction

Hong Kong is one of the two special administrative regions (SARs) of China. The city's unique status as an SAR can be reflected from the 'one country, two systems' institutional configuration, in which Hong Kong would maintain their current economic and political systems for at least 50 years, as well as enjoy a high degree of autonomy in all affairs except foreign affairs and national defense. Hong Kong has long been known as a highly developed trading entrepot and an international metropolis. After World War II, Hong Kong's economy developed rapidly. It not only ranked among the "four little dragons in Asia", together with Singapore, South Korea and Taiwan, but also became one of the richest, most developed and highest living standards in the world. The city ranks highly in terms of international business competitiveness. According to the Global Competitiveness Index in 2019, which is published annually by the World Economic Forum (WEF), Hong Kong ranks third with 83.1 points. In the world competitiveness rankings released by IMD, Hong Kong ranked second in 2019 and fifth in 2020. Further, the Shenzhen-Hong Kong-Guangzhou science and technology cluster ranked second based on the Global Innovation Index 2021.

One major bright spot for Hong Kong's science, technology, and innovation (STI) performance is linked to the presence of prestigious research universities. Many of the city's universities have demonstrated excellence in research and teaching, as shown by their high positions in QS and THE rankings. However, in terms of the development of technological innovation, Hong Kong has been considered as a laggard; this has been highlighted in both academic literature (c.f. **Baark and Sharif, 2006**; **Fuller, 2010**) and various innovation-related indices. For illustrations, the city ranked 14th in the Global Innovation Index in 2019. In the Bloomberg Innovation Index 2020, Hong Kong only ranks 39th. By comparison, China ranks 15th. Moreover, despite the well-recognised basic research capabilities of Hong Kong universities, a study report by **Our Foundation HK (2020)** pointed out their weaknesses in commercialisation of university research and generation of societal impacts. In recent years, Hong Kong government has adopted more proactive innovation policies to improve its less-than-satisfactory performance in innovative activities. In the following sections, we will first briefly describe the industry development and R&D capabilities in Hong Kong, followed by an overview of the existing government policies to promote R&D, talent, and diversified functions of Hong Kong universities.

The development of industrial structure of Hong Kong

Historically, there has been a lack of upgrading the manufacturing industry, which has been primarily driven by consumer goods and persistently faced a low absorptive capacity due to limited R&D (**Baark and Sharif, 2006; Fuller, 2010; Huang and Sharif, 2009**). From the 1950s to the 1970s, Hong Kong's local manufacturing sector flourished, reaching a record high

of 31% of GDP in 1970, with manufacturing employment accounting for over 40% of total employment. The development of the manufacturing sector drove the take-off of the Hong Kong economy into a phase of sustained high growth, with Hong Kong's average annual growth rate of 9% during this phase. This manufacturing boom led to the construction of infrastructure such as transport and electricity and the development of tertiary industries, and the value of exports of local products rose rapidly as a proportion of total export trade. From the end of the 1970s to the handover of Hong Kong, under the influence of the oil crisis, increased protectionism, numerous competitors and the reform and opening up of the Mainland, Hong Kong's economic development ushered in new opportunities. By forming the so-called "front shop, back factory" cooperation model with the mainland, Hong Kong has made full use of the comparative advantages of the two places, and has transformed from a free port based on Hong Kong product exports to a free port based on service economies. Since the 1980s, more and more local enterprises have started to relocate their largely low-end production and assembly functions to Mainland China, especially cities in nearby Guangdong Province. As a result, the manufacturing industry, which once led Hong Kong's development, has continued to shrink, while the service industry's share in GDP and employment continued to rise, eventually becoming the leading industry in Hong Kong's economic development (**Thun, 2010**). According to World Bank and the city's Census and Statistics Department, Hong Kong's manufacturing value-added-to-GDP ratio has been precipitously dropping from nearly 5% in 2000 to approximately 1% as of 2018 (details in Figure 4-6 below). The role of manufacturing is weakened to an extent that it makes little contribution to the SAR's economy in terms of GDP output.

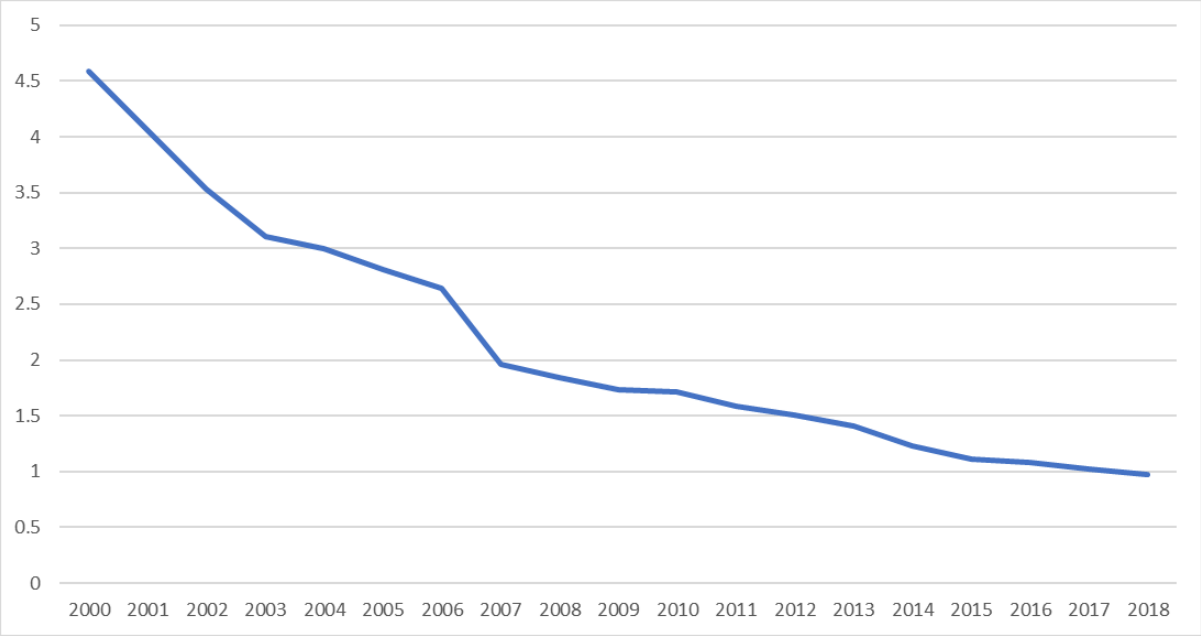


Figure 4-6 Hong Kong's manufacturing value-added as a % of GDP (2000-2018)

Instead, Hong Kong has transitioned into a city driven largely by four key industries, namely finance, tourism, international trade and logistics, and professional services. As a 'gateway' to mainland China, Hong Kong has utilized their position to develop their international capital market. While manufacturing has largely stagnated, these four major industries continue to

play a major role in the city's economic activities, as shown from Table 4-4 below.

Table 4-4 Percentage share of value added in GDP (%)

Percentage share of value added in GDP (%)	2018	2019
Four Key Industries		
(I) Financial services	19.8	21.2
(II) Tourism	4.5	3.6
(III) Trading and Logistics	21.2	19.8
(IV) Professional Services and Other Producer Services	11.9	11.9
Other Selected Industries		
Cultural and creative industries	4.8	4.7
Air transport	2.8	2.5
Sports and related activities	1.4	1.4

Source: Census and Statistics Department, HKSAR

4.4.1.2.Challenges of government innovation policies in Hong Kong

There has historically been a lack of government support on nurturing proactive innovation policies until recent years (**Baark and Sharif, 2006; Fuller, 2010**). In a 2010 book titled *Innovation Policy and the Limits of Laissez-Faire*, **Fuller (2010)** attributed Hong Kong's lackluster innovation dynamics to several driving forces as follows:

- The limited legal mechanism to support and protect intellectual property rights (IPR), as attributed by the presence of very few IP specialists in the city and the near-absence of legal measures to protect home-grown innovations. This landscape only changed recently with reforms to IPR laws in December 2019
- The persistent institutional condition – in terms of competitive funding grant application – that causes universities and public research organizations (represented by the city's government-funded R&D Centers) to compete against each other, instead of engaging in collaborative research
- Failure to provide support for emerging, innovative industries, as contributors of the edited book have demonstrated from the case studies of 'failed' semiconductor and biotechnology industries in the city
- The low absorptive capacity of manufacturing industries, accompanied by the government's laissez-faire attitude in upgrading these firms' capabilities

Nevertheless, although Hong Kong's R&D spending (both in absolute terms and as a ratio to GDP) has been demonstrating an upward trend, the city's R&D activities continue to pale in comparison with other major innovation hubs.

At present, Hong Kong's R&D expenditure has been disproportionately driven by research activities performed by the higher-education sector (and business sector secondarily), whereas research performed by government agencies has been grossly insufficient. As shown in Table 4-5 below, higher education institutions – primarily represented by universities – have consistently accounted for (more than) half of the proportion of R&D activities. Business expenditure in R&D (BERD), which briefly overtook higher-education R&D (HERD) in the mid-2000s, has not demonstrated a significant increase in their research investments.

Table 4-5 R&D expenditure in Hong Kong by performing sector as % of GDP (1995-2018)

Year / Sector	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
GERD	0.36	0.39	0.38	0.43	0.46	0.47	0.55	0.59	0.69	0.74	0.80	0.82	0.77	0.72	0.77	0.75	0.72	0.73	0.73	0.74	0.76	0.79	0.80	0.86
BERD	0.11	0.13	0.10	0.12	0.11	0.08	0.16	0.19	0.29	0.36	0.41	0.43	0.37	0.31	0.33	0.32	0.32	0.33	0.33	0.33	0.33	0.34	0.35	0.39
HERD	0.24	0.25	0.27	0.30	0.34	0.38	0.37	0.38	0.39	0.36	0.37	0.37	0.38	0.39	0.41	0.39	0.37	0.37	0.38	0.38	0.40	0.41	0.41	0.43
GOVERD	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04

Table 4-6 lists some of the key government funding support for R&D activities and university technology transfer.

Table 4-6 Government Funding support

Funds/Schemes	**Main programs/objectives**	**Target recipients**
Supporting Research & Development (R&D)		
Innovation and Technology Support Programme (ITSP) under Innovation and Technology Fund	ITSP (Platform & Seed); ITSP (Mid-stream, theme-based)- encourage universities funded by the University Grants Committee (UGC) to collaborate with leading research institutes worldwide to conduct more theme-based inter-disciplinary and translational R&D work in focused technology areas	UGC-funded Universities/Academic and research institutions
Enterprise Support Scheme under Innovation and Technology Fund	Provide funding support for local companies to conduct in-house research and development (R&D)	Enterprises
Research and Development Cash Rebate Scheme	Encourage private sector to enhance co-operation with local public research institutions	Enterprises
Supporting collaborative research		
Collaborative Research Fund (CRF) under RGC	Supports multi-investigator, multi-disciplinary projects (a total of HK$285 million in 2021-2022 CRF)	

Theme-based Research Scheme (TRS) under RGC	Focus on the themes of strategic importance to the long-term development of Hong Kong (a total approved budget of $414.941 million in 2021/22 Exercise)	
Research Impact Fund (RIF) under RGC	Encourage projects with potentially high research impact and wider regional influence (RGC funds 70% while university/partner(s) match the remaining 30%, budget totaling 75 million in 2021/22)	
Strategic Topics Grant	Support collaborative research in five strategic topics (10% matching funding from participating universities)	
Midstream Research Programme for Universities (MRP) under Innovation and Technology Fund	Encourage UGC-funded universities to conduct more interdisciplinary and translational R&D with world-class research institutes (HK$10 million per project for Collaboration Projects involving multiple disciplines or research institutes)	Universities
Cyberport University Partnership Programme support by Cyberport Creative Micro Fund ("CCMF")		
Supporting Technology Start-ups		
Technology Start-up Support Scheme for Universities (TSSSU) under Innovation and Technology Fund	Provide funding to six universities[2] to support their teams in starting technology businesses and commercialising their research and development (R&D) results (a maximum amount of HK $1.5 million per year for at most 3 years)	Universities, enterprises
Acceleration and Incubation programme		
HKSTP Venture Fund under Hong Kong Science and Technology Park Corporation (HKSTP)	Encourage investors and venture capitalists to fund early-stage startups	Enterprises
Acceleration Programme under HKSTP	Support high potential startups looking to scale globally (funding of up to HK$4.8 million)	Enterprises
Cyberport Creative Micro Fund	Support high potential digital tech projects and early-stage start-ups	

[2] The six universities are The University of Hong Kong, The Chinese University of Hong Kong, City University of Hong Kong, The Hong Kong University of Science and Technology, Hong Kong Baptist University and The Hong Kong Polytechnic University.

Box 1. Hong Kong's excellence in academic research: illustrations of top scientists

While Hong Kong has been performing relatively weak in terms of industry-related innovation, the city has excelled with regard to their scientific and academic research. This recognition could be attributed from the fact that half of the R&D activities and funding in Hong Kong have been driven primarily by the higher-education sector, particularly universities. In turn, the city's strong performance in basic research has been evident through the illustrations of 'star scientists' we briefly profiled in the bullet points below:

- Charles Kuen Kao, the father of optical fiber, immigrated to Hong Kong at the age of 16. He joined the Department of Electronics of the Chinese University of Hong Kong (CUHK) in 1970. He was a chair professor of engineering, and subsequently the President of the university from 1987 to 1996. Given the scientific achievement associated with optical fiber, Kao was awarded Nobel Prize in Physics in 2009
- Shing-Tung Yau, the first Fields Award (a Nobel Prize-equivalent scientific prize in the field of mathematics) laureate of Chinese origin, founded and served as the first director of the Institute of Mathematical Sciences at CUHK. At present, he is a member of Hong Kong Academy of Science and remains a chair professor at the university. Before CUHK, he was a professor at Harvard University.
- Yuet-Wai Kan, a Hong Kong native, is one of the pioneers of modern DNA analysis methods. A winner of the Lasco Medical Award – one of the highest biomedical awards in the United States, Kan was a chair professor at the Department of Diagnostics at the University of California – San Francisco (UCSF); he was educated at HKU Medical School
- Ching W. Tang, a Hong Kong native, was one of the pioneers of OLED technologies. An awardee of Wolf Award (one of the world's most prestigious prizes in chemistry), he was a professor at the Institute of Advanced Studies at the Hong Kong University of Science and Technology (HKUST)
- Dennis Yuk-Ming Lo, currently a chair professor at CUHK, is one of the earliest inventors of non-invasive DNA prenatal diagnosis testing. He joined the university in 1997. In the same year, one of his articles – "Fetal DNA in maternal fetal plasma and serum", which spurned the invention of this technology, was published in The Lancet. He has served as a scientific co-founder to four spin-offs that seek to commercialize the prenatal diagnostics technology. In 2016, Lo won Thomson Reuters Citation Award as one of the world's most cited researchers. At present, he is currently a deputy dean of the School of Medicine at CUHK.

We argue that Hong Kong's lackluster performance in innovation activities – as well as the absence of the universities from major innovative universities ranking, e.g. Reuters World's Innovative Universities, may have to do with their historically limited commitment to R&D investments. Nevertheless, R&D alone cannot be singled out as an explanatory factor;

excellence in innovation reflects a systemic interplay of multifaceted determining forces, ranging from supportive innovation policy instruments (Bloom et al., 2019) to the role of entrepreneurial universities (Etzkowitz, 2012), networks of knowledge circulation and exchange (Saxenian, 1994; Almeida and Kogut, 1999), presence of financing instruments dedicated towards local enterprises (Sorenson and Stuart, 2001), as well as a high degree of university linkages/collaboration with non-university stakeholders (Etzkowitz and Leydesdorff, 2000).

In the following sections (which we will replicate across the remaining case studies), we propose to study innovation dynamics in each of the innovation hubs through three types of analyses. First, given the increasing realization that innovation reflects inter-organizational networks of knowledge flows and exchange (Almeida and Kogut, 1999; Owen-Smith and Powell, 2004), we seek to study the evolution of these networks – over time – using patent data we retrieved from the United States Patent and Trademark Office (USPTO). Given the inadequacy of identifying inter-organizational networks from patent data alone, we rely on two additional methods as follows. Regarding the former, we made use of university-industry (U-I) co-publication datasets (as suggested by Tijssen et al., 2009) that we have generated from the five selected Hong Kong universities that we studied in Task 1 report, in which we seek to identify the types of firms that perform collaboration with these institutions. We relied on Lens.org, an open-source database for patent and publication data, to extract the publication data, as well as various databases and manual search in identifying the affiliation – and identity – of these publication collaborators. Finally, for the latter, we collected information on financing activities by Hong Kong-based investment firms, and following Sorenson and Stuart (2001), we seek to identify the proportion with which these investment deals end up in Hong Kong-based technology companies. Our primary source for identifying the list of investors – and their investment activities – was Crunchbase.

4.4.1.3. INTER-ORGANIZATIONAL NETWORKS: EVIDENCE FROM USPTO PATENT DATA

In this section, we focus on innovation networks in Hong Kong. Having collected patent data from USPTO, we created a separate subset for US-filed patents invented in Hong Kong. Given the long time span of our study (covering 36 years from early-1983 to end-2018), we conducted further analysis by splitting the time span into 6 separate six-year periods. After removing design patents and no-assignee patents, we managed to collect a total of 13,050 patent filings originating from the city. Our basis for social network analysis – the figures by which will be displayed shortly – was from **Graf and Henning (2009)**, in which we draw network linkages based on the presence of co-applied patents (patent filings involving two or more organizational assignees) and patents from multiple organizations involving the same inventor (as proxied from their distinctive inventor identification number).

Our indicators of interest from this analysis are two-fold: 1) we are interested to identify the most active patenting organizations across different time periods from 1983 up to 2018, and; 2) to observe organizations exerting significant influence within the innovation networks in

Hong Kong, which we proxy with betweenness centrality score, a measure of the degree of knowledge flows through a node of interest as well as an intermediary for the shortest possible paths taken for any node dyads to form linkages (**Freeman, 1977**). The higher the betweenness centrality scores of these nodes, the more significant the degree of influence they exert in a network with respect to knowledge dissemination (**Graf and Henning, 2009**).

Table 4-7 below highlights the most active patenting organizations in Hong Kong within the whole period of analysis. Interestingly, more than half of the top assignees are universities (represented by HKUST, CityU, PolyU, HKU, and CUHK) and public research organizations – as shown by the presence of ASTRI. These initial results affirm the importance of higher-education institutions and public research institutes in driving scientific, technological, and innovation activities in Hong Kong (**Wang et al., 2021**). We also seek to understand the evolution of Hong Kong innovation system by identifying the most active organizations across different time periods, as shown in Table 4-8 in the next page.

Table 4-7 List of top-10 patenting assignees in Hong Kong (all-time)

Name	Patent filings (13,050)
SAE Magnetics	489
ASTRI	421
Johnson Electric	419
HKUST	404
Cree	362
CityU	347
PolyU	302
HKU	294
CUHK	243
ASM Assembly	225
Share of top 10	26.9%
No. of organizations	2,388

Table 4-8 List of top-10 patenting assignees in Hong Kong throughout different time periods (patent filings indicated in brackets)

1983-1988 (177)	1989-1994 (314)	1995-2000 (1,135)	2001-2006 (2,968)	2007-2012 (4,214)	2013-2018 (4,073)
Johnson Electric (23)	Johnson Electric (14)	HKUST (39)	SAE Magnetics (186)	Cree (235)	Johnson Electric (195)
Windmere Corp (9)	ASTEC (13)	Motorola (24)	PolyU (105)	ASTRI (229)	CityU (172)
W. Haking Enterprise (8)	Motorola (13)	Human Genome Sci (22)	HKUST (94)	SAE Magnetics (199)	ASTRI (145)
Arco Industries Ltd (5)	CJ Associates (11)	CJ Associates (20)	HKU (93)	HKUST (170)	TSMC (115)
Hoechst Celanese (4)	Outboard Marine Corp (7)	Concord Camera Corp (20)	ASM Assembly (75)	Johnson Electric (143)	Cree (110)
Polaroid Corp (4)	Hunter Fan Co. (6)	PolyU (18)	Microsoft (70)	PolyU (130)	SAE Magnetics (100)
Zima Products Ltd (4)	Polycity Ltd (6)	World Wide Co Ltd (17)	Headway Tech (56)	CityU (112)	HKUST (99)
ASTEC (3)	Tak Fi International (6)	IBM (15)	CityU (54)	Headway Tech (104)	HKU (95)
Conair (3)	Imperial Chemical (4)	Toymax Inc (15)	Ultra Biotech Ltd (52)	CUHK (92)	CUHK (92)
Fyrnetics (3)	Solar Wide Indus (4)	HKU (14)	ASAT Ltd (50)	HKU (91)	HKBU (90)
Share of top 10: 37.2%	Share of top 10: 26.8%	Share of top 10: 18.0%	Share of top 10: 28.1%	Share of top 10: 35.7%	Share of top 10: 29.8%
No. of organizations: 94	No. of organizations: 171	No. of organizations: 429	No. of organizations: 731	No. of organizations: 842	No. of organizations: 865

Table 4-9 List of top-10 patenting assignees in Hong Kong in terms of betweenness centrality scores (scores indicated in brackets)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
-	Video Tech Indus (1)	CUHK (2)	HKU (1246)	ASTRI (2522)	HKUST (2368)
-	-	HKUST (2)	HKUST (624)	PolyU (2376)	CityU (1960)
-	-	HP Intell Corp (1)	CUHK (579)	HKUST (1789)	HKU (1825)
-	-	-	PolyU (482)	CUHK (1146)	ASTRI (1778)
-	-	-	ASTRI (300)	HKU (1011)	CUHK (1619)
-	-	-	CityU (194)	CityU (884)	Johnson Electric (1423)
-	-	-	SAE Magnetics (169)	SAE Magnetics (765)	PolyU (1420)
-	-	-	ASM Assembly (135)	Procter & Gamble (335)	NAMI (1313)
-	-	-	Microsoft (114)	Hospital Authority (333)	SAE Magnetics (1037)
-	-	-	MIT (75)	Huawei (258)	Huawei (998)

In the first two columns (1983-1988 and 1989-1994 period), the top-10 assignees were completely dominated by manufacturing firms, one notable example being Johnson Electric. Founded in Hong Kong in 1959, Johnson Electric has been among the world's largest manufacturers of automotive components, industry-related equipment, and medical devices. The company is also among the most prolific patenters in Hong Kong, although at one point was absent from the top-10 lists in 1995-2000 and 2001-2006 periods. Nevertheless, at the same time, Hong Kong's innovation system was highly fragmented, with almost no triadic-based network structures emerging in the 1983-1988 and 1989-1994 periods.

From mid-1990s onward, universities began to exert their influence, as some universities (notably HKUST, PolyU, and HKU) entered the top-10 assignee list for 1995-2000 period. In terms of betweenness centrality score, HKUST and CUHK also became among the most influential nodes, although their reach to other nodes remained highly limited (with the details visualized in Figure 3). These results were particularly significant for HKUST, as the university had only been established in 1991. Over time, the number of patent filings has substantially grown throughout successive time periods, especially from 2001 onward. Simultaneously, the contribution by universities (followed by public research organizations) grew in parallel, with the top-10 lists progressively dominated by these organizations.

Our results align closely with **Graf and Henning (2009)** regarding the central role played by universities and research institutes in driving innovation activity dynamics within their localities, as reflected from their high betweenness centrality scores. Nevertheless, our finding also contrasts with the existing observation that no Hong Kong universities is ranked highly with respect to innovative activities, as attested by the results from Reuters World's Most Innovative Universities Ranking. In the preceding Task 1 report, we have argued that such lukewarm performance by Hong Kong universities may be attributed to their historically limited knowledge/technology transfer activities, particularly to industry actors. Given the high betweenness centrality scores for at least six such universities (CityU, CUHK, HKU, HKUST, PolyU, and more recently, HKBU), we speculate that inter-organizational linkages for these universities may primarily take place within the academia with limited interaction with industry partners, possibly explaining their weak performance.

From Table 4-10 below, we discovered that our proposition was not completely confirmed, as academia linkages with other local universities have *actually declined* – as a proportion of all their existing inter-organizational linkages – for most of the universities (with the exception of CUHK) over time. In other words, interpreting from the results below, we can argue that knowledge dissemination has increasingly taken place beyond the scope of academia alone. The next question, nevertheless, relates to *what other types of organizations* the technical knowledge has been transmitted into.

Table 4-10 Percentage of inter-organizational linkages with local universities in Hong Kong

	2001-2006	2007-2012	2013-2018
CityU	53.5%	29.3%	24.6%
CUHK	12.5%	37.5%	21.8%
HKBU	92.3%	60.0%	2.2%
HKU	63.2%	29.5%	25.0%
HKUST	17.8%	10.5%	6.5%
PolyU	23.5%	16.0%	10.0%

In this regard, we expand our analysis by estimating the proportion of inter-organizational linkages that these universities have with: 1) local public research organizations (PROs); 2) local industries, and; 3) foreign organizations. Specific for foreign organizations, we include multinational enterprises (which may or may not have subsidiaries in hong Kong), foreign universities, mainland Chinese-based organizations, foreign research institutes, as well as non-Hong Kong government agencies. Results from the follow-up analysis are highlighted in

Table 4-11 below. Given our specific interest in universities' linkages with local industries, we highlighted and indicated the resulting figures for 'local industries' in bold.

Overall, we found that the proportion of linkages occurring between local universities and local industries, over time, has been consistently decreasing for 3 of the universities (CUHK, HKUST, and PolyU), fluctuating for other 2 universities (CityU and HKBU), and only increased for 1 of them (namely HKU). In terms of linkages with local PROs, we found only CityU and HKUST recorded a substantial increase in the percentage of their linkages. Quite interestingly, across all universities, there has been a considerable increase in the proportion of their linkages with foreign organizational actors. In other words, knowledge dissemination and/or spillover is increasingly leaning towards non-Hong Kong entities.

Interpreting the results, we speculate that Hong Kong universities' limited impact on the city's innovation ecosystem may be largely driven by inter-organizational linkages with foreign organizations, which may manifest in several different pathways. First, it is possible that university researchers more actively engage in co-patenting activities with their counterparts from overseas (especially those involving foreign and/or mainland Chinese universities). Second, university researchers may also engage in career mobility moves towards these non-local organizations, whether as industry scientists in foreign firms or as faculty members in non-Hong Kong universities, particularly in mainland China. Third, local university researchers – perceiving the limited absorptive capacities of local firms, as attested by our interviews in the previous Task 1 report – may prefer to engage in informal networking with non-local industry actors.

Table 4-11 Further elaboration on the table above

	Types of links	2001-2006	2007-2012	2013-2018
CityU	Local universities	53.5%	29.3%	24.6%
	Local PROs	4.7%	9.4%	17.9%
	Local industries	**32.6%**	**50.8%**	**32.9%**
	Foreign organizations	9.2%	10.5%	24.6%
CUHK	Local universities	12.5%	37.5%	21.8%
	Local PROs	28.1%	25.0%	4.6%
	Local industries	**37.5%**	**0.6%**	**4.6%**
	Foreign organizations	21.9%	36.9%	69.0%
HKBU	Local universities	92.3%	60.0%	2.2%
	Local PROs	0.0%	0.0%	0.6%
	Local industries	**7.7%**	**0.0%**	**9.4%**
	Foreign organizations	0.0%	40.0%	87.8%
HKU	Local universities	63.2%	29.5%	25.0%
	Local PROs	3.5%	20.0%	5.2%
	Local industries	**17.5%**	**23.3%**	**43.8%**
	Foreign organizations	15.8%	27.2%	26.0%
HKUST	Local universities	17.8%	10.5%	6.5%
	Local PROs	1.2%	9.3%	25.3%
	Local industries	**50.0%**	**24.0%**	**19.5%**
	Foreign organizations	31.0%	56.2%	48.7%
PolyU	Local universities	23.5%	16.0%	10.0%
	Local PROs	27.5%	27.2%	2.7%
	Local industries	**11.7%**	**16.8%**	**10.3%**
	Foreign organizations	37.3%	40.0%	77.0%

In addition to patent data analysis, we also consider universities' joint publications with industry firms (which, for the purpose of simplicity, we label as 'U-I co-publications'). U-I co-publications have been touted as a vital indicator for benchmarking the degree of linkages with industries across different universities (**Tijssen et al., 2009**). In this regard, we collected our data from Lens.org, a database of over 200 million academic publications and patents worldwide. We extracted publication data from 5 Hong Kong universities that encompass 2009-2018 period (a total of 10 years), with a particular interest in obtaining the affiliation data to identify publications that include industry collaborators. After engaging in extensive data cleaning of the authors' affiliation, we managed to identify U-I co-publications involving these

universities, the figures by which are shown in Table 4-12 below. Interpreting these results, we found that Hong Kong universities 'under-performed' in terms of their joint publications with industry actors in comparison to the global average of 7% as estimated by **Tijssen et al. (2009)**.

Table 4-12 Publication data in Hong Kong and information on U-I co-publications (2009-2018)

University	Total number of publications	Total number of U-I co-publications	U-I co-publications as % of all publications
CityU	20,041	696	3.47
CUHK	29,976	1,429	4.77
HKU	34,185	1,265	3.70
HKUST	14,312	647	4.52
PolyU	23,918	677	2.83

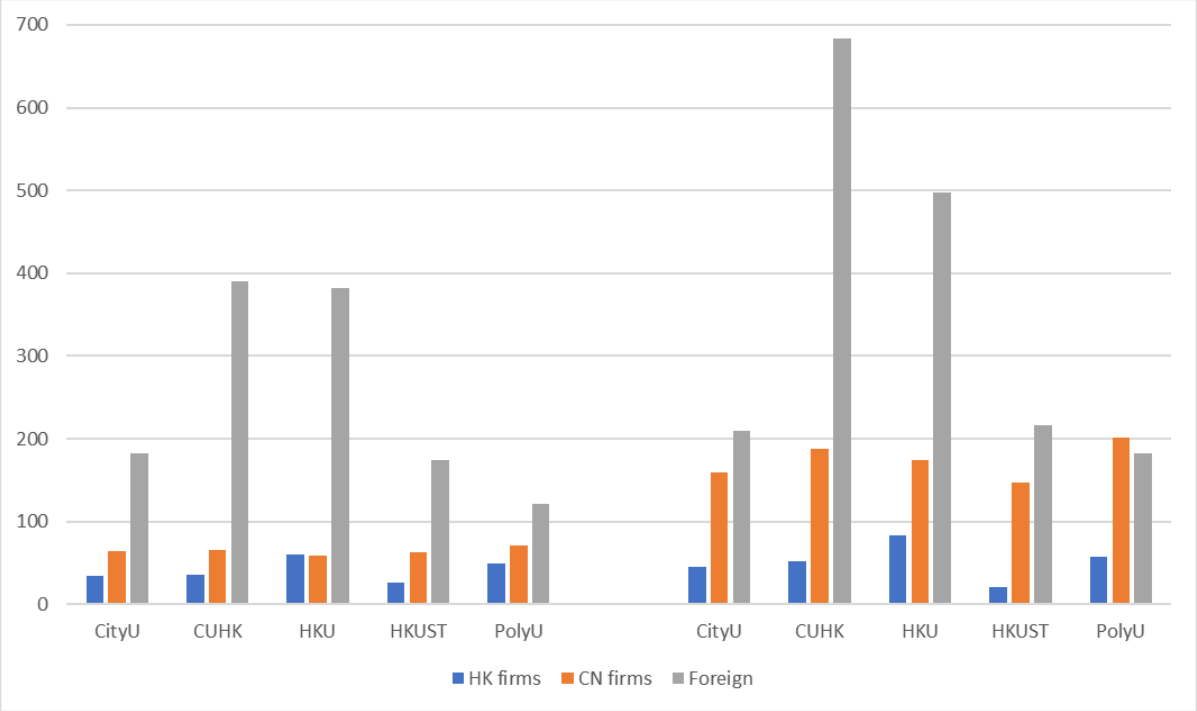


Figure 4-7 Joint U-I co-publications involving Hong Kong universities (left-side: 2009-2013 period; right-side: 2014-2018 period)

Figure 4-7 above compares and contrasts U-I co-publication output from the five universities in two different sub-periods (2009-2013 and 2014-2018, respectively). Joint publications with local, Hong Kong enterprises are represented in blue bars, whereas those involving domestic non-local (mainland Chinese) and foreign firms are represented in dark-orange and grey bars. Through this figure, we found that there has been a very rapid growth in co-publications involving mainland Chinese enterprises, and to a certain extent, with foreign firms. The substantial increase in research collaboration with mainland Chinese firms (as reflected by

these publications) was reflected across all universities. Much of this was attributed to the rapid increase in university collaboration with technology firms (and in particular those based in Shenzhen), notably Huawei, BGI, and Tencent, with Huawei serving as a leading collaborator across all five universities (see Table 4-13). The number of U-I co-publications involving foreign firms has also increased considerably, especially for CUHK and HKU; such dynamics were enabled by the universities' strong partnerships with multinational pharmaceutical firms (due in part to the presence of medical schools). Indeed, across these two universities, all but two in the top-10 industry-collaborator lists were pharmaceutical companies, with Microsoft and Philips being the major exception. By contrast, the growth in co-publications involving local companies has been rather sluggish across all studied universities; some of the companies appearing on the top-10 local-firm lists appear to be university spin-offs (e.g. SenseTime and Sanomics in the case of CUHK, CryptoBLK and Vitargent for CityU).

Table 4-13 Top 10 collaborating firms with Hong Kong universities in U-I co-publications (2009-2018 period, number of co-publications indicated in brackets)

CityU		
Local firms (N = 80)	Domestic non-local firms (N = 224)	Foreign firms (N = 391)
Canaan Microelec (14)	Huawei (37)	IBM (17).
Compass Technology (3)	BGI (13)	Microsoft (13)
ConvenientPower (3)	Tencent (10)	ARUP Labs (9)
CryptoBLK (3)	SAE Magnetics China (8)	Bell Labs (9)
Dickson Computer (3)	Dongguan Litewell (7)	Google (9)
Vitargent (3)	Baidu (5)	Samsung (9)
ADC Tech Int'l (2)	China Mobile (4)	Rolf C. Hagen (7)
China Merchant Bank (2)	Huijin-Teer Coatings (4)	Philips (6)
Leighton Contractors (2)	State Grid (4)	General Motors (5)
MTR Corporation (2)	WeHealthGene (4)	Qualcomm (5)
CUHK		
Local firms (N = 88)	Domestic non-local firms (N = 254)	Foreign firms (N = 1,073)
SenseTime (6)	BGI (36)	Novartis (65)
HK Serv Res Lab (6)	Huawei (28)	AstraZeneca (61)
Bio-Cancer Treatment (4)	Tencent (14)	Pfizer (61)
Compr Drug Enterpr (3)	Alibaba (7)	Microsoft (50)
HK Jockey Club (3)	Baidu (7)	Hoffmann-La Roche (40)
BGI Hong Kong (2)	Dongguan EONTEC (7)	Boehringer Ingelheim (39)
Dickson Computer (2)	CGNPC (5)	GlaxoSmithKline (34)
OOCL (2)	CNPC (5)	Merck (32)
R&C Biogenius (2)	MediaTek (5)	Bristol-Myers Squibb (20)
Sanomics (2)	CITIC Securities (3)	Philips (19)

HKU		
Local firms (N = 144)	Domestic non-local firms (N = 234)	Foreign firms (N = 879)
Ocean Park Corp (15)	BGI (23)	Merck (36)
Bio-Cancer Treatment (14)	Huawei (13)	Pfizer (34)
Dragages HK Ltd (6)	CNPC (9)	Philips (30)
813 Medical Center (4)	China South Power Grid (8)	Novartis (28)
ConvenientPower (4)	SINOPEC (7)	Microsoft (24)
Dickson Computer (4)	Anshan Iron & Steel (6)	Bristol-Myers Squibb (21)
China Merchant Bank (3)	CGNPC (6)	Hoffmann-La Roche (20)
L3 Bioinformatics (3)	China Mobile (4)	GlaxoSmithKline (18)
Sun Hung Kai (3)	Huaiji Dengyun Auto (4)	Eli Lilly (17)
Atal Engineering (2)	Li-Ning (4)	Genentech (15)
HKUST		
Local firms (N = 48)	Domestic non-local firms (N = 210)	Foreign firms (N = 390)
Dickson Computer (5)	Huawei (48)	Microsoft (54)
R&C Biogenius (5)	Baidu (7)	IBM (20)
Visual Perception Labs (4)	Jiangyin Changdian (7)	ARUP Labs (11)
Genetic Finance HK (3)	Alibaba (5)	AT&T (8)
Solomon Systech (3)	Chengdu CoilEasy (4)	Dow Chemical (7)
Adv Pack Technology (2)	Shenzhen Airlines (4)	Google (7)
Noah's Ark Lab HK (2)	Suzhou Jiren Hi-Tech (4)	Indium Corp (7)
Hyder Consulting (2)	AECC China (3)	Intel (7)
Lee's Pharmaceutical (2)	China Telecom (3)	InterDigital (7)
Acoustic Metamaterials (1)	GZ New Vision Opto (3)	Oracle (7)
PolyU		
Local firms (N = 106)	Domestic non-local firms (N = 282)	Foreign firms (N = 304)
HKSTP Corporation (4)	Huawei (20)	AECOM (8)
Ocean Park Corp (4)	Li-Ning (12)	Google (7)
Bio-Cancer Treatment (3)	Pharmanex (10)	National Grid plc (6)
Canaan Microelec (3)	State Grid (7)	ARUP Labs (5)
CSA (M&E) Ltd (3)	China Mobile (6)	IBM (5)
EDMS HK Ltd (3)	China South Power Grid (6)	Merck (5)
MacGregor Education (3)	COMAC (6)	Dynex Semiconductor (4)
MTR Corporation (3)	Shanghai Waterway (5)	Pfizer (4)
Techtronic Industries (3)	Do-Fluoride Chem (4)	Aerosol d.o.o. (3)
A&P Instruments (2)	Tencent (4)	Carl Zeiss (3)

With specific regard to U-I co-publications involving local firms, we also identified some additional works involving local university spin-offs (whether founded by alumni, professors, or researchers). As shown from Table 4-14, a high proportion of Hong Kong universities' joint

publications with local firms are with their own university spin-offs. Of all five universities studied, HKUST has the highest number of identified spin-offs, whereas CityU has the highest number of joint scientific publications. Table 4-15 displays the sectoral focus of these university spin-offs, with CUHK and HKU having the highest concentration of such firms in biotechnology/pharmaceutical industry; HKUST is an outlier given their strong emphasis on spinning off start-ups in the areas of material sciences and electronics. Our caveat from these findings, however, is that our identification may overlook spin-offs that do not necessarily engage in joint academic works with faculty members, as well as the burgeoning student start-ups.

Table 4-14 Number of spin-offs & joint publications with Hong Kong universities (2009-2018)

	No. of identified spin-offs	No. of U-I co-publications	% of local-firm co-publications
CityU	10	37	46
CUHK	12	22	25
HKU	16	28	20
HKUST	21	34	70
PolyU	12	17	16

Table 4-15 Specialization of Hong Kong university spin-offs identified from U-I co-publications (2009-2018)

	CityU	CUHK	HKU	HKUST	PolyU
Artificial intelligence	-	2	-	1	-
Biotechnology/pharmaceuticals	3	7	11	2	2
Blockchain	1	-	-	-	-
Computer service	1	-	1	1	-
Consulting	1	-	1	-	3
Edu-tech (education technology)	-	-	1	-	-
Electronics	-	-	-	3	-
Fintech (financial technology)	-	1	-	-	-
Geoinformatics	-	-	1	-	-
Healthcare	-	1	-	-	-
Insur-tech (insurance technology)	1	-	-	-	-
Internet of things (IoT)	-	-	-	1	-
Logistics	-	-	-	-	1
Manufacturing	-	-	-	-	2
Material science	-	-	-	6	-
Medical device	-	-	-	2	-
Nursing	-	-	-	-	1
Psychology	-	1	-	-	-
Renewable energy	-	-	-	1	-
Robotics	-	-	-	1	-

	CityU	CUHK	HKU	HKUST	PolyU
Semiconductor	1	-	-	2	2
Software	1	-	-	1	1
Wireless	1	-	1	-	-

In addition to patent and U-I co-publication data, we also analyze venture capital, private equity, and other types of financing activities in Hong Kong, with a particular interest in examining the degree to which investment flows by Hong Kong-based funds are oriented towards local enterprises (**Sorenson and Stuart, 2001**). One of our primary motivating reasons to include this analysis is due to the high concentration of VC funds in Hong Kong, but with very limited impact towards the city given that these funds oftentimes serve as 'parking stations' for institutional investors and high-net-worth individuals taking advantage of the city's favorable tax incentives (**Klinger-Vidra, 2018**). We are interested to observe the degree to which such observation continues to prevail in Hong Kong innovation ecosystem.

We obtained the investment activity data from Crunchbase, a database of technology companies and related investment and merger-and-acquisition (M&A) activities across the globe. At present, Crunchbase hosts information on over 1 million technology companies globally, as well as 200,000 investors (both organizations and individuals alike). Afterwards, we filter our location search to only 'Hong Kong', and identified a total of 1,352 investors based in the city. Our attention turns to the top 25 investors and takes into consideration the cumulative number of investments, portfolio organizations, as well as the proportion of those targeting locally-based companies.

Table 4-16 below provides description about the investors in Hong Kong based on the size of their investment activities. Nearly 40% of them had no records about their existing investment activities, and another roughly 31% of these investors had one-time investment experience only. For investors with a cumulative experience of over 50 investment activities, the proportion was less than 2%. Afterwards, we turn our attention to examining the top 25 investment funds to identify the proportion of their deals going to Hong Kong-based enterprises. Further information about the top 25 funds is elaborated in Table 4-17 below.

Table 4-16 Information about investors in Hong Kong (source: Crunchbase)

Size of investment activities	Number of investors
No information about investments	539
1 investment only	423
2-9 cumulative investments	282
10-25 cumulative investments	72
26-50 cumulative investments	15
51-99 cumulative investments	12
100-999 cumulative investments	9
1,000 or more cumulative investments	0
TOTAL	1,352

Table 4-17 below, we identified some interesting findings. Of the top 25 investment funds in Hong Kong, nearly one-third (8) of them are mainland Chinese-based, with some of them serving as capital investment arms of Chinese state-owned enterprises (e.g. CITIC, China Merchant Bank, and China Construction Bank). Among these funds, their proportion of investment activities in Hong Kong technology companies was very low, with some of them having no investment deals in Hong Kong at all (e.g. CDH Investments, Ceyuan Ventures). In addition, we also identified specialized VC funds that were established by some of the world's richest billionaires, notably Li Ka-shing's Horizons Ventures, Yuri Milner's DST Global, and Jack Ma's YF Capital.[141] Quite similarly, very few of the existing investment activities by these funds end up channeled towards local Hong Kong enterprises; instead, a large proportion of the capital is invested on major start-up unicorns in other innovation hubs, such as Spotify and Zoom (in the case of Horizons Ventures), Flipkart (with respect to DST Global), or mainland Chinese technology giants such as Alibaba and Xiaomi (by YF Capital).[142] Furthermore, 6 of the 25 largest investment funds are specifically oriented towards blockchain and cryptocurrencies, and most of their investment deals end up on start-ups in similar technologies outside Hong Kong.

The exceptions were Cyberport and Alibaba Entrepreneur Fund, for which more than half of their investments have been allocated towards local Hong Kong companies. With regard to Cyberport, their high proportion of financial support for local firms is not surprising, given that the technology park was established by the Hong Kong government specifically to nurture the city's local ecosystem (**Baark and So, 2006**). Indeed, we suspected the actual percentage (and actual number of portfolio companies) could have been much higher, possibly as some of the invested companies may have relocated from Hong Kong to elsewhere. In the case of Alibaba Entrepreneur Fund, their high proportion of financial deals involving local enterprises can be attributed to the fund's original mission of supporting emerging-technology companies in both Hong Kong and Taiwan. One major feature that differentiates Cyberport from Alibaba Entrepreneur Fund is the latter's commitment of providing larger financing resources compared to Cyberport's, which is primarily limited to seed-stage start-up funds. Notable companies supported by Alibaba Entrepreneur Fund include Prenetics (a diagnostic health testing company established as a CityU spin-off), AQUMON (a robo-advisory financial-technology firm established by an HKUST alumnus and former lecturer), and GoGoX (formerly GoGoVan, one of Hong Kong's first unicorns).

Table 4-17 Top 25 investment funds in Hong Kong and proportion of investments in Hong Kong technology companies

Name	Summary	No. of investments	Investments in HK	No. of portfolio organizations	Portfolio organizations in HK
SAIF Partners	A private equity firm with bases in Hong Kong and mainland China	373	4 (1.1%)	272	3 (1.1%)
Horizons Ventures	A VC firm founded by Li Ka-shing, one of Hong Kong's richest billionaires	269	3 (1.1%)	166	2 (1.2%)
DST Global	A VC firm founded by Yuri Milner, a Russian-Israeli billionaire	203	2 (1.0%)	128	2 (1.6%)
CDH Investments	One of China's earliest asset management firms, with main office in Beijing	181	0 (0.0%)	141	0 (0.0%)
Cyberport	One of Hong Kong's earliest technology parks that also offers early-stage start-up incubation funds	181	108 (60.0%)	175	104 (60.0%)
Brinc	A VC fund and start-up accelerator focused on deep-technology firms	128	17 (13.3%)	127	17 (13%)
YF Capital	A private equity firm co-founded by Jack Ma (founder of Alibaba) and David Yu (founder of Target Media)	124	0 (0.0%)	104	0 (0.0%)
IOSG Ventures	Early-stage fund for blockchain-related companies and decentralized protocols	113	3 (2.7%)	99	2 (2.0%)

Ceyuan Ventures	Early-stage VC fund with specific interest on IT and emerging-growth firms, primarily in mainland China	111	0 (0.0%)	83	0 (0.0%)
Alameda Research	Quantitative trading firm and VC fund with a focus on cryptocurrency markets and blockchain-related start-ups	90	3 (3.3%)	88	3 (3.4%)
CITIC Capital	Asset management and VC funding arm of CITIC Group, one of China's largest state-owned enterprises (SOEs)	75	2 (2.7%)	68	2 (3.0%)
Kenetic	Proprietary trading and VC fund focused on blockchain-related start-ups and digital, cryptocurrency assets	72	4 (5.5%)	64	3 (4.7%)
Hashkey	Digital asset management firm and VC fund focused on digital asset and blockchain-related companies	69	3 (4.4%)	61	3 (5.0%)
Animoca Brands	Developer of mobile games and products, as well as VC fund with complementary focus on blockchain start-ups	66	10 (15.0%)	63	8 (12.7%)
Ally Bridge Group	Asset management firm offering VC, buyout, hedge fund investments on healthcare firms worldwide	62	0 (0.0%)	52	0 (0.0%)
CMB International Capital	VC and private equity arm of China Merchant Bank, one of China's largest banking state-owned enterprises (SOEs)	57	1 (1.8%)	49	1 (2.0%)

CCB International	Asset management unit under China Construction Bank, one of China's largest banking SOEs	53	2 (3.7%)	51	2 (4.0%)
MindWorks Capital	VC fund focused on pan-Asian technology firms for rapid adoption and scale-up (based in Hong Kong, Beijing, and Jakarta)	52	24 (46.0%)	35	12 (34.3%)
Alibaba Entrepreneur Fund	A non-profit funding initiative by Alibaba Group to support emerging-technology companies in both Hong Kong and Taiwan	52	32 (61.5%)	42	23 (55.0%)
Greenwoods Asset	Investment and asset management company with a special focus on mainland Chinese companies	51	0 (0.0%)	49	0 (0.0%)
Vectr	A VC fund established by serial entrepreneurs based in Hong Kong	51	13 (25.5%)	48	12 (25.0%)
Click Ventures	A VC firm established in Hong Kong focused on early-stage technology companies in Asia and North America	48	9 (18.8%)	35	5 (14.3%)
Zeroth.AI	Accelerator and specialized VC fund for emerging and early-stage artificial intelligence (AI) start-ups	47	10 (21.3%)	42	10 (23.8%)
Lemniscap	Investment fund focusing on cryptocurrency and blockchain-related firms	44	0 (0.0%)	38	0 (0.0%)

Orchid Asia Group	A Japanese fund offering investments in companies utilizing franchise services	40	0 (0.0%)	34	0 (0.0%)
TOTAL (for top 25 funds)		2,571	250 (9.7%)	2,114	214 (10.1%)

4.4.1.4.DISCUSSION AND CONCLUSION

From our analysis of USPTO patent data, U-I co-publications, and investment activities, we found one interesting common pattern: a high tendency for Hong Kong's innovation actors to collaborate with their counterparts outside the city. Specific for patents and joint publications, we indeed found an increasing tendency for Hong Kong universities to build more linkages with non-local innovation actors, particularly with mainland Chinese and foreign enterprises. By contrast, local university-industry linkages appear to be largely stagnant (and surprisingly declining in the case of some universities), and only increase sluggishly with respect to joint scientific publications, with PolyU being the sole university to demonstrate a decline. Furthermore, based on our studies of financing activities by the largest 25 investment funds in Hong Kong (encompassing VC and private-equity firms), we found that the percentage of such support channeled towards local Hong Kong firms was approximately only 10%, with the rest targeted towards mainland China and the rest of the world.

Does this imply that the lack of performance by Hong Kong universities in innovative activities (as exemplified by their absence in major innovative-university rankings) is causally linked to the weak university-industry relationships? While we refrain from providing a definitive answer to this question, the limited U-I linkages may – in part and parcel – explain such phenomenon. Indeed, past studies have demonstrated that Hong Kong's local firms, in general, lack absorptive capacities, particularly in carrying out R&D activities (Huang and Sharif, 2009). Nevertheless, this is far from the only contributing factor that explains Hong Kong universities' lackluster performance. Cultural values – as shown by the tendency of Hong Kong university graduates to seek stable, high-income jobs in the face of living-cost pressures – do also contribute to the historically limited entrepreneurial activities from Hong Kong universities (Dowejko and Au, 2017). Moreover, as we have argued in the preceding Task 1 report, policies by most Hong Kong universities – until the last 3-4 years – have been generally restrictive in terms of promoting the commercialization of university research output. The lack of proactive government policies in encouraging U-I linkages at the local level (as well as more synergies with government-funded R&D centers) also partially explained Hong Kong's lackluster innovation performance (Fuller, 2010; Tsui et al., 2015). Transforming Hong Kong's innovation ecosystem, in this regard, cannot be solely implemented through policy changes alone; a shift in mindset and structural barriers hindering richer linkages among local innovation actors are also needed.

Nevertheless, there were some bright spots from our findings. We have identified some outstanding university spin-offs through our analysis of U-I co-publications that are building on the most recent emerging technologies. Furthermore, in recent years, the Hong Kong government has been investing substantially in enhancing the city's innovation and technology infrastructure, such as expansion of HKSTP and Cyberport, and the construction of a joint technology park with Shenzhen on Lok Ma Chau. New, additional funds targeted for local technology companies (with Alibaba Entrepreneur Fund being a notable example) have also been launched, such as Hong Kong X-Tech Start-Up Platform and a HK$2 billion Innovation and Technology Venture Fund (ITVF). While the long-term outcomes of these efforts remain to be seen, there is cause for optimism that these efforts will pay off.

4.4.2. Beijing

4.4.2.1.Introduction

Beijing has long been China's cultural and political center for centuries and serves as a major hub for scientific research and technological activities (**Liefner and Zeng, 2008**). Supported by intensive efforts by Chinese central government and Beijing municipal authorities, as well as abundant education system and talent resources, the city has rapidly developed into one of the most innovative high-tech economic zones and has the biggest share of the services sector in GDP among all Chinese cities. In 2021, Beijing's GDP has exceeded 4 trillion yuan ($630 billion) for the first time, registering an 8.5% year-on-year increase. Meanwhile, based on the Zhongguancun Science City Unicorn Enterprise Sustainability Report (**2022**), Beijing hosted 91 unicorns in 2021, ranking first in China and second largest globally. Among them, unicorns in the aerospace sector and artificial intelligence, headquartered in Beijing, accounted for 50% and 40% of unicorns nationwide, respectively. Its distinctive title as a leading scientific and R&D hub is particularly significant; as an illustration, according to Nature Index 2020 Top 200 Science Cities, Beijing ranked first globally (**Nature, 2020a**).[143] Relatedly, 18%, or close to 1/5, of China's top 100 universities are in the municipality (**Shanghai Ranking, 2021**). Further, Beijing is home to more than 28,000 high-tech enterprises in 2020, ten thousand more than Shenzhen, with around 1.3 million employees working in the information technology sector(**Beijing Municipal, 2021**).

Recent years have witnessed Beijing's efforts in accelerating the construction of international science and technology innovation centers and world-leading science and technology parks. As put forward in the municipality's 14th Five-Year' Plan for Building a Science and Technology Innovation Center, the city aims to promote the regional digital economy competitiveness and the integration of finance and technology innovation, relying on the synergy among Zhongguancun Science Park, Huairou Science City, Future Science City, and multiple innovative industrial cluster demonstration areas (i.e., "Three Cities and One Zone"). More scientific and technological centres and research institutes are expected to be positioned in the above-mentioned three "cities," including several national interdisciplinary platforms led by Peking University, new campus of Renming University of China, and Tsinghua University Tongzhou Financial Development and Talent Training Base. The importance of universities as multidisciplinary knowledge sources and reservoirs for training and cultivating compound talents have also been stressed by **Beijing Government (2021)**, aiming to strengthen and consolidate Beijing's status as the world's leading innovator. Specifically, the municipal government has prioritized the materialization of cutting-edge technologies and application innovations in accordance with national strategic priorities for promoting scientific research and advanced manufacturing. A great many technological projects kicked off, involving new materials, integrated circuits, artificial intelligence, and biomedicine.

As we have highlighted in the previous paragraph, Beijing's strengths can be attributed to the high degree of concentration for talents, funding schemes, scientific research facilities, and other relevant resources. For example, in 2020 alone, a total of RMB232.66 billion (over US$33.7 billion equivalent) was invested in research and development (R&D), of which

approximately RMB100.6 billion (US$14.6 billion equivalent) and RMB26.2 billion (about US$3.8 billion) were allocated to research institutes and universities, respectively. Beijing's total R&D investment in 2020 was equivalent to nearly 6.5% of the city's GDP output in the same year (which was about RMB3.61 trillion, or equivalent to US$568 billion). Benchmarking this with Hong Kong's figure (for which its annual R&D-to-GDP ratio, on average, has been around 0.8%), Beijing scored substantially higher. In the same year, it is estimated that Beijing's universities and research institutes hosted 123,428 and 136,478 R&D personnel (**Beijing Municipal Bureau, 2021a**). In comparison to Shenzhen and Shanghai, and indeed the remaining provinces and autonomous regions within mainland China, Beijing's R&D-to-GDP ratio would rank the city as the most research-intensive in the country. Simultaneously, Beijing's total allocation of R&D resources for universities and public research institutes – about 3.5% of its GDP – was unprecedentedly high.

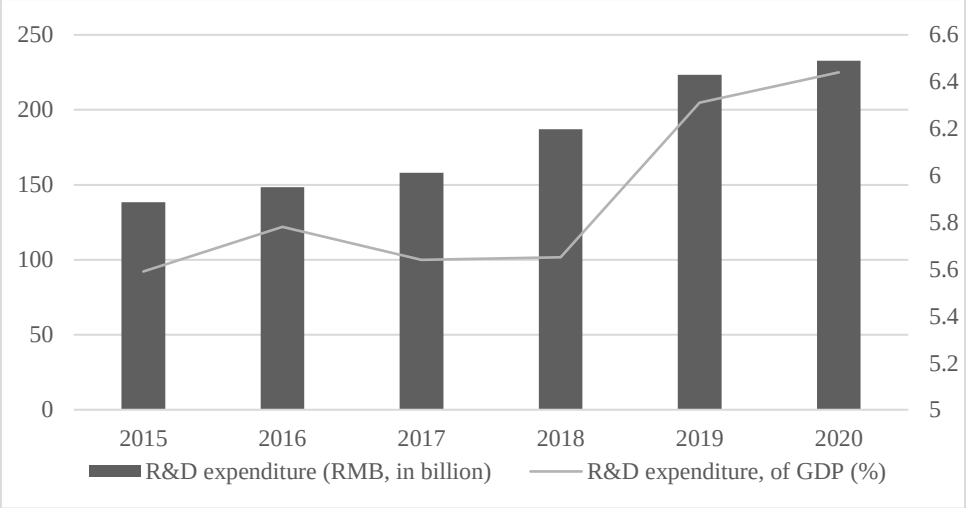


Figure 4-8 R&D expenditure in Beijing, 2015-2020.

Source: Beijing Municipal Bureau Statistics, Qianzhan Industry Institute.

Bulk of Beijing's prowess in research investments could be attributed to the presence of nationally significant organizations such as Chinese Academy of Sciences (CAS), Tsinghua University, Peking University, as well as other notable organizations (e.g. Beijing University of Technology, Renmin University of China, Beihang University, Beijing University of Posts and Telecommunications / BUPT, Chinese Academy of Medical Sciences / CAMS, Academy of Military Medical Sciences / AMMS, etc). Further, Zhongguancun, the country's first and largest science park, is home to over 60 universities and consists of a number of sub-parks throughout Beijing, with the largest concentration of national-level laboratories, research institutes, and high-tech startups. As of 2020, Beijing recorded a total of 138 higher-education institutions and 1,175 research institutes within the municipality (**Beijing Municipal Bureau, 2021b**). From a historical perspective, however, Beijing did not have such a flurry of resources dedicated towards R&D until the recent decade. In the following sections, we would briefly provide an overview regarding the historical development of government' attempts to enhance

its role as an innovation engine, the progress and transformation of universities and other key innovation actors, as well as the collaboration activities between universities and industry in Beijing.

4.4.2.2.Government policies and programs

Changing roles and structure of STI-related government organizations

In 2008, the Beijing government issued an outline called the mid-to-long term scientific and technological strategic plan. The plan stressed that the government would make an effort to promote industry-university-research cooperation **(Yang and Welch, 2012**). On the governmental level, it would develop institutions that could conduce to the collaboration between enterprises and universities. The government would encourage nationwide research facilities to root in Beijing by granting political or financial support. Additionally, the government would lead the reform in universities to enhance their function as research facilities with the attempt to help universities establish the knowledge transfer office or other necessary departments. Following the strategic plan, the Beijing Municipal Science and Technology Commission, the primary public agency in developing scientific strength, undertook the task to promote Beijing's knowledge transfer. This commission aims to facilitate, monitor, and evaluate the scientific research and knowledge transfer in Beijing. Its mission statements include: 1) To promote the scientific institution reform. 2) To design an annual development plan for national scientific innovation centres. 3) To put forward strategic suggestions for scientific development. 4) To establish knowledge transfer institutions and supervise the technology market (**Beijing Municipal Science and Technology Commission, 2021**). Specifically, it established subordinate offices that focus extensively on the university-industry-collaboration and corresponding knowledge transfer. They are namely *Center of Beijing High-tech knowledge transfer service*, *Center of technology trade service*, *Beijing Technology Trade Promotion Center*, *Beijing High-tech Entrepreneurship Service Center*, *Beijing Technology Market Management Office*. These offices' primary task is to coordinate different kinds of KT affairs. In recent years they have organized numerous activities and built several platforms to cultivate KT competitiveness.

In April 2021, the municipal government announced that the Beijing Municipal Science and Technology Commission and the Zhongguancun Science and Technology Park Management Committee are co-located under the name of "Beijing Municipal Science and Technology Commission and Zhongguancun Science and Technology Park Management Committee." Institutional units were restructured to coordinate and promote the reform of Beijing's science and technology system, including *Beijing Science and Technology Innovation Promotion Centre*, *Beijing Science and Technology Achievement Transformation Service Center*, *Zhongguancun High-tech Industry Promotion Centre*, *Zhongguancun Government Procurement Promotion Centre*, *Beijing Science and Technology Talent Development Center*, and *Beijing Information Technology Development Centre*. These six institutions have undertaken important missions in building a national strategic scientific and technological force,

promoting the transformation of scientific and technological achievements, cultivating high-precision and cutting-edge industries, serving the development of science and technology parks, and creating an innovative and entrepreneurial ecology.

In 2021, the Office of the Beijing Joint Council for Promoting the Transformation of Scientific and Technological Achievements is established under the framework of Beijing Office for Promoting Science and Technology Innovation Centre and the Special Group for Science and Technology System Reform of Beijing Municipal Committee for Comprehensively Deepening Reform. In October 2021, this municipal-level joint office issued the "Operation Guidelines for the Transformation of Scientific and Technological Achievements," providing guidelines for the government-established R&D institutions, universities and medical and health institutions' achievement transformation management agencies and researchers to carry out the transfer and transformation of scientific and technological achievements.

Policies and programs to promote technology transfer

One of the milestones the Beijing Municipal Science and Technology Commission made was that it issued the key policy document, *Regulations of Beijing Municipality*, on promoting the transfer of scientific and technological achievements (**Beijing Government, 2019**). Specifically, regarding the knowledge transfer in universities, this regulation is aimed to facilitate the transfer from three aspects:

- First, the regulation clarifies the role of knowledge transfer in faculty performance assessment. It is clearly regulated that the achievement in knowledge transfer should be an important indicator in the performance measurement system. The amount of annual funding would be directly contingent on the measurement outcome. Furthermore, it is regulated that universities should take researchers' performance in knowledge transfer into consideration when it grants professorial titles. In this way, this regulation ensures that universities have the motivation to transfer their scientific research findings into commercialized products.
- Second, the regulation is aimed to protect the right of researchers in the process of knowledge transfer. According to the regulation, while the university can decide the distribution of the license income independently. Researchers should share no less than 70% of the revenue. Also, researchers are granted more independence. They can decide when and how to conduct the transfer and whether to conduct the asset appraisal. Compared with the traditional pattern that the university owns the intellectual property, the regulation stresses that researchers can maintain ownership in some circumstances.
- Third, the regulation makes for the knowledge transfer on the institutional level. It announces that the government will coordinate between research facilities and enterprises in regard to contract research and commercialized research findings. In 2019, the Beijing government organized several exhibitions and conferences to help researchers find funders. Moreover, to attract enterprises, the government will prioritize innovative products or services in procurement or open tenders. To conclude, this policy document, as comprehensive guidance on knowledge transfer, has put forward many powerful regulations from the perspective of every stakeholder.

It is worth noting that this Regulation has specified that Beijing encourages R&D institutions and higher education institutions to give priority to transfer scientific and technological achievements to SMEs. This provision provides stronger support for SMEs to participate in the transformation of scientific and technological achievements of universities and research institutes.

Another policy document which has significantly facilitated the knowledge transfer is *Regulations on Beijing Technology Market* (**Beijing Government, 2021**). It is the first set of regulations that has standardized the technology market covering four major aspects of the technology business:

- Detailed regulations for activities in the technology market. The regulations made it clear how to trade scientific technologies and what the seller and purchaser should do in trading activities;
- Detailed regulations for agent service in the technology market. It has defined that the conception of technology trading agents and regulated the duty of trading agents;
- Specific terms to encourage trading activities and to ensure the interest of two sides. For example, it takes the cost of purchasing technologies into consideration in reducing taxation. And it has regulated that researcher can share a certain proportion of the income in contracts;
- It clearly announced the potential legal consequences for violating this set of regulations or other concerned laws. It also expressed the legal process in a lawsuit about technology trading contracts.

The Beijing municipal government has also placed emphasis on the cultivation of professionalized technology transfer talent. As already mentioned in the *Regulations of Beijing Municipality on promoting the transfer of scientific and technological achievements (2019)*, Beijing encourages the establishment of various types of science and technology service institutions to provide training for technology transfer transformation professionals, including technology brokers and technology managers. In the *Action Plan of the Beijing Bureau of Talent Work*, the goal of “training 3,000 backbone talents for technology transfer” is also included and highlighted by the government. Several key strategies include:

- In October 2019, Beijing Municipal Bureau of Human Resources and Social Security and the Beijing Municipal Science and Technology Commission issued the "Beijing Engineering Technology Series (Technical Broker) Professional Technical Qualification Evaluation Trial Measures", officially adding the professional title of technology manager.
- In December 2020, Beijing Municipal Science and Technology Commission, jointly with other eight units including Beijing Technology Market Management Office and Beijing Technology Market Association, released the first local standard for capacity building of technology transfer service personnel in China.
- In July 2022, Beijing government has signed agreement with Tsinghua university and established the first degree program which integrated deeply technology innovation and finance in China. Through providing technology transfer-specificialised scholarship, high-level talent training talent based deeply on university-industry, and talent supportive service and apartment, the government attempts to achieve more scientific breakthrough

and services.

As for funding schemes, in 2019, the Beijing government issued a supplementary document on funding management. The thrust of the document is to decentralize the authority to approve scientific research, which corresponds to the regulation. Accordingly, the government developed a system to evaluate universities' management in research funding. Qualified universities, which have no deception record and complete monitoring institutions, will be granted with authority to approve funding schemes independently. In this way, researchers in universities can enjoy more freedom to declare their research projects. In the meantime, the document has revised the traditional auditing regulations. Traditionally, the receipt is the only evidence in the financial statement. The document makes it legal that other evidence, like the record of meetings about funding schemes, can also be evidence to prove the usage of funding. Also, the government will help universities to hire third-party auditing companies in an annual check. The document reflects the determination the government has made to eliminate obstacles regarding application for research funding. It is a part of institutional changes that contribute to the development of knowledge transfer.

Other than the institutional changes, the government has also organized various activities to promote collaborations between enterprises and universities. The roadshow exhibition could serve as a vivid example. In November 2019, the Beijing department of science and technology, together with Beijing high-tech knowledge transfer platform, organized some special roadshows. It is worth mentioning that the platform was a new office established by the Beijing department of science and technology, following the guidance of Regulations of Beijing Municipality on promoting the transfer of scientific and technological achievements. The exhibition lasted for three hours. In the exhibition, ten universities in Beijing displayed their latest findings in scientific research in turn. Another group of participants was enterprises in the innovation field. Since the main target of the exhibition is to attract investors to collaborate with researchers, the government invited investors in more than fifty enterprises. These investors could contact research groups who had introduced their research outcome in the exhibition. It is estimated that the exhibition has helped researchers in the ten universities to win contracts valuing more than 100 million RMB in total.

Policies to attract talents

The municipal authorities formulated a series of preferential policies to recruit domestic and overseas talents (the latter referring to Chinese returnees, in particular) to work and/or establish companies in Zhongguancun. Zhongguancun regional officials, in particular, also launched their “Thousand Talents Plan”, “Sea Gathering Project” (specifically for returnees), followed by other favorable policies, such as establishing a ‘pioneering industrial park’ for overseas talents that are interested to set up technology companies. Furthermore, in March 2021, Beijing Municipal Science and Technology Commission and Zhongguancun Administrative Committee jointly launched China’s first standardization efforts for incubation of existing science and technology start-ups, in which this pilot project – implemented within Zhongguancun – aims to streamline the types of services provided by start-up incubators for

these S&T-oriented early-stage companies.

The construction of technology innovation talent teams is a key area of concern for the Beijing. Beijing adheres to the principles of high starting point and high standard in building teams of innovative talents, and plans to use research universities as a platform to create a number of outstanding research groups with international influence. In September 2016, the State Council issued the General Plan for Strengthening the Construction of National Innovation and Technology Hub in Beijing, emphasizing support for higher education institutions, research institutes and qualified enterprises to jointly build basic research teams, accelerate the construction of scientists' studios, innovate. Establish flexible and diversified modes of innovative talent flow and employment, encourage the mutual recruitment of talents from higher education institutions and research institutes, and allow higher education institutions and research institutes to set up a certain proportion of mobile positions to attract talents from enterprises to work part-time. In October 2019, the Beijing Municipal People's Government issued "Several Policy Measures on Deepening the Reform of Science and Technology System in the New Era to Accelerate the Construction of National Innovation and Technology Hub" to encourage higher education institutions in Artificial intelligence, integrated circuits, cloud computing, translational medicine and precision medicine and other fields to strengthen the training of highly skilled personnel and professional management personnel in high-precision industries. Expand the funding of the city's Natural Science Foundation and Postdoctoral Program. In addition to the training of researchers, in November 2021, the Beijing Municipal People's Government issued the "Construction Plan of Beijing International Science and Technology Innovation Center in the 14th Five-Year Plan", which not only focuses on the training of researchers, but also promotes the "enterprise mentorship system" in colleges and universities in the mode of school-enterprise cooperation. "The plan not only focuses on the cultivation of researchers, but also encourages enterprises in high precision industries and frontier science and technology fields to set up postdoctoral research stations. And it also puts forward the requirement of increasing the training of technology brokers, supporting universities and institutes to establish additional technology transfer majors and build technology transfer colleges, and training a group of specialized technology transfer teams that understand the laws of science and technology innovation and industrial technology needs.

4.4.2.3.Universities in Beijing innovation system

Beijing ranks first in the country by holding 34 universities of the “Double First-Class Project.” In this section, we briefly introduce three major forces driving the scientific and technological activities in Beijing: Chinese Academy of Sciences (CAS), Tsinghua University, and Zhongguancun – the third being a high-technology industry cluster often dubbed as the closest China has to a Silicon Valley-like ecosystem.

CAS

As already highlighted in the beginning, Beijing hosts a higher number of research-performing organizations than any other localities within mainland China, and CAS stands as one of its biggest behemoths. Established in 1949, the academy ranked first globally in the 2020 Nature

Index for top-performing institutions (**Nature, 2020b**), and is also the leading hub for academic research in natural science-related fields in China. At the outset of its establishment, CAS – supported by the Chinese government – relied on Chinese returnee scientists in running the institution. Over time, these scientists would enable CAS to pioneer the development of science and technology infrastructure in mainland China. Nevertheless, given that the CAS – and China's S&T system more broadly – was based on Soviet model, there had been, historically, no commercialization activities for breakthroughs resulting from research at CAS (**Chen and Kenney, 2007**). It was only from 1980s onward – given the budget cuts and China's experimentation with economic reforms – that the Academy began spinning-off their research units into enterprises. As an illustration, in 1987, CAS founded Science and Technology Promotion for Economic Development Foundation, in which one of its core functions was to encourage staff at CAS-affiliated research institutes to establish their technology companies. Moreover, in 1993, the Academy established a venture capital (VC) firm – one of the first instances in China – known as China Science and Technology Promotion and Economic Investment Company, which has since been renamed CAS Investment Management Co. Ltd.

In 1997, CAS launched a study on innovation system for the knowledge economy era and submitted a research report entitled "Embracing the Knowledge Economy Era and Building a National Innovation System" to the Central Government. The report examined China's science and technology development in a holistic and systematic perspective, proposing that the main functions of the national innovation system are knowledge innovation, technological innovation, knowledge dissemination and knowledge application, specifically including the execution of innovation activities, the allocation of innovation resources (human, financial and information resources, etc.), the establishment of an innovation system and the construction of relevant infrastructure. The report put forward the ideas of building China's national innovation system for the 21st century and the strategic positioning of the Chinese Academy of Sciences, and recommends the implementation of a national knowledge innovation project.

As of 2014, these organizations have successfully supported 300+ commercialization projects based on research breakthroughs at the institutes (**CAS Investment Management Co. Ltd., 2014**). CAS also serves in an advisory role for the formulation and implementation of science and technology policies,

Tsinghua university

Tsinghua University has been extensively covered and profiled in the Task 2 report, but in this write-up, we will – whenever relevant – draw linkages between the university and Beijing's innovation system, whether in the form of inter-organizational relationships through patent data or scientific collaboration with industry actors. To recap, we again briefly summarize about the institution. As China's most prominent research-oriented and teaching university for decades, Tsinghua has developed a very strong talent pool and contributed tremendously to the development of Beijing's innovation ecosystem, and China's national innovation system more broadly. At present, the university employs 15,772 faculty members (comprising of 3,641 professors, 9,598 non-professorial academic staff, 2,533 postdoctoral fellows), and 53,302 full-

time students (Tsinghua University, 2021a). As of December 2021, the university also hosts a total of 421 scientific research institutions within the campus (Tsinghua University, 2021b).

One major aspect with respect to Tsinghua has been their well-established, complex technology transfer ecosystem, for which we will recap again in the analysis on Tsinghua's scientific collaboration linkages with industry actors. Relatedly, the university's innovation output has been among the highest in comparison with other mainland Chinese institutions. As an illustration, for 2016-2020 period alone, the university possesses a portfolio of 11,852 domestic patents and 1,443 overseas patents, many of which were filed to the USPTO (Tsinghua University, 2021c). Moreover, a significant number of spin-offs have been established in order to commercialize scientific breakthroughs from research taking place at the university, for which we will further cover in the analysis on Tsinghua's scientific collaboration linkages.

Zhongguancun

Zhongguancun, where both CAS and Tsinghua are located, has also served as another driving nexus in the development of Beijing's innovation ecosystem. Being a cluster of computer shops as its progenitor, this area has since been undergoing a significant transformation over the decades into one of China's leading entrepreneurship hubs (**Segal, 2003**). The presence of leading research-performing institutions, coupled with decades of economic reforms and opening-up to foreign direct investments (FDI) that led foreign multinationals to establish production and research centers, has been the fundamental driving factors of Zhongguancun's historical transformation (**Zhou and Xin, 2003**). Such evolution continues to take place at the present, as reflected in the following statistics. For illustration, as of 2021, among all national-level high-technology development zones within China, Zhongguancun hosts the largest number of high-technology enterprises (27,487) and employees (over 290,000), with the biggest cumulative operating revenue (RMB722 billion, approximately US$110 billion) in comparison to their other Chinese counterparts (**Zhongguancun Index, 2021**). The operating income of enterprises in Zhongguancun accounts for 14% of the operating income of enterprises in all state-level high-tech development zones in China. Zhongguancun not only has a large number of enterprises, but also the proportion of technology revenue of enterprises is increasing.

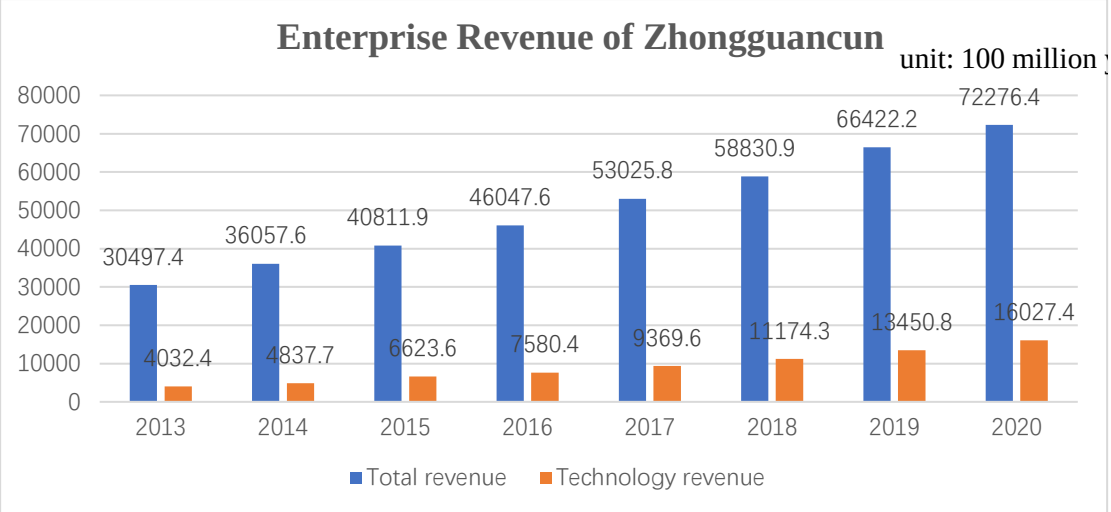


Figure 4-9 Enterprise revenue of Zhongguancun

Source: *Beijing Statistical Yearbook 2021*

Moreover, Zhongguancun received further boost from the establishment of Tsinghua Science Park (TusPark) by the university in 1994. Since its inception up to present, TusPark has been a home to over 1,000 high-technology firms, start-ups, as well as various research-performing institutions beyond Tsinghua and CAS. In addition, TusPark has set up over 150 science parks and start-up incubation bases beyond Beijing, incubating a total of over 5,000 start-ups. Within TusPark in Zhongguancun, a large number of foreign multinationals have also established R&D centers, most notably Microsoft (with their Microsoft Research Asia being one of the company's largest R&D bases outside the United States). The presence of TusPark has further mutually strengthened university-industry collaboration, with the former acquiring university-generated knowledge for their business development, and the latter obtaining industry support for further scientific ventures.

The other influential university in Beijing: the case of Peking University

Similar to Tsinghua, Peking is one of the country's leading universities, and one of the highest-ranked institutions globally. As of December 2020, Peking hosts a total of 11,694 faculty members, 90 of whom serve as members of the prestigious Chinese Academy of Sciences (CAS), 25 in the Chinese Academy of Engineering (CAE), and another 38 in the World Academy of Sciences (**Peking University, 2020**). Moreover, the university also serves as a technology transfer base of the Ministry of Education, an organizational vice-chair unit of the China University Technology Transfer Alliance, and a council member of the International Strategic Technology Alliance (ISTA). In a pattern quite similar to our observation of Tsinghua University in the Task 2 report, Peking University's technology transfer institution is operated under the Office of Science and Technology Development, which is primarily responsible for the promotion, incubation, and commercialization of registered S&T achievements originating from the university.

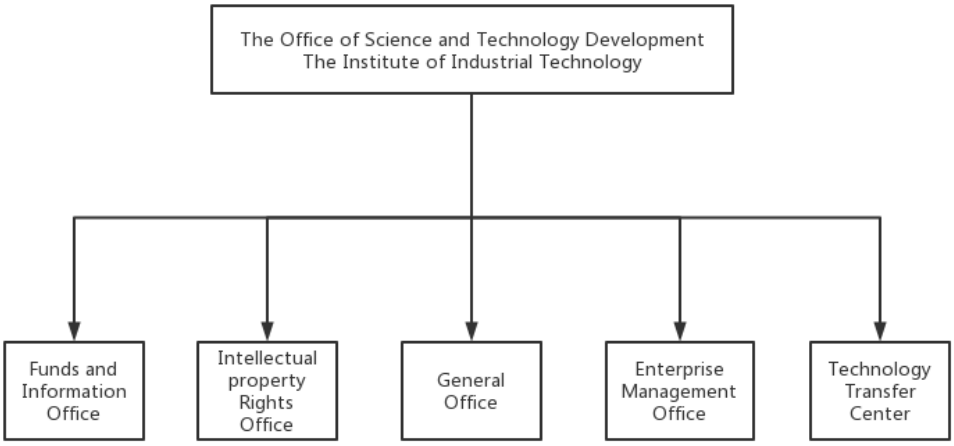


Figure 4-10 Organizational structure of the Office for Science and Technology Development of Peking University

The organization operates five subordinate offices (as displayed in Figure 4-10 above), namely: Funds and Information Office, Intellectual Property Rights (IPR) Office, General Office, Enterprise Management Office, and Technology Transfer Center. The office is primarily responsible for managing technology transfer and U-I collaboration agreements involving Peking University, as well as formulating relevant regulations surrounding these practices. One of the most vital organizations constituting the Office of S&T Development is Peking's Technology Transfer Center (TTC), which houses the university's capital resources and IP portfolio (notably patents). The TTC collaborates closely with local governments and investment funds, manages a dedicated 'patent commercialization fund', and is also responsible for the examination, evaluation, and funding of projects supported by this fund. The Institute of Industrial Technology, in which its organizational hierarchy status is on par with the Office of S&T Development (and co-oversees these five organizations), works closely with the latter in carrying out and performing industry-oriented research at Peking (**Office of Science and Technology Development of Peking University, 2022**).

We also found that beyond Beijing, Peking University has expanded their technology transfer practices through branch institutes – in close collaboration with local governments – in Guangdong Province, Tianjin, Jiangsu Province, Shandong Province, Zhejiang Province, Jiangxi Province, Chongqing Municipality, and Shanghai. The university has issued a series of long-term management mechanism to guide and regulate the establishment of these institutes, providing full process management and professional support development for these off-site research institutions and affiliated enterprises.

In a way not dissimilar to Tsinghua, Peking University has also actively embarked on U-I collaboration projects, and one of the most common approaches in implementing these projects is through the establishment of joint research centers with industry actors. At present, the university has signed joint collaborative research agreements with more than 80 large enterprises (both domestic and foreign) to build jointly-operated research centers, spanning a

large variety of research areas, e.g. cybersecurity, big data, biomedical sciences, smart manufacturing, environmental protection, financial protection/fintech, etc. Table 4-18 below provides some examples of U-I collaborative works and their project periods.

Table 4-18 Examples of joint U-I research centers involving Peking University

Name	Faculty	Partner (Origin)	Project Period
ENN Technology Innovation Center of Peking University	School of Engineering	ENN Group (CN)	07/2015 – 07/2025
Peking-BOE Group Innovation Research Institute	School of Engineering	BOE Technology Group (CN)	05/2017 – 05/2027
Peking-Longsoft Technology Smart Energy Institute	School of Earth and Space	Longsoft Technology (CN)	08/2018 – 12/2027
Peking-SenseTime Smart Computing Joint Laboratory	School of Information	SenseTime (CN/HK)	10/2018 – 09/2023
Huawei-Peking Intelligent Media Technology Center	School of Information	Huawei (CN)	12/2018 – 12/2021
Huawei-Peking Mathematics Joint Center	School of Mathematical Sciences	Huawei (CN)	06/2019 – 06/2022
Huawei-Peking Programmable Hardware Center	School of Information	Huawei (CN)	06/2019 – 05/2024
Huawei-Peking Semiconductor Research Center	School of Information	Huawei (CN)	01/2021 – 01/2024
Peking-Bayer 3rd Phase Collaboration Framework	College of Life Sciences	Bayer (DE)	05/2020 – 05/2023
Peking-China Resources Molecular Engineering Center	School of Chemical and Molecular Engineering	China Resources Life Sciences (CN)	11/2020 – 11/2023
ZTE-Peking Basic Software Joint Laboratory	School of Information	ZTE (CN)	03/2021 – 03/2024
Peking-Boehringer Ingelheim Framework Agreement	College of Life Sciences	Boehringer Ingelheim (DE)	08/2021 – 07/2026

4.4.2.4.Inter-organizational networks: evidence from USPTO patent data

Our first analysis – which relates to the observation of evolution in inter-organizational networks over time – entails the use of patent data (specifically from USPTO). We filtered our USPTO dataset and limited our focus on all patents filed in Beijing. After further data cleaning and analysis, we generated a subset of Beijing-specific data, which consist of 36,224 patent applications in total, and almost all of which were filed within the 36-year, 1983-2018 period. For a better understanding of who the major innovation actors in Beijing are, Table 4-19 below highlights the top-10 applicants for patent filings based on inventions in the city. Quite interestingly, BOE Technology Group (also known in Chinese as 'Jingdongfang') is the most active innovating organization in Beijing's innovation system.[144] The company, founded in 1993 by an amalgamation of spin-offs from engineering research institutes and formerly state-owned factories, and known for their expertise in designing and manufacturing display-related products, was responsible for over 1/6 (N = 6,856) of the city's cumulative patent applications, most of which were filed in the 2013-2018 period; indeed, BOE Technology's patent application count even surpassed the cumulative number of filings by the next three innovation actors combined.[145]

Huawei was distantly placed as the second most active patenting organization, with a total of 2,732 patents to protect their inventions – most of which, similar to BOE, were invented in 2013-2018 period. IBM, placed at the third position, is the most actively patenting foreign enterprise in Beijing; this was mainly attributed to the longstanding presence of the US multinational firm in the city, particularly after the merging of their personal computer (PC) division with Chinese computer maker Lenovo, as well as their expanding R&D presence (**Zhou and Xin, 2003**). Tsinghua University, at the fourth rank of the top-10 list, and with over 2,000 cumulative US patent filings, is the most actively innovating higher-education institution in Beijing, and possibly in the whole of mainland China.

Table 4-19 List of top-10 patenting assignees in Beijing (all-time)

Name	Patent filings (36,224)
BOE Technology Group	6,856
Huawei	2,732
IBM	2,045
Tsinghua University	2,009
Microsoft	1,882
Hon Hai-Foxconn	1,385
Intel	881
Lenovo	873
Ericsson	706
Chinese Academy of Sciences	648
Share of top 10	54.7%
No. of organizations	2,210

Overall, based on simple description in Table 4-19 above, we found that three major types of

innovation actors contributed to Beijing's ascendance as a globally leading innovation hub: universities and research institutes (notably represented by Tsinghua and Chinese Academy of Sciences / CAS), affiliates of foreign multinationals (as shown by IBM, Microsoft, Hon Hai-Foxconn, Intel, Lenovo, and Ericsson), and more recently, mainland Chinese 'domestic champions' (as BOE Technology and Huawei attest). By contrast, state-owned enterprises (SOEs), despite being headquartered in Beijing given its status as China's capital, have not provided as significant a role as those three types of actors shown in Figure 4-11 above. This observation appears to support the observation by **Segal (2003)** and **Zhou and Xin (2003)** regarding the dynamics of innovative activities in the city.

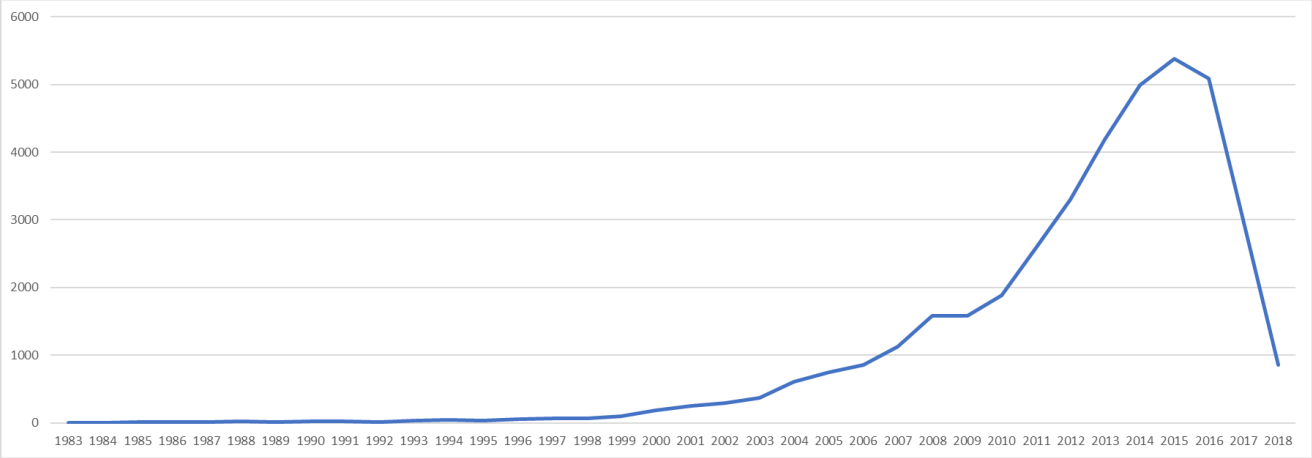


Figure 4-11 USPTO patent filings in Beijing (1983-2018)[146]

However, from Table 4-21 in the following page, we can observe that MNCs did not initially play a leading role in Beijing's transformation into a major innovation hub. Throughout the first three 6-year periods (1983-1988, 1989-1994, 1995-2000), SINOPEC (abbreviation of China Petrochemical Corporation) was the most frequent patenter in the city, followed by local universities – notably Tsinghua – and affiliates of foreign universities, research institutes, and government agencies. While the annual figures largely 'plateaued' from early 1980s to 2000, the growth in innovative outputs – as shown from Table 4-20 below – has been fairly significant, with the number rising from 62 in 1983-1988, to 142 in 1989-1994, and eventually 489 in 1995-2000 period.

A major impetus began to take place from 2001-2006 period onward, as the aggregate count of patent filings more than quintupled in comparison to those in the 1995-2000 period. Here, SINOPEC's patent filings began to stagnate, and the city's innovation landscape shifted to one dominated by foreign multinationals, a lot of which are involved in ICT- and electronics-related industries. Non-mainland Chinese enterprises, notably Microsoft, Hon Hai-Foxconn, IBM, Intel, Nokia, and Samsung, were on the top-10 patenter list throughout this period. Moreover, Tsinghua University also emerged as not only a provider of graduates, but also innovation outputs, as well as spin-offs (with NUCTECH, another member of the top-10 list, being one of them).

The dynamics in Beijing's innovation system became even more complex throughout the 2007-2012 and 2013-2018 periods. Regarding the former, inventors and organizations within the city

quadrupled the number of patent filings (to slightly above 11,000), a figure that was considerably higher than those we observed in 2001-2006 (N = 2,592). The total output further doubled in 2013-2018, with the aggregate number of filings almost surpassed 22,000. While foreign firms initially oversaw such patenting boom – as demonstrated by the ongoing influence of Microsoft, Hon Hai-Foxconn, IBM, Nokia, Ericsson, and Intel, over time home-grown technology companies gained their clout as well. By 2013-2018 period, 5 out of the top-10 patenting organization list have been occupied by mainland Chinese enterprises, which include: BOE Technology Group, Huawei, Xiaomi, Lenovo, Hefei Xinsheng (which is a 'sister firm' of BOE Technology).

The case of Lenovo, in particular, has been interesting. It is one of the most notable and successful spin-offs emerging from CAS (which we have mentioned in the introduction section). It was established in 1984 by Liu Chuanzhi and ten other scientists from CAS' Institute of Computing Technology. The company's formation year coincided with China's reforms of S&T system, as well as the gradual emergence of private-sector entities in China (**Segal, 2003**). Lenovo, in its first few years, received RMB2 million start-up loan from CAS, in addition to access to research facilities and technologies at the institute. Nevertheless, the company's 'innovation burst' only occurred during 2013-2018 period, with 596 out of their portfolio of 873 patent grants filed within this 6-year timeframe. Indeed, an in-depth analysis by **Fuller (2016)** provided explanation on why Lenovo was a relative 'innovation laggard' in comparison to other enterprises in the top-10 patenting innovator list. Despite their initial innovation in simplified Chinese-language keyboards and pioneering of non-state PC manufacturing, the company's growing dependence on state procurement and subsidies would significantly slow down their innovation efforts (see the case of ZTE in the Shenzhen write-up for further similarities regarding this issue).[147]

Previously, we have briefly mentioned about Tsinghua University's influential roles as not only in producing graduates, but also in spinning off their inventions into commercial entities. Interestingly, when readers sifted through Table 4-21 and Table 4-22 (where we provided top-10 lists across various 6-year periods and their respective betweenness centrality scores), we found only 1 instance where a Tsinghua spin-off was in the top-10 list, which was 2001-2006, where NUCTECH was included. Other than this period, no other 6-year periods had Tsinghua-affiliated spin-offs mentioned in the lists. While the near-absence could be attributed to the limited technological and absorptive capacities that many of these spin-offs also faced (**Fuller, 2016**), we also suggested caution regarding this finding, especially as we proceeded to the second analysis, by which we identified a far greater number of science-driven companies through close examination of Tsinghua's U-I co-publications.

Afterwards, we turned our attention towards identifying the shifts in the most influential innovation actors in Beijing using two centrality measures: betweenness centrality (measured by the potential number of dyadic links between any two nodes in a network that can be facilitated/bridged by the node of interest) and degree centrality (the number of direct ties a node builds with other nodes in a network), following **Freeman (1977)**. Two other tables in the next pages provide results on the most influential organizations across different time periods based on the two network analysis-related centrality properties, which we will elaborate

in the following paragraph below.

In terms of betweenness centrality, historically, we can observe that universities, research institutes, and – to a limited degree - SOEs, were the most important innovation actors in Beijing's innovation system. From early-1980s to end-1990s, Tsinghua University, Chinese Academy of Sciences (CAS), Chinese Academy of Medical Sciences (CAMS), Beijing Polytechnic University, and SINOPEC were highlighted as organizations with influential position in the city's emerging innovation networks. This finding reflects Beijing's initial competitive advantage given their considerable research-supporting infrastructure (**Zhou and Xin, 2003; Yusuf and Nabeshima, 2010**). Separately, when measured from degree centrality, roughly half of the highest-ranked patenting organizations in 1983-2000 period were research-performing institutions (despite their fairly low centrality scores under this dimension). We speculate that their position was in large part due to their roles in spinning off research units within these organizations into commercial entities, whereas their low degree centrality scores could be attributed to the limited influence of the resulting spin-offs for Beijing's – and China's, in particular – broader economy (**Zhou and Xin, 2003**).[148]

We further investigate the types – and composition – of organizations with which Beijing's major universities and research institutes have the most frequent linkages with. Specifically, we pay attention to the top-10 organizations in which the select organizations – namely Tsinghua University, Peking University, Beijing University of Technology, Chinese Academy of Sciences, and Academy of Military Medical Sciences – develop the highest number of recurrent ties, which is proxied by the number of times investors in an organization are also listed in the patents of another organization. While we may not have a definitive knowledge about the precise drivers of such linkages, there may be several possible scenarios: 1) career mobility, in which university scientists/researchers either graduated or moved workplaces (**Almeida and Kogut, 1999**); 2) multiple-applicant patents, by which a patent is jointly owned – under some collaborative agreements – by 2+ organizations (**Hagedoorn, 2003; Ter Wal and Boschma, 2009**); 3) other organizations, especially firms, contract out their research to university inventors (**Ter Wal and Boschma, 2009**), and/or; 4) informal collaboration between inventors across different entities (**Fleming et al., 2007**).

As already stated, we collected the top-10 organizations from each of the five institutions based on their number of recurrent linkages with every single organization, which we obtained from these organizations' degree centrality scores, a proxy that represents the number of organizational actors they have direct linkages with. For example, CAS' degree centrality score, as of 2013-2018, was 355, an indication of their direct ties with 355 other innovation actors within Beijing. Out of these 355 entities, we chose the most significant 10 of them on the basis of their repeated ties. Afterwards, we replicated our approach to the four other remaining institutions. We primarily focused on 2001-2018 period, given that universities and PROs only began to more actively participate in Beijing's innovation ecosystem from early 2000s onward. Table 4-20 below displays results from our analysis.

Table 4-20 Most frequent direct inter-organizational linkages involving Beijing-based HEIs and public research organizations (number of recurrent linkages in brackets)

	2001-2006	2007-2012	2013-2018
Tsinghua Univ	Hon Hai-Foxconn (23074) NUCTECH* (4048) BJ Funate Innov (651) CapitalBio* (609) Aviva Biosci (144) IBM (122) Microsoft (114) Stanford Univ (111) Visionox* (48) Samsung (40)	Hon Hai-Foxconn (543118) BJ Funate Innov (42294) NUCTECH* (18960) IBM (4184) Microsoft (1247) Sony (899) Thomson (578) BOE Tech Group (446) CapitalBio* (426) Yahoo (395)	Hon Hai-Foxconn (189331) NUCTECH* (19739) BOE Tech Group (9244) IBM (2106) Huawei (1344) BJ Funate Innov (870) Hefei Xinsheng Opto (729) EMC Corp (589) CAS (518) Ericsson (442)
Peking Univ	Microsoft (186) Founder Group* (125) BJ 2nd Optical Instr (24) Tsinghua Univ (23) NUCTECH (20) IBM (15) SINOPEC (8) Sony (4) Sichuan Heben Bio (3) CAS (2)	Founder Group* (774) Microsoft (375) IBM (164) CAS (41) Tsinghua Univ (41) Fujitsu (40) Nokia (36) Ericsson (35) Chin Acad Telecom (33) BOE Tech Group (32)	BOE Tech Group (1207) Founder Group* (1046) Huawei (264) Ericsson (169) Acad Mil Med Sci (165) NUCTECH (157) Tsinghua Univ (128) Fujitsu (108) BJ Boyuan Hengsheng (80) Yongfeng Boyuan Ind (80)
BJ Univ Tech	Nanomat Tech SG (21) Alcatel-Lucent (11) CAS (8) Datang (5) SH Ultim Power ICT (5) Sichuan Heben Bio (3) ABB (2) O2Micro (2) Philips (2) Qualcomm (2)	BOE Tech Group (72) Microsoft (61) IBM (55) Thomson (50) Intel (44) Tsinghua Univ (41) SINOPEC (39) Nokia (36) Hon Hai-Foxconn (30) Chin Acad Telecom (20)	BOE Tech Group (640) Fujitsu (75) Xiaomi (53) Huawei (52) IBM (37) Samsung (33) Tsinghua Univ (30) Guizhou Expressway (26) Ordos Yuansheng (25) Philips (24)
CAS	Microsoft (70) SINOPEC (16) AMMS (15) Altachem Pharma (5) Yantai Zhenghai Bio (5) BJ Molecule S&T (4) Huawei (4) Lenovo* (2) Alcatel-Lucent (2) General Motors (2)	Tsinghua Univ (224) IBM (146) Microsoft (128) Intel (124) BOE Tech Group (118) NTT (111) Hon Hai-Foxconn (102) Huawei (100) Nokia (80) Sursen Corp (72)	BOE Tech Group (2850) Tsinghua Univ (518) BJ Zhongkaihongde (327) Huawei (258) IBM (243) Hefei Xinsheng Opto (149) Xiaomi (128) Sony (123) Lenovo* (122) NTT (97)
AMMS	BJ Molecule S&T (32)	BJ Molecule S&T (484)	BOE Tech Group (296)

	CAS (15)	PLA Gen Hospital (154)	Peking Univ (165)
	HN Yangpu Pharma (11)	IBM (28)	Tsinghua Univ (126)
	Ericsson (10)	Huawei (15)	Merck (102)
	Luyin Lihua Pharma (8)	BOE Tech Group (14)	CAS (94)
	Samsung (6)	Chengdu Yiping Medic (12)	PLA Gen Hospital (88)
	ZJ Xianju Pharma (5)	Lenovo (12)	IBM (46)
	CAMS (2)	Samsung (12)	SINOPEC (44)
	Hon Hai-Foxconn (2)	General Electric (9)	Huawei (43)
	Inventio AG (1)	CAS (8)	Hefei Xinsheng Opto (34)

* refers to companies that are either owned by the university/research institute or spun off from research taking place in these organizations

Results from the table above provide some interesting insights about the dynamics of inter-organizational linkages within Beijing's innovation system. First, both foreign and domestic enterprises have benefitted immensely from active knowledge exchange and/or career mobility flows with talents from universities and research institutes. Multinational ICT firms, in particular, as exemplified by Microsoft and IBM, have had their USPTO patent filings from Beijing invented by individuals with backgrounds from Tsinghua, Peking, Beijing University of Technology, and CAS (either as employees for both companies or researchers contacted by these enterprises), supporting the observation by **Zhou and Xin (2003)**. What is even more interesting is the very in-depth repeated ties between Tsinghua researchers and Hon Hai-Foxconn, a Taiwanese multinational contract manufacturer. Their high scores could also be attributed to the high number of joint patents between the two organizations (possibly given the presence of a joint technology center).[149] Nevertheless, the frequency of their two-way relationships has been declining in recent years, as an increasing number of Chinese domestic technology firms (the largest being BOE Technology Group, followed by Huawei, Xiaomi, as well as technology spin-offs from these insitutions, e.g. Lenovo, Founder Group, NUCTECH, CapitalBio, Visionox) also began to more actively court these inventors. While foreign firms continue to rely on their expertise for inventive activities as of 2013-2018, the competitive landscape is increasingly intense. Tsinghua, Peking, and CAS stood out, in particular, given the spin-offs they have produced (**Chen and Kenney, 2007**).

Overall, there has been a significant shift in the dynamics of Beijing's innovation ecosystem across decades, particularly since the 21st century. As already demonstrated in the previous paragraphs, foreign multinationals only began to play a more visible role in Beijing's innovation landscape from early 2000s onward. Two best known examples, Microsoft and IBM, had been responsible for establishing some of the world's largest R&D centers in Beijing, largely in order to leverage the growing community of engineering talents in Zhongguancun, where Tsinghua, Peking, CAS, and various other institutes were located. Tsinghua's stature – in both betweenness and degree centrality measures – also grew in tandem with the influence exerted by these foreign enterprises. Since early 2010s, China's 'domestic champions', notably BOE Technology Group and Huawei, as well as Lenovo, Xiaomi, and Baidu to some extent, have risen considerably in centrality terms. Indeed, based on the degree centrality scores, by 2013-2018 period BOE Technology Group and Huawei have established direct linkages with 642 and 417 organizations respectively (whether for career mobility, knowledge exchange,

technology transfer, etc); these findings demonstrate the large extent to which these firms have depended on external sources to drive their innovation. Overall, echoing **Yusuf and Nabeshima (2010)**, ICT industry – and Beijing's relatively seamless integration with the industry's global value chain – has enabled the city to be positioned as a strategic hub in the global innovation landscape.

Table 4-21 List of top-10 patenting assignees in Beijing throughout different time periods (patent filings indicated in brackets)

1983-1988 (62)	1989-1994 (142)	1995-2000 (489)	2001-2006 (2,592)	2007-2012 (11,060)	2013-2018 (21,993)
SINOPEC (8)	SINOPEC (15)	SINOPEC (83)	Microsoft (698)	Tsinghua Univ (988)	BOE Technology (6,197)
Univ of Minnesota (6)	Bayer (10)	Microsoft (72)	Tsinghua Univ (241)	Microsoft (842)	Huawei (2,280)
Chin Acad Sciences (4)	UMC (8)	IBM (22)	Hon Hai-Foxconn (146)	Hon Hai-Foxconn (800)	IBM (1,175)
Bayer (3)	Univ of Minnesota (8)	Intel (16)	IBM (113)	IBM (739)	Tsinghua Univ (764)
Chin Acad Med Sci (3)	US DHHS (6)	Chin Acad Med Sci (14)	Intel (93)	BOE Technology (653)	Xiaomi (622)
Tsinghua Univ (3)	Chin Acad Med Sci (5)	UMC (12)	SINOPEC (78)	Huawei (428)	Lenovo (596)
Beijing Polytech Univ (2)	Tsinghua Univ (5)	Nokia (11)	Nokia (71)	Nokia (358)	Hefei Xinsheng (491)
Bio-Rad (2)	British Nuclear Fuels (4)	Winbond (11)	Chin Acad Sciences (47)	Chin Acad Sciences (337)	Intel (485)
Iowa State Univ (2)	Chin Acad Sciences (4)	British Nuclear Fuels (10)	Samsung (46)	Ericsson (299)	Hon Hai-Foxconn (437)
Lummus-Crest (2)	Michigan State Univ (4)	Inventec (10)	NUCTECH (39)	Intel (288)	Ericsson (380)
Share of top 10: 56.5%	Share of top 10: 48.6%	Share of top 10: 53.4%	Share of top 10: 60.6%	Share of top 10: 51.8%	Share of top 10: 61.1%
No. of organizations: 31	No. of organizations: 62	No. of organizations: 125	No. of organizations: 399	No. of organizations: 1,052	No. of organizations: 1,250

Table 4-22 List of top-10 patenting assignees in Beijing in terms of betweenness centrality scores (scores indicated in brackets)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
Beijing Polytech Univ (2)	Chin Acad Sciences (6)	SINOPEC (21)	Tsinghua Univ (4400)	IBM (41028)	BOE Technology (135079)
-	Chin Acad Med Sci (2)	Chin Acad Sciences (17)	Microsoft (3764)	Chin Acad Science (34119)	IBM (50374)
-	SINOPEC (1)	Tsinghua Univ (7)	SINOPEC (2001)	Tsinghua Univ (32424)	Huawei (41016)
-	-	Chin Acad Med Sci (1)	Nokia (1182)	Microsoft (230)	Chin Acad Science (36406)

-	-	-	Chin Acad Science (1127)	Huawei (20658)	Tsinghua Univ (28895)
-	-	-	IBM (1104)	BOE Technology (18746)	Lenovo (19319)
-	-	-	Chin Acad Med Sc (1030)	Nokia (13454)	Xiaomi (18298)
-	-	-	Acad Mil Med Sci (924)	SINOPEC (12604)	Hefei Xinsheng (15587)
-	-	-	Alcatel-Lucent (914)	Acad Mil Med Sci (10845)	Peking Univ (12229)
-	-	-	Lenovo (865)	Peking Univ (10408)	Microsoft (11520)

Table 4-23 List of patenting assignees in Beijing with the highest degree centrality scores (scores indicated in brackets)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
Beijing Polytech U (3)	*Chin Acad Sci (5)*	SINOPEC (4)	*Tsinghua Univ (55)*	IBM (295)	BOE Tech Group (642)
Xingnong Tec Dev (2)	*Chi Acad Med Sci (3)*	*Chin Acad Sci (4)*	Microsoft (55)	*Chin Acad Sci (233)*	IBM (439)
Beijing Agri Univ (2)	Chi Nat Elec Imp (3)	*Tsinghua Univ (2)*	SINOPEC (36)	Microsoft (230)	Huawei (417)
SINOPEC (1)	Chi Xiao Feng Tec (3)	*Chi Acad Med Sci (2)*	IBM (27)	*Tsinghua Univ (226)*	*Chin Acad Sci (355)*
Bayer (1)	Wide Trade Found (3)	TEPCO (2)	*Chin Acad Sci (25)*	Huawei (207)	Hefei Xinsheng (323)
Chin Acad Sci (1)	SINOPEC (2)	Furukawa Electric (2)	Huawei (19)	BOE Tech Group (178)	*Tsinghua Univ (298)*
CNPC (1)	*Tsinghua Univ (2)*	*Intl Super Tec Ctr (2)*	Nokia (18)	Lenovo (152)	Xiaomi (281)
CITIC (1)	Tokyo Seimitsu (2)	Univ of Hawaii (2)	CapitalBio (18)	Nokia (146)	Lenovo (256)
PLA Gen Hosp (1)	*China Pharm Uni (2)*	*Beijing Vege Res (2)*	Lenovo (17)	SINOPEC (134)	Microsoft (206)
Lummus-Crest (1)	*Jiangsu Family Plan (2)*	Mitsui Norin (1)	Alcatel-Lucent (16)	Intel (119)	SINOPEC (188)
				China Mobile (111)	Ordos Yuansheng (187)
				Google (111)	*Peking Univ (184)*
				Ericsson (109)	Baidu (184)
				Beijing Univ Tec (106)	State Grid (163)
				Peking Univ (100)	Samsung (160)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
					Beijing Univ Tech (153) General Electric (146) Intel (142) Ericsson (133) Fujitsu (131) Qihoo (130) Tencent (129) NUCTECH (126) CNPC (125) Nokia (123) Sony (113) *Acad Mil Med Sci (110)* VMware (110) VIA (108) CSOT (105)

Note: for organizations that are italicized, these refer to non-industry entities, e.g. universities, research institutes, hospitals, government agencies, etc.

FINANCING SUPPORT FOR LOCAL TECHNOLOGY COMPANIES: EVIDENCE FROM CRUNCHBASE DATA

In the third analysis, we will study the dynamics of investment activities by Beijing-based venture capitalists (VCs) and investors, with a particular interest in examining the degree to which their financing activities have been channeled towards co-located technology firms, following **Sorenson and Stuart (2001)**. Such activities are considered strategically vital in order to ensure the continued 'regeneration' of ecosystem resources, particularly in the form of successful entrepreneurs-turned-investors supporting a new generation of disruptive, emerging-technology firms that will reshape the ecosystem in response to internal and external disruption (**Stam and Spigel, 2016**).

To conduct our analysis for this sub-section, we relied on Crunchbase in collecting the list of inventors for Beijing, as well as details surrounding their backgrounds. Through these efforts, we were able to retrieve a total of 3,422 investors based in the capital. In aggregate, they are responsible

for 18,129 financing deals and transactions cumulatively at 14,942 technology companies across the globe. Less than 10% of them (N = 333) had no publicly known information regarding their prior and/or existing financing records. In addition, a further 53% (N = 1,813) of these investors had solely one-time investment records. The number of large-scale investors (those with involvement in 50+ cumulative deals) is 54, almost equivalent to 1.6% of all Beijing-based investors.

Table 4-24 Information about investors in Beijing (source: Crunchbase)

Size of investment activities	Number of investors
No information about investments	333
1 investment only	1,813
2-9 cumulative investments	977
10-25 cumulative investments	183
26-50 cumulative investments	62
51-99 cumulative investments	31
100-999 cumulative investments	22
1,000 or more cumulative investments	1
TOTAL	3,422

Once we limited our attention to the top 1,000 investors, we found that they were responsible for a total of 15,984 financial transactions at 13,103 technology firms; these figures represent more than 87% of all recorded deals and close to 88% of collective portfolio by all Beijing-based investors. Replicating the approach we have performed with regard to other Task 3-covered hubs, we further limited our attention to the city's 25 largest investors, ordered on the basis of their cumulative investment activities. Details about their profiles – as well as their investment records – are shown in Table 4-25 below (after the mini-box elaborating about Beijing-based unicorn startups). All in all, these top-25 investors accounted for 7,016 financial transactions in 5,110 technology firms, whether within Beijing, mainland China more broadly, or overseas. These figures were equivalent to over 38.5% of all recorded financing deals, and 34% of cumulative investment portfolio of the entire population of Crunchbase-listed Beijing-based investors.

From further investigation of the profiles of these top-25 investors and their start-up transaction records, we identified two interesting features characterizing these entities. The first insight relates to the high proportion of foreign-invested funds, of which we identified a total of 7 of them, as shown in the following list: IDG Capital, Sequoia Capital China, Matrix Partners China, Microsoft Accelerator Beijing, Bertelsmann Asia Investments, CICC, and Vertex Ventures China. The cases of IDG, Sequoia, and Matrix in particular were interesting, as they were among China's earliest – and at present remain the most active – technology start-up investors, and are subsidiaries of US-based VC firms (with Sequoia Capital and Matrix Partners headquartered in Silicon Valley/San Francisco Bay Area). These funds have also accounted for the proliferation of some of China's leading start-up unicorns and/or most successful technology firms, notably Meituan, iQiyi, Didi, Ping An Healthcare, NIO, SenseTime, etc. Most of their investments also happen to be geographically concentrated in a small number of municipalities, mainly Beijing, Shanghai, and Shenzhen. Moreover, some of these funds are

also affiliated with foreign multinational enterprises, namely Microsoft Accelerator Beijing (a start-up accelerator and seed-fund program for Chinese start-ups by the US, Seattle-based software giant), Bertelsmann Asia Investments (a corporate VC fund by the German-based multinational publishing group), CICC (China's first Sino-foreign joint venture between US-based Morgan Stanley and China Construction Bank), and Vertex Ventures China (a subsidiary of Singaporean-based Vertex Ventures, a VC fund under Temasek Holdings).[150]

The other revelation is linked to the significant presence of corporate VC (CVC) funds of China's largest technology companies within the top-25 list, of which we identified 8 of them. Beyond Bertelsmann Asia Investments, the other seven CVC investors are namely: Legend Capital and Legend Star (both of which belong to Legend Holdings, Lenovo's parent company), Xiaomi's internal investment unit, Baidu's internal CVC fund and Baidu Ventures, Fosun RZ Capital (of Fosun Group), and another internal CVC unit of JD.com, one of the largest e-commerce platform websites in China. For most of these investors, less than half of their investment transactions and aggregate portfolio were allocated for Beijing-based technology start-ups.

We also would like to bring readers' attention to two other VC firms beyond the existing two categories above that have significantly contributed to Beijing's – and China's broader – innovation ecosystem: ZhenFund and Sinovation Ventures. ZhenFund, together with IDG Capital and Sequoia Capital China (the latter by which served as ZhenFund's institutional co-founder), have been positioned as China's most influential private-sector investors, especially in financing technology start-ups across the country. Established in 2011, and currently led, by two education-technology/ed-tech entrepreneurs Bob Xu and Victor Wang, ZhenFund – as of late-2021 – has accounted for nearly 740 investment deals in nearly 500 start-ups within China and overseas. The VC fund is also actively seeking investment opportunities in start-ups in Silicon Valley and the United States more broadly, as demonstrated by their setting up of a branch office in Palo Alto. The case of Sinovation Ventures is no less interesting; it was established in 2009 by Kai-Fu Lee, a renown Taiwanese-American computer scientist and former vice president of Apple, Microsoft, and Google, as well as a co-founder of Microsoft Research Asia (the roles by which we have mentioned in the first two analyses). Sinovation's focus is primarily on investing in Chinese technology start-ups, and to a limited extent other early-stage companies overseas.

Table 4-25 Top 25 investment funds in Beijing and proportion of investments in Beijing technology companies

Name	Summary	No. of investments	Investments in Beijing	No. of portfolio organizations	Portfolio organizations in Beijing
IDG Capital	A US, Boston-based VC fund with multiple main offices around the globe (incl. Beijing), and is the earliest VC investor in mainland China	1,356	446 (32.9%)	867	260 (30.0%)
Sequoia Capital China	A subsidiary of US, Silicon Valley-based Sequoia Capital, specially focused on investing in China's technology start-ups across multiple stages (seed, mid-stage, late-stage, growth)	779	307 (39.4%)	549	202 (36.8%)
ZhenFund	A VC fund focused on telecom-media-technology (TMT), healthcare, education-related start-ups, and one of the biggest angel investors in China	737	303 (41.1%)	495	208 (42.0%)
Matrix Partners China	A subsidiary of US, San Francisco-based Matrix Partners that focuses on investing in China's technology start-ups in telecom, wireless, data storage, ICT, semiconductor, etc	600	232 (38.7%)	391	149 (38.1%)

Name	Summary	No. of investments	Investments in Beijing	No. of portfolio organizations	Portfolio organizations in Beijing
Shunwei Capital	A VC fund focused on offering early-stage to mid-stage investments in Internet-related technology companies in China	373	149 (39.9%)	262	105 (40.1%)
Legend Capital	A corporate VC (CVC) unit of Legend Holdings, the parent company of Lenovo, one of the world's largest PC makers	339	130 (38.3%)	255	101 (39.6%)
Sinovation Ventures	A VC fund established by Kai-Fu Lee, former head of Microsoft China and Google China, that invests in China's technology start-ups	305	127 (41.6%)	236	91 (38.6%)
Northern Light Venture Capital	A VC fund that offers early-stage to growth-stage funding to start-ups/companies focused on consumer tech-related sectors	273	93 (34.1%)	180	55 (30.6%)
K2VC	A VC fund that focuses on early-stage investments in promising technology start-ups across mainland China	225	85 (37.8%)	177	68 (38.4%)
China Growth Capital (CGC)	A VC fund that offers early-stage investments in start-ups focused on enterprise solutions, emerging	196	89 (45.4%)	157	76 (48.4%)

Name	Summary	No. of investments	Investments in Beijing	No. of portfolio organizations	Portfolio organizations in Beijing
	technologies, and marketplace-related platforms				
Xiaomi	A corporate VC (CVC) unit of Xiaomi, one of the largest smart home device & smartphone manufacturers globally	171	64 (37.4%)	150	56 (37.3%)
Microsoft Accelerator Beijing	A corporate accelerator and investment fund by Microsoft, one of the world's largest software firms, focused on Chinese technology start-ups	152	105 (69.1%)	152	105 (69.1%)
Legend Star	Another corporate VC (CVC) unit of Legend Holdings, the parent company of Lenovo, that focuses on disruptive-technology start-ups	140	62 (44.3%)	114	49 (43.0%)
Innoangel Fund	An investment firm that offers VC, PE, and angel investments, primarily in early-stage technology companies	140	80 (57.1%)	123	68 (55.3%)
FREES Fund	A VC fund that offers early-stage and growth-stage financing support for technology start-ups in China and the United States	138	52 (37.7%)	100	31 (31.0%)

Name	Summary	No. of investments	Investments in Beijing	No. of portfolio organizations	Portfolio organizations in Beijing
Bertelsmann Asia Investments	A corporate VC (CVC) unit of Bertelsmann, a German-based multinational publishing group, focused on technology start-ups in China and Asia-Pacific	136	61 (44.9%)	94	41 (43.6%)
Baidu Ventures	A corporate VC (CVC) unit of Baidu, one of the largest Internet and search-engine companies in mainland China, that focuses on multiple-sector start-ups	122	52 (42.6%)	92	38 (41.3%)
CBC Capital	An investment firm that offers private equity funding for tech companies focused on media and communications	113	58 (51.3%)	91	45 (49.5%)
CICC	China's first Sino-foreign joint venture (Morgan Stanley and China Construction Bank) focused on investment banking and financial services	112	39 (34.8%)	106	37 (34.9%)
Fosun RZ Capital	A corporate VC (CVC) unit of Fosun Group, one of China's largest multi-sector industry conglomerates	110	34 (30.9%)	85	25 (29.4%)
PreAngel	An investment fund that offers	110	28 (25.5%)	101	26 (25.7%)

Name	Summary	No. of investments	Investments in Beijing	No. of portfolio organizations	Portfolio organizations in Beijing
	early-stage funding and angel investments, with specific focus on Internet-related start-ups				
Baidu	Another corporate VC (CVC) unit of Baidu, this time focused on technology start-ups in Internet-related sectors	108	55 (50.9%)	95	45 (47.4%)
Vertex Ventures China	A China-focused subsidiary of Vertex Ventures, a Singaporean VC fund operated by Temasek, one of the world's largest sovereign wealth funds	103	30 (29.1%)	81	27 (33.3%)
JD.com	A corporate VC (CVC) unit of JD.com, one of the largest e-commerce websites in China and the world	92	22 (23.9%)	82	22 (26.8%)
MSA Capital	A VC fund that offers multiple-stage investments (early-stage to growth-stage deals) at deep-tech start-ups, ranging from smart mobility, gene sequencing, IoT	86	24 (27.9%)	75	20 (26.7%)
		7,016	2,727 (38.9%)	5,110	1,950 (38.2%)

4.4.2.5.Discussions and conclusions

Throughout the introduction and the three analyses we performed in the previous pages, we have managed to identify interesting findings regarding Beijing. In the first analysis, we studied the evolutionary dynamics of inter-organizational linkages constituting the city's innovation system across different timeframes within the 1983-2018 period. Of more than 36,000 USPTO patent filings based on inventions taking place in the city, over 90% of them were filed in the two most recent periods (2007-2012 and 2013-2018), an indication of the very rapidly proliferating landscape of innovation networks in the capital. A multitude of organizations of different types also contributed to the creation of such ecosystems, ranging from universities (most notably represented by Tsinghua, and to some extent, other HEIs like Peking), public research organizations (given the presence of Chinese Academy of Sciences), foreign firms (with Microsoft and IBM being some of the major examples), to, more recently, the emerging domestic 'technology champions', as indicated by the establishment of large-scale R&D centers by firms like Huawei, BOE Technology Group, Lenovo, Xiaomi, etc. What we found to be particularly interesting is the fact that these organizations acted 'in unison' in building a thriving innovation ecosystem within Beijing; geographical proximity – as demonstrated by the co-location of many of these entities within the Zhongguancun cluster – may partly explain the existence of such dynamics.

The second analysis further investigates the roles of universities regarding their linkages with their locality by expanding our discussion on the case of Tsinghua University, which we have covered extensively in the Task. We specifically pay attention to the exchange of scientific knowledge between Tsinghua-affiliated scientists and their industry counterparts, using the proxy of U-I co-publications, following **Tijssen et al. (2009)**. Over time, we found the number of such co-publications has increased significantly on a year-to-year basis, multiplying from fewer than 200 in 2009 to almost 700 by 2018. The university also actively engages in scientific research efforts with various types of enterprises, ranging from state-owned enterprises (SOEs) to foreign multinationals and university spin-offs. Some of the world's leading corporations have also established either joint research centers or joint postgraduate programs – as demonstrated by the case of Siemens – with their counterparts in Tsinghua. Returnee-founded enterprises, in particular, have frequently engaged in such linkages with those in Tsinghua; much of this reflects the fact that some of these returnees happened to be alumni from the university. Nevertheless, the case of Tsinghua Tongfang – especially pertaining to its rapid rise and fall – suggested a caveat about the limits to success given the university's involvement in technology transfer activities (**Fini et al., 2018**).

The third analysis further explores Beijing's entrepreneurial ecosystem by accounting for the extent to which investor and VC communities within the city are likely to invest in co-located technology companies and early-stage start-ups. We limited our attention specifically to the top-25 investors on the basis of their cumulative financing deals, and found that the share of co-located investments (more than 38%) is nearly 4 times higher than our finding in the Hong Kong case. Many of the city's largest investors happen to be affiliates of foreign management funds (e.g. Sequoia Capital, IDG Capital, Matrix Partners), corporate VC funds of China's largest technology companies, as well as overseas returnees. The dense concentration of

investment communities within Beijing has, to some degree, enabled the widespread proliferation of start-up unicorns; nevertheless, we advise caution on associating Beijing's success as an ecosystem with an abundance of unicorn start-ups, given that some of these companies may have been overvalued relative to their actual financial performance; such phenomenon is not necessarily limited to Beijing alone, but also to various ecosystems across the globe.

4.4.3. Shenzhen

Introduction

Shenzhen, located in the southern China region, is one of the four original Special Economic Zones (SEZs) designated by the Chinese government in 1980 to support the country's opening-up reform.[151] It was also the first special economic zone granted with legislative power, allowing more flexible government strategies and innovative experiments. More recently, the city has been inducted as one of the leading 'creative and innovative metropolises' in the newly-announced Greater Bay Area (GBA) Initiative in early 2019, and anointed as 'the Pioneering Demonstration Zone for Socialism with Chinese Characteristics' in 2020. The accolades that Shenzhen has received could be attributed to the significant economic transformation in which the city has undergone through over the last four decades, from a small village with poor infrastructure into one of China's leading innovation and technological hubs with a population with more than 20 million. Today, Shenzhen is often referred to "China's Silicon Valley," and has formed a high-tech industrial cluster in information technology, biotechnology, new energy, and advanced materials, as well as a center in financial securities, insurance, and transportation. For example, Tencent alone has the net worth of over 400 billion US dollars (top 10 in the word in 2018), and Huawei has grown into the world's largest telecommunications equipment manufacturer and a leader in 5G infrastructure (Chang et al. 2017). Many domestically well-known brands have also risen in Shenzhen, such as BYD, the world's leader in rechargeable batteries and electric cars."

In terms of economic development, Shenzhen's GDP has massively increased over 10,000-fold, from RMB270 million in 1980 to over RMB2.7 trillion (equivalent to US$430 billion) as of 2019, a figure that has surpassed Hong Kong's GDP output since 2018. The city's Nanshan district, home to about 195 listed companies and more than 4,000 state-level high-tech enterprises, has a higher GDP per capita than Hong Kong. The increased economic output is, by and large, enabled by the rapid population growth within the city; according to the latest 2020 national census, Shenzhen's population has risen 50-fold from 350,000 in 1982 to about 17.5 million as of 2020, placing the city as the third most populous in mainland China (**Shenzhen Municipal Government, 2021**).

Paralleled with its unprecedentedly rapid economic growth, Shenzhen was simultaneously welded into a promising innovative city with modern infrastructure, powerful manufacturing industries, well-integrated supply-chain networks, and unique regional advantages. According to the Global Innovation Index 2021 carried out by WIPO, INSEAD, and Cornell (2021), the Shenzhen-Hong Kong metropolitan region ranked second globally under the 'top science and technology (S&T) cluster' ranking, given their massive output in both scientific publications and patent filings. Relatedly, Shenzhen accounted for nearly 37% of China's international patent applications via Patent Cooperation Treaty (PCT) in 2020 (Guangdong Provincial Government, 2020). Furthermore, in the Annual Report on Urban Competitiveness released by Chinese Academy of Social Sciences, Shenzhen ranked third nationally after Beijing and Shanghai in terms of STI-related competitiveness, and ranked second after Shanghai in China's annual comprehensive economic competitiveness index as of 2021.

Unlike its counterparts known for the existence of prestigious universities and research institutes (such as Beijing and Shanghai), Shenzhen's emergence resembled the argument by Mayer (2011) on how aspiring innovative regions, even in the absence of research universities, can still end up positioning themselves on the global innovation map, with enterprises oftentimes playing a 'surrogate university' role in training science, technology, and engineering-related talents.

Shenzhen in Transition: Historical developments

Originally considered as a low-cost "world-factory (Chen & Kenney, 2007)," Shenzhen is becoming a competitive player undertaking high-tech activities. On a historical basis, the development of a dynamic innovation system within Shenzhen – following and modifying from **O'Donnell et al. (2017)** – can be divided into four stages shown below[152]:

- Stage 1 – experimentation (1979-1992): this was the period when Shenzhen began to be designated as one of the first-generation special economic zones (SEZs), as well as a hub for policy experimentation relating to China's early efforts on economic reforms and opening-up. Simultaneously, within this timeframe, the Chinese central government began to devolve greater administrative powers to local authorities in approving investment projects (**Wong, 1991**). By offering financial incentives, including low taxes and rental costs, on top of administrative flexibility, Shenzhen municipal government was strongly oriented on attracting as much foreign direct investment (FDI) as possible, particularly from Hong Kong enterprises (**Oborne, 1986; Wei, 2000**). The city's direct proximity to Hong Kong, complemented by an abundant supply of low-cost labor, made Shenzhen attractive for FDI activities (**Wei, 2000**). Within this period, Shenzhen authorities began exploring the notion of closer collaboration with their Hong Kong counterparts on science, technology, and innovation-related activities, but the latter's response was largely lukewarm (**Shen and Luo, 2013; Shen, 2014; Zhang, 2012**).

- Stage 2 – uncertain exceptions (1992-2004): on one hand, privatization of state-owned enterprises (SOEs) within this period allowed these subsequently 'private' firms to generate more profits based on their discretion, rather than adhering to government-set priorities. On the other hand, a growing number of private-sector and foreign enterprises were encouraged to operate their own businesses in accordance with their own strategies and market-driven needs (**Shen and Kee, 2017**). Simultaneously, an informal economy began to take shape, most notably with 'shanzhai' businesses, oftentimes infamous for their 'copy-cat' products (**O'Donnell et al., 2017**). Nevertheless, from early 1990s onward, given the rising labor and land costs, coupled with increasing competition from other localities within mainland China, there were shared concerns about the city losing its competitive edge. In response, Shenzhen authorities began to shift towards attracting technology-intensive industries (**Wong, 1991**). In order to achieve this objective, the municipal government established several 'high-technology industry parks' throughout the city, the most notable illustration by which was Shenzhen High-Tech Industrial Park (SHIP) in 1996 (**Cheng et al., 2014**). Moreover, the authorities established a series of policies centered on their Science and

Technology Development Plans, as well as special offices and agencies to provide services supporting technological innovation and intellectual property right (IPR) protection (**Wei, 2000**).

- Stage 3 – extensive consolidation (2004-2018): in this timeframe, informal businesses began to 'formalize' their practices, and pioneer entrepreneurs from 'Stage 2' began to consolidate their competitive advantages. An increasing number of domestic technology 'champions', e.g. Huawei and ZTE (which we will profile in the coming pages shortly), began to heavily invest in R&D activities and increase their shares in the global market, particularly in the telecommunication equipment industry (**Yeung et al., 2009**). Simultaneously, both Shenzhen and Hong Kong began to engage in closer cooperation, primarily on a government-to-government level, with major impetus being the Comprehensive Economic Partnership Agreement (CEPA) – signed in 2004 – and the Hong Kong-Shenzhen Innovation Circle Agreement in 2006 (**Bauhinia Foundation Research Center, 2007; Fuller; 2010; Shen and Luo, 2013; Shen, 2014**). Moreover, the Chinese central government – notably State Council – began to pay more attention on promoting greater regional integration in the Pearl River Delta (PRD) region by releasing an official framework on the development of a 'Greater Bay Area' in 2015, with both Hong Kong and Shenzhen proposed as 'core steering cities' for the initiative. Relatedly, the central government designated an enclave in Shenzhen – later known as Qianhai District – as a special experimental zone for the development of financial service-related industries in the city, in close collaboration with their Hong Kong counterparts. No less importantly, the municipal government began to more actively steer the city to prioritize the development of strategic emerging industries (**Yang, 2014; Yang, 2015**).

- Stage 4 – unprecedented challenges (2018-present): we decided that one more stage requires a final addition, given the sequence of events rapidly taking place after the publication of 'Learning from Shenzhen' by **O'Donnell et al. (2017)**. Since 2018, Shenzhen's core competitiveness has been rendered vulnerable by intensifying friction in the US-China relations, particularly on matters surrounding trade and technology development. Two of the city's major technology companies, Huawei and ZTE, were significantly impacted by a series of policies by the US government that restricted transfer of core technologies, many of which are based in the United States. As we will show in the coming pages, Huawei happened to cope somewhat better than ZTE regarding these challenges, given the former's R&D-intensive orientation. Nevertheless, these issues have brought to the forefront the serious issues with Shenzhen's mastery of core technologies, and the municipal government has – in recent years – been making efforts to strengthen their capabilities in performing basic and applied research, as opposed to experimental development (which we will also elaborate in the next section). Within the same timeframe, the Greater Bay Area (GBA) framework was subsequently formalized in early 2019, while both Hong Kong and Shenzhen implemented a series of additional plans to strengthen their linkages in science, technology, and innovation (STI) activities, principally through the (currently ongoing) construction of Lok Ma Chau Loop Innovation and Technology Park.

Table 4-26 Some basic innovation-related indicators for Shenzhen (by year)

Indicator	2010	2015	2020
R&D expenditure (% GDP)	3.48	4.18	5.46
R&D personnel (% of population)			
R&D personnel (in full-time equivalent, 1000s)	157.43	173.76	345.78
Researcher	79.48	77.87	124.4
Basic Research	0.55	2.34	13.85
Applied Research	3.44	20.93	33.2
Experimental Development	153.34	150.5	298.73

Source: Shenzhen Statistical Yearbook 2021.

The transformation of Shenzhen's innovation ecosystem is set to receive further boost with the introduction, and implementation, of the 14th Five-Year Plan (2021-2025) of the Chinese government. The targeted objectives set by the central government would encompass:

- An annual increase of national R&D expenditure by over 7% throughout 2021-2025
- Increase in the basic research-to-R&D expenditure ratio to more than 8%
- Targeted support for sectors and industries pioneering government-designated future, emerging technologies: 1) quantum computing; 2) photonics and micro-nano electronics; 3) network communication; 4) artificial intelligence; 5) biomedicine, and; 6) modern energy systems
- Ongoing establishment of national-level state key laboratories across the country
- Increase in the share of digital economy-to-GDP ratio from 7.8% to 10% by 2025

The Shenzhen municipal government, in their 14th Five-Year Plan version, has also stated additional details that they will implement (or would expect to be achieved) within the city:

- Increase in R&D-to-GDP ratio from over 4% to 5.5%-6% by 2025
- Increase in basic research-to-R&D expenditure ratio to 5.5%-6% by 2025
- Having over 22,000 nationally-certified high-technology enterprises from Shenzhen
- Cumulative output by these high-technology enterprises to surpass RMB1.1 trillion
- 25% of the city's population to have received higher education-related degrees
- Prioritizing the "20+8" strategy (20 industrial clusters within 7 designated strategic emerging industries and 8 future industries), such as: 1) network and communication; 2) semiconductor and integrated circuit (IC); 3) ultra high-definition video display and intelligent terminal; 4) chip design and manufacturing; 5) green and low-carbon energy fields, e.g. solar, hydrogen, nuclear, carbon-neutral technologies, etc.
- Building "four platforms", namely: 1) Guangming Science City; 2) Lok Ma Chau Hong Kong-Shenzhen Technology Park; 3) Qianhai Shenzhen-Hong Kong District, and; 4) Xili Lake International Science and Education City
- Focusing on "four supports", namely: 1) building an integrated, city-level laboratory system; 2) establishing scientific research institutions (similar to the four examples

above); 3) accelerating the development of high-level research universities, and; 4) ongoing support to cultivate globally-leading S&T-oriented enterprises.

Shenzhen municipal government

Evolution of the role of Shenzhen municipal government

It should be noted that the Shenzhen Municipal Government has played an important role given that it is the first national innovation city designated by the State Council. Through a sequential elaboration of historical events in Shenzhen over the last four decades above, we can observe an evolution in the role played by the municipal government over time. Mirroring the analysis by **Liu and Cai (2018)**, from 1980 to mid-1990s, when Shenzhen's innovation landscape was largely embryonic (in which readers may observe in our first analysis of inter-organizational linkages), the municipal government's roles were primarily limited to the provision of basic infrastructure and incentives for the development of light industries and manufacturing, e.g. allocation of land plots and business-friendly rules on labor recruitment. Indeed, in terms of policy learning, Shenzhen municipal government initially experimented – and replicated – many existing, and seemingly *laissez faire*, policies from their neighbors in Hong Kong, e.g. the first land auction in China, the establishment of the first, fully-private law firms, first stock exchange, semi-privatization of housing market, etc. (**Zhang, 2012**). Moreover, the authorities conferred significant decision-making powers to private enterprises, thus creating a *laissez-faire*, very market-friendly environment to firms (and especially non-mainland Chinese investors). In the subsequent, later stages, the government began to undertake a more interventionist stance, particularly in the face of rising challenges to the city's long-term competitiveness.

Some of the following illustrations here demonstrate Shenzhen's major role in embarking on policy innovation and experimentation in building the city's innovation system, given its status as a special economic zone. According to the China Development Institute, Shenzhen has enacted about 200 regulations specific to the SEZ, with over 130 of them currently still in place. Moreover, among 105 pilot regulations implemented specifically within the SEZ, over 40 of them were enacted in advance of the national laws and administrative regulations (**China Development Institute, 2021**). In this regard, we can observe the innovative role of the government in molding the innovation ecosystem.

Complementing the government's experimental attitude on policymaking is their strong emphasis on maximizing efficiency. As early as 1997, Shenzhen municipal authorities have commenced a series of reforms on administrative rule examination and approval systems, which have often been highlighted as a major concern in terms of slowing down policy approval and implementation. From 1997 to 2011, it was estimated that the municipal government has reduced the number of examination and approval items from 1,091 to 391, a massive reduction by close to two-thirds of the original number (**Shenzhen Municipal Government, 2011**). More recently, according to the 2020 Annual Small and Medium Enterprise Development Environment Assessment Report released by the Ministry of Industry

and Information Technology (MIIT), Shenzhen ranked second nationally among 36 assessed municipalities, and ranked first with respect to market environment assessment (**Ministry of Industry and Information Technology, 2021**).

The government's constant focus on streamlining administrative powers and maintaining a relatively 'flat' organizational structure – on top of cutting red tape, which has demonstrated a substantial 'simplification' of government apparatus within the municipal authorities. With specific regard to science, technology, and innovation policies, the scope of policymaking in this area is, at present, consolidated under a single government entity, Shenzhen Municipal Science, Technology, and Innovation Commission (SZSTI). These results also align with the observation by **Sharif and Chandra (2021)** with regard to the city's innovation policy structure.

While the government has set the stage in the direction of innovation policymaking and seen their roles evolve over time across several decades, enterprises have also substantially played their part in the co-evolutionary dynamics of Shenzhen's innovation system. Indeed, as we will demonstrate in the coming sections, firms actually play a disproportionately large role in building the innovation ecosystem, as shown from the presence of generations of 'anchor firms', ranging from Hong Kong and Taiwanese contract manufacturers (with Hon Hai-Foxconn being the most notable example) to the rise of new, domestic technology champions (best exemplified by Huawei, ZTE, Tencent, CSOT, BGI, Kuang-Chi, and other firms).[153] In the section where we examine dynamics of inter-organizational linkages as proxied by patent data, we will specifically pay attention to the profiles of Hon Hai-Foxconn, Huawei, ZTE, and to some extent, Tencent and CSOT.

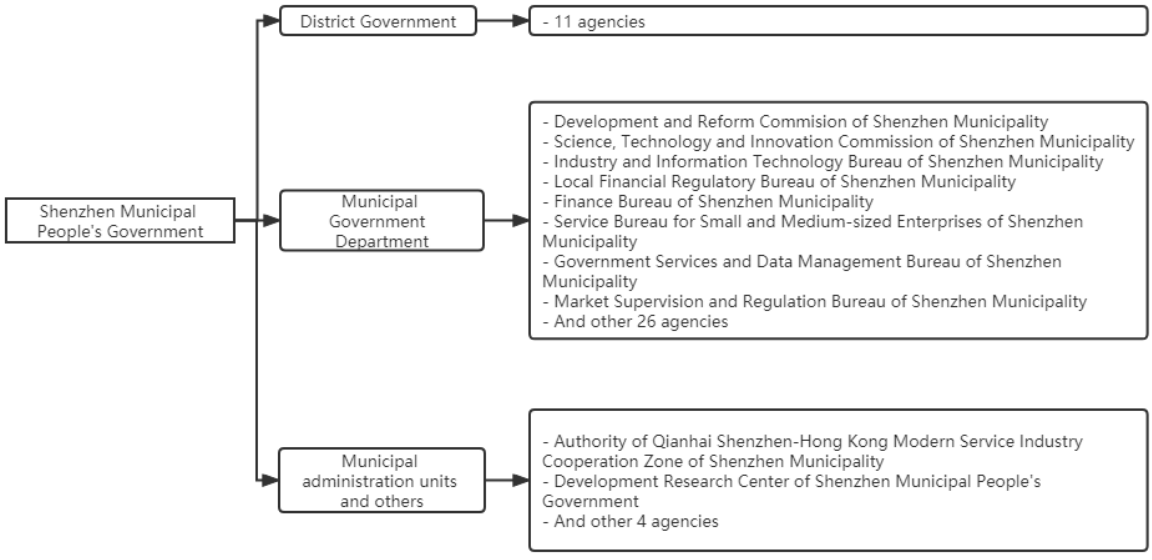


Figure 4-12 Organizational structure of Shenzhen municipal government

Talent policies

Shenzhen government has invested considerable efforts in attracting and retaining talents. A representative government practice is the "Peacock Plan," which was initiated in 2011 to attract overseas high-level innovative talents. Different evaluation criteria are set, ranging from Nobel Prize winners to red dot design award winners, in accordance with three categories of A/B/C talent standards. Eligible individuals could be provided with 1.6 million to 3 million yuan, as well as support for residence, settlement, medical education, spouse employment and other aspects of welfare treatment. Teams could be given up to 100 million yuan of special funding.

As of April 2021, Shenzhen has a total of 6 million talents of all kinds, including over 2 million scientific and technological talents. Starting from September 2021, Shenzhen will no longer accept the issuance of rental and living allowances for newly introduced talents, and the incentive policy has changed to give more prominence to the role of the main employer and market incentive orientation, focusing on ability and performance. The policy will also focus on the international perspective, through one-stop service, R-word visa application, and continue to optimize the approval process of foreigners' work permits to China, etc. to attract foreign "high precision and shortage" innovative talents.

Universities in Shenzhen

For a long time, the shortage of university resources and innovative talents has become an important problem hindering the development of Shenzhen's high-end innovative industries. In recent years, the Shenzhen Municipal Government has invested heavily in higher education, as exemplified by the presence of branch research institutes of Hong Kong universities in the Shenzhen Virtual University Park / SZVUP (**Sharif and Tang, 2014**), or the more recent establishment of branch campuses and/or institutes by the most leading universities in mainland China and overseas to expand the city's education infrastructure, such as:

- Chinese University of Hong Kong-Shenzhen (CUHK-Shenzhen)
- Peking University Shenzhen campuses, mainly: Peking University Shenzhen Law School, Peking University Shenzhen Hospital, and Peking-HSBC Business School
- Moscow State University-Beijing Institute of Technology (MSU-BIT) Shenzhen
- Georgia Institute of Technology (Georgia Tech) Shenzhen Institute
- Tsinghua-UC Berkeley Shenzhen Institute (TBSI)
- Shenzhen University Town, which – in recent years – has begun hosting graduate school campuses for some of mainland China's most renown universities, e.g. Tsinghua, Peking, Harbin Institute of Technology (HIT), etc.

Notably, the public universities or research institutes have been instrumental in either commercializing scientific research in the form of spin-off formation or transforming

themselves into research-intensive for-profit firms. Some representative research-intensive institutions are:

- Research Institute of Tsinghua University in Shenzhen (RITS): alternatively known as Shenzhen Tsinghua Research Institute / SZTRI (**Mao and Motohashi, 2016**), RITS was jointly established in 1996 by the Shenzhen municipal government and Beijing-based Tsinghua University. As the first research institution in mainland China structured in the form of an enterprise, RITS' unique organizational configuration enabled it to run one of the first experimental VC funds in China, as well as provide financing resources for start-ups incubated within the institute. RITS blends in the functions of a start-up incubator, a research-performing institution, a university, as well as an intellectual property (IP) platform. By late-2021, RITS is estimated to have incubated a total of 2,500 technology companies, 22 by which have been publicly listed (**RITS, 2022**). Interestingly, despite its status as a company, RITS – as stated in the agreement by Tsinghua and Shenzhen municipal government – cannot aim to achieve its status as a for-profit company. Moreover, it has been clearly stated in the MOU that eventually RITS will be an entity independent of both its parent organizations.

- Shenzhen Institute of Advanced Technology (SIAT): a joint partnership between Shenzhen municipal government, CUHK, and the Chinese Academy of Sciences (CAS), it was established in 2006 to further incentivize other major universities and PROs across Hong Kong and mainland China in establishing research facilities in Shenzhen (**Chen and Kenney, 2007; Sharif and Tang, 2014**). Such move was especially significant considering that the city's capabilities in basic and applied research – as of 2000s – remained at its infancy. Similar to RITS, SIAT represents an institutional innovation in the organization of scientific research in Shenzhen as it combines basic science, postgraduate education, industry technology transfer and commercialization, as well as capital support for commercializing spin-offs (**Shenzhen Institute of Advanced Technology, 2022**). As of late-2021, SIAT currently hosts 9 national-level, 34 provincial-level, and 67 municipal-level laboratories and innovation platforms. The institute is also one of the first in Shenzhen to promote cross-country academic collaboration as well as recruit leading foreign talents, conduct research in sectors/technologies in support of the government's strategic emerging industries (SEIs), and working closely with Shenzhen municipal government and district-level authorities in building new institutes in 2019, namely: Shenzhen Institute of Advanced Electronic Materials for International Innovation, Shenzhen Institute of Synthetic Biology, and Shenzhen Institute of Brain Science Innovation (**Tu et al., 2019; Shenzhen Institute of Advanced Technology, 2022**).

- Beijing Genomics Institute (BGI): founded in 1999 in Beijing (thus its title name), BGI is China's first genomic sequencing center, and also the first such institute to fully transform into a world-renowned life sciences and genomics-related company. The entity only relocated to Shenzhen from 2007 onward, as BGI's scientists saw the limits to commercialization potential as long as they were reliant on state-based funding in Beijing (**Tu et al., 2019**).[154] BGI's organizational status is also unique, in the sense that it is a 'government-supported, privately-run' entity. Government support has been particularly

generous; from 2001 to October 2012, BGI was estimated to have received over RMB800 million in funding support – mostly in the form of non-reimbursable policy grants – from the Ministry of Science and Technology (MOST), Ministry of Agriculture (MOA), Guangdong provincial government, Shenzhen municipal government, etc. Such assistance has enabled them to conduct research on genomics and high-throughput genomic sequencing, as well as establish a complete research model that amalgamates basic science, frontier research, development of emerging technologies, and industrial commercialization.

- Kuang-Chi Institute: founded by a group of five overseas Chinese returnee scientists in 2010, with joint support by RITS, Mindray, and VC firms introduced by the Shenzhen municipal government, Kuang-Chi represents another institutional innovation given its status as a 'privately-run, non-enterprise' research institute that is structured as a non-profit company (**Luo, 2013**).[155] Its uniqueness is reflected from their flexible organizational structure that permits researchers substantial freedom in focusing on their own exploratory, frontier research, while receiving substantial financial support from the government. Since their establishment in 2010, Kuang-Chi – through their establishment of China's first national-level laboratory on metamaterials – has successfully produced several spin-offs, and also become one of the world's leading metamaterial-focused firms. Their research is also centered on three major axes constituting a 'research chain': 1) R&D of ultra large-scale structures; 2) creation of a patent pool to protect their inventions, and; 3) development of national industry standardization and integration of industry chain from upstream to downstream (**Yang, 2019**).

Enterprises

Figure 4-13 below visualize the overwhelming roles of enterprises in R&D investments, as well as their aggregate economic value. Most of the research expenditure is driven by industry actors, a large proportion by which was principally driven by major corporations such as Huawei, ZTE, Tencent, CSOT, BGI, etc. Despite the growing investments, the share allocated towards basic research – as we will show in the coming pages – remains insignificantly small, although this pattern is changing.

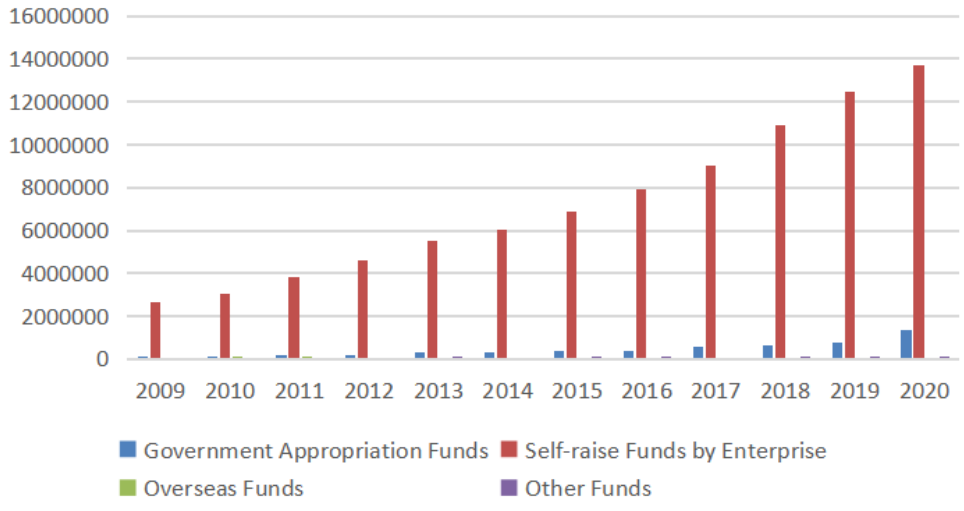


Figure 4-13 Expenditure on R&D (CNY ’10,000) based on sources of funding

Source: Shenzhen Statistical Yearbook 2021

4.4.3.1. INTER-ORGANIZATIONAL NETWORKS: EVIDENCE FROM USPTO PATENT DATA

Similar to what we have studied in Hong Kong, we will replicate the same analytical approaches for Shenzhen. Throughout this analysis, and the remainder of this case study, readers may expect our comparative analysis with our findings in Hong Kong, largely as a complement to previous academic works that compare and contrast the two cities’ innovation systems (c.f. **Sharif et al., 2021; Sharif and Chandra, 2021; Wang et al., 2021**).

The first analysis will – by means of patent data – take into consideration the historical and evolutionary dynamics of Shenzhen’s innovation ecosystem by proxying it with the city’s inter-organizational innovation networks. We extracted our patent filing information from USPTO, and created a separate subset of data for patent applications filed from Shenzhen. Afterwards, we removed design and plant patents, those with missing values, as well as no-assignee patent applications. An inter-organizational network is defined as existing when we identified a ‘linkage’ involving at least two distinct organizations with patents filed by the same person(s) based on their distinctive inventor ID, which has been assigned under the USPTO Patentsview program. While it is difficult to establish the exact causes of such inter-organizational linkages – which **Laforgia and Lissoni (2009**) explained may be attributed to: 1) career mobility flows, in the sense that inventors change their workplaces, or; 2) inter-organizational formal collaboration, in which two or more entities engage in formal R&D consortia or collaborative research, or; 3) informal exchange of knowledge among these inventors, or; 4) university-industry collaboration), one thing we can be certain about is that there exist such inter-organizational linkages when 1 inventor happened to file invention(s) on behalf of 2, or more, organizations.

Table 4-27 List of top-10 patenting assignees in Shenzhen (all time)

Name	Patent filings (26,425)
Hon Hai-Foxconn	7,123
Huawei	6,662
ZTE	3,038
CSOT	1,711
Tencent	1,369
AAC	647
BYD	356
Chimei-Innolux	334
Johnson Electric	321
DJI	288
Share of top 10	82.7%
No. of organizations	981

Afterwards, we made use of these aggregate inter-organizational networks to quantify the betweenness centrality of all listed Shenzhen-based patent applicants, following **Freeman (1977)**. This network property, which refers to the number of possible dyadic ties between all nodes that can be brokered – or 'bridged' – by the node of interest, has been shown to be a relevant indicator for assessing the extent to which an organization may facilitate knowledge flows across organizational boundaries within their surrounding environment (**Graf and Henning, 2009**). Replicating the authors' approaches in their comparative analysis of Germany's regional innovation systems, we seek to identify, in Table 4-28 and Table 4-29 in the following page, which organizations have been pivotal in 'seeding' Shenzhen's ecosystem.

We first provided description on the most actively involved patenting organizations in Shenzhen, in aggregate, with details displayed in Table 4-27 in the previous page. Our attention is primarily on the top-10 innovators, a descriptive approach that we will also replicate for the remaining innovation hubs in this report. Collectively, over 26,000 USPTO patents have been filed on the basis of technical advances taking place in Shenzhen; this figure is slightly twice as high as that of Hong Kong (which was around 13,000). Unlike what we saw with its southern neighbor, Shenzhen's top-10 innovator list is completely dominated by enterprises, and the degree of concentration of innovative activities within the city (at nearly 83%) is extremely high. 5 of its biggest enterprises (Hon Hai-Foxconn, Huawei, ZTE, CSOT, and Tencent) are industrial entities with over 1,000 US patent applications each, with Hon Hai-Foxconn playing a disproportionately influential role in contributing to the city's early stages of innovation ecosystem development (**Wang et al., 2021**).[156] It appears that in the absence of research-performing public institutions, these firms played a major role as 'surrogate research universities' in stimulating regional development (**Mayer, 2011**).[157]

Table 4-28 in the following page provides further breakdown of changes in the city's top-10 innovator lists over different time periods. Throughout the 1980s and the first half of the 1990s, Shenzhen's innovation landscape was largely 'non-existent', with no patent filings in 1983-1988 period, and only 8 such applications in the 1989-1994 timeframe. By and large, the city's industrial cluster was initially dominated by Hong Kong-based manufacturers who had relocated to Shenzhen to take advantage of China's economic reforms and opening-up (**Wu, 1995; O'Donnell et al., 2017**).

What about the roles of universities? Mirroring the observation by **Chandra (2019), Liu and Cai (2018)**, and **Wang et al. (2021)**, we found the universities' contribution to Shenzhen's innovation system, historically, has been very minimal. Much of this could be attributed to the minuscule education and research infrastructure in Shenzhen, which was primarily centered on Shenzhen University (SZU). It was only from the mid-2000s onward that the municipal government invested more substantially on expanding the city's infrastructure in both areas, as demonstrated by initiatives to establish a special zone near SZU campus for branch campuses and research institutes from highly-ranked universities (**Chen and Kenney, 2007**), the establishment of Southern University of Science and Technology / SUSTech (**Liu and Cai, 2018**), research institute and start-up incubator by Tsinghua University (**Mao and Motohashi, 2016**), as well as branch campuses and research institutes by Hong Kong's top universities

(**Sharif and Tang, 2014**). While some of these institutions have been ranked highly in terms of betweenness centrality scores (as demonstrated by the branch campuses and research centers of Tsinghua and Peking University), it remains to be seen the extent to which Shenzhen's education and research infrastructure will further propel the city's innovation ecosystem in the future. Specific to SZU and SUSTech, we will further elaborate about their roles in the coming subsection.

Overall, Shenzhen's innovation ecosystem has been historically driven by enterprises, and Hon Hai-Foxconn, at one point, was positioned as the city's 'anchor firm' with regard to manufacturing and patenting output. Nevertheless, Shenzhen was able to successfully transition from an anchor firm-dominated innovation system into one with multiple driving nodes, all without causing an 'ecosystem collapse' given the departure of the anchor firm (**Spigel and Vinodrai, 2020**). Although the degree of concentration of innovative activities by the top-10 innovators remain persistently high, the share over time has been gradually falling, from nearly 90% of all patent filings in 2001-2006 to 79% as of 2013-2018 period. There has also been a steady increase in the entry of new innovative firms with USPTO patents (e.g. DJI, which we will elaborate in a mini-box in the following pages), despite the slowdown in patent applications in recent years.

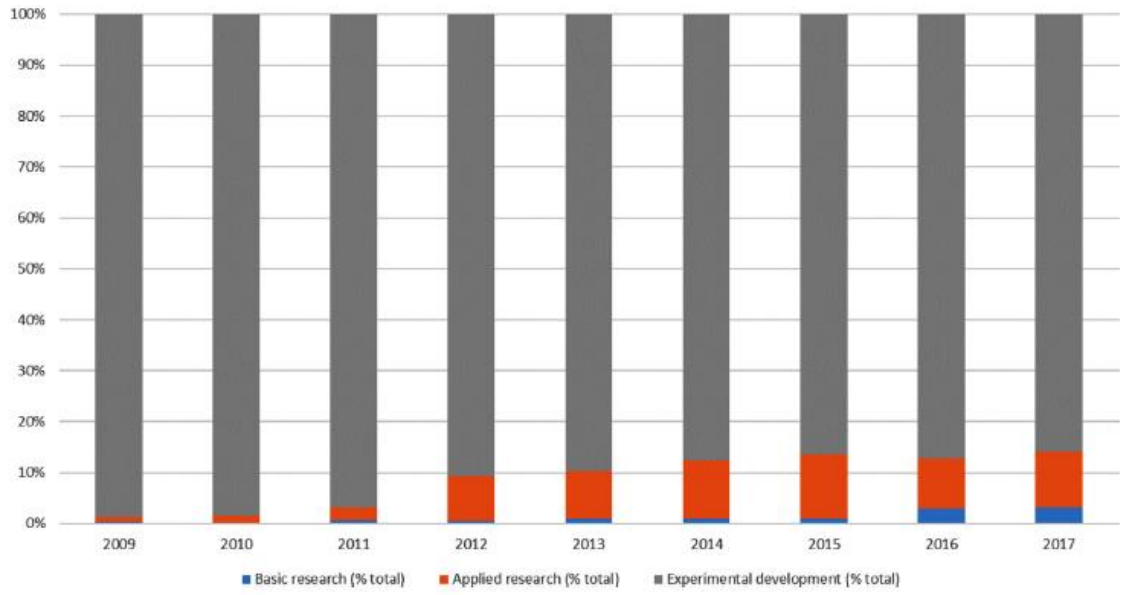


Figure 4-14 Breakdown of R&D expenditure by types of activity in Shenzhen (2009-2017); source: **Shenzhen Statistical Yearbook (2018)** and **Sharif et al. (2021)**

Nevertheless, the city remains vulnerable to external shocks, especially with the ongoing US-China tensions on technology competition. At present, a large proportion of Shenzhen's R&D expenditure continues to be driven by experimental development (activities intended to enhance the features and/or quality of existing product areas), as displayed by Figure 4-14 above. Shenzhen municipal government is deeply aware about this issue, and in the city's most recent 14th Five-Year Plan (2021-2025) on science, technology, and innovation (STI) development, the authorities pledge to invest an equivalent of US$108 billion in the next five years, with 30% of them to be allocated to basic and applied research (**Rui, 2021**).[158] How the

enterprises – and universities, in particular – plan to strengthen their absorptive capacities, particularly with the recent Five-Year Plan, remains to be seen in the near future.

Table 4-28 List of top-10 patenting assignees in Shenzhen throughout different time periods (patent filings indicated in brackets)

1983-1988 (0)	1989-1994 (8)	1995-2000 (50)	2001-2006 (1,895)	2007-2012 (12,262)	2013-2018 (12,148)
-	AT&T (2)	Hon Hai-Foxconn (31)	Hon Hai-Foxconn (1,104)	Hon Hai-Foxconn (5,178)	Huawei (4,053)
-	CN Nat Elec Imp Exp (1)	SZ STS Microelec (3)	Huawei (293)	Huawei (2,293)	ZTE (1,246)
-	CN Xiao Feng Tech (1)	Peak International (2)	ZTE (88)	ZTE (1,704)	Tencent (1,244)
-	HK Link Bicycles (1)	Shanghai Jiao Da Onlly (2)	Sutech (52)	CSOT (670)	CSOT (1,034)
-	Texaco (1)	CIMC (1)	Chimei-Innolux (39)	Chimei-Innolux (292)	Hon Hai-Foxconn (808)
-	Weatherford-Lamb (1)	Clipper Products (1)	Innocom Tech (37)	Innocom Tech (185)	AAC (578)
-	Wide Trade Fnd Ltd (1)	Emerson Corp (1)	BYD (34)	BYD (174)	DJI (281)
-	-	High-Density Energy (1)	Mindray (26)	Mindray (166)	Johnson Electric (171)
-	-	Huawei (1)	Siemens (16)	Johnson Electric (148)	BYD (148)
-	-	Ksai Electronics (1)	Emerson Corp (9)	Tencent (122)	STMicroelectronics (81)
Share of top 10: - No. of organizations: 0	Share of top 10: 100.0% No. of organizations: 7	Share of top 10: 88.0% No. of organizations: 16	Share of top 10: 89.6% No. of organizations: 128	Share of top 10: 89.2% No. of organizations: 413	Share of top 10: 79.4% No. of organizations: 642

Table 4-29 List of top-10 patenting assignees in Shenzhen in terms of betweenness centrality scores (scores indicated in brackets)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
-	-	-	Hon Hai-Foxconn (121)	Huawei (6564)	Huawei (14416)
-	-	-	Huawei (111)	ZTE (4719)	ZTE (10043)
-	-	-	ZTE (41)	Hon Hai-Foxconn (3955)	Tencent (8457)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
-	-	-	Emerson Corp (21)	Peking University (1187)	Hon Hai-Foxconn (4483)
-	-	-	Mindray (8)	Tencent (656)	CSOT (1939)
-	-	-	Sutech (5)	STMicroelectronics (534)	AAC (1284)
-	-	-	Tsinghua University (4)	BYD (429)	Goodix (1075)
-	-	-	O-Net Comm (3)	Hytera Comm (347)	BYD (882)
-	-	-	-	Johnson Electric (280)	DJI (864)
-	-	-	-	Mindray (261)	Johnson Electric (742)

UNIVERSITY-INDUSTRY COLLABORATION IN SCIENCE: EVIDENCE FROM ANALYSIS OF JOINT PUBLICATIONS

From the first analysis, we have learned that universities historically played a very limited role in the evolution of Shenzhen innovation system. Our analysis of inter-organizational linkages through patent data demonstrates that innovation dynamics within Shenzhen-based entities primarily took place in the form of inter-firm career mobility movements and/or informal collaboration between inventors of these organizations; in this aspect, the role of universities has been, by and large, 'missing'. Nevertheless, such limitation did not preclude us from conducting the second analysis, by which we investigate the extent to which Shenzhen's two premier universities – SUSTech and SZU – have shaped the city's scientific research landscape (especially in collaboration with industries) in recent years.

In conducting our second analysis, similar to our approach in the Hong Kong case study (and for which we will replicate in the remaining hubs), we relied on Lens.org for collecting publication records from the two universities. Our focus was primarily on peer-reviewed journal articles involving SUSTech- and SZU-based scientists that were published within a ten-year period (from January 1, 2009 up to December 31, 2018). Descriptive statistics from our analysis were displayed at Table 4-30 below. The former's publication records (N = 1,357) were significantly smaller in comparison to those from SZU (N = 12,201), given the very recent nature of SUSTech, which was founded only as recent as 2009.

Table 4-30 Publication data in Shenzhen and information on U-I co-publications (2009-2018)

University	Total number of publications	Total number of U-I co-publications	U-I co-publications as % of all publications
SUSTech	1,357	46	3.39
SZU	12,201	340	2.79

Due to our interest in investigating the universities' scientific research landscape in collaboration with industries, we proxy for their existence using university-industry joint publications – simply abbreviated as 'U-I co-publications' – as our unit of analysis, following **Tijssen et al. (2009)**. We label a peer-reviewed journal article as a co-publication by examining the institutional affiliation of the co-authors, with a particular interest in co-authors employed by large, incumbent corporations, start-up companies, as well as any organizations with company-relevant incorporation titles, e.g. 'Co.Ltd.', 'Inc.', 'Corp.', 'Corporation', 'Company', etc. We utilized a combination of text mining and manual checks in identifying collaborating enterprises. Whenever necessary, we also follow the method by **Powell et al. (2016)** by engaging on comprehensive 'site visits' of these company websites.

Descriptive statistics on U-I co-publications are shown on the second column of Table 4-31 below. Overall, we identified a total of 46 U-I co-publications in the case of SUSTech (equivalent to 3.4% of their entire publication records), and 340 for SZU (roughly 2.8% of their

cumulative population of journal articles). When the two universities' figures are conjoined together, the rate of U-I co-publication dropped to slightly above 2.9%, substantially below the annual average figures – approximately within the range of 6-7% of all publications worldwide – as estimated by **Tijssen et al. (2009)**. Interpreting these findings, we argue that the universities' scientific research collaboration landscape with industries remains nascent, largely due to their recent establishment, as well as their not-long-past engagement in knowledge/technology transfer activities.

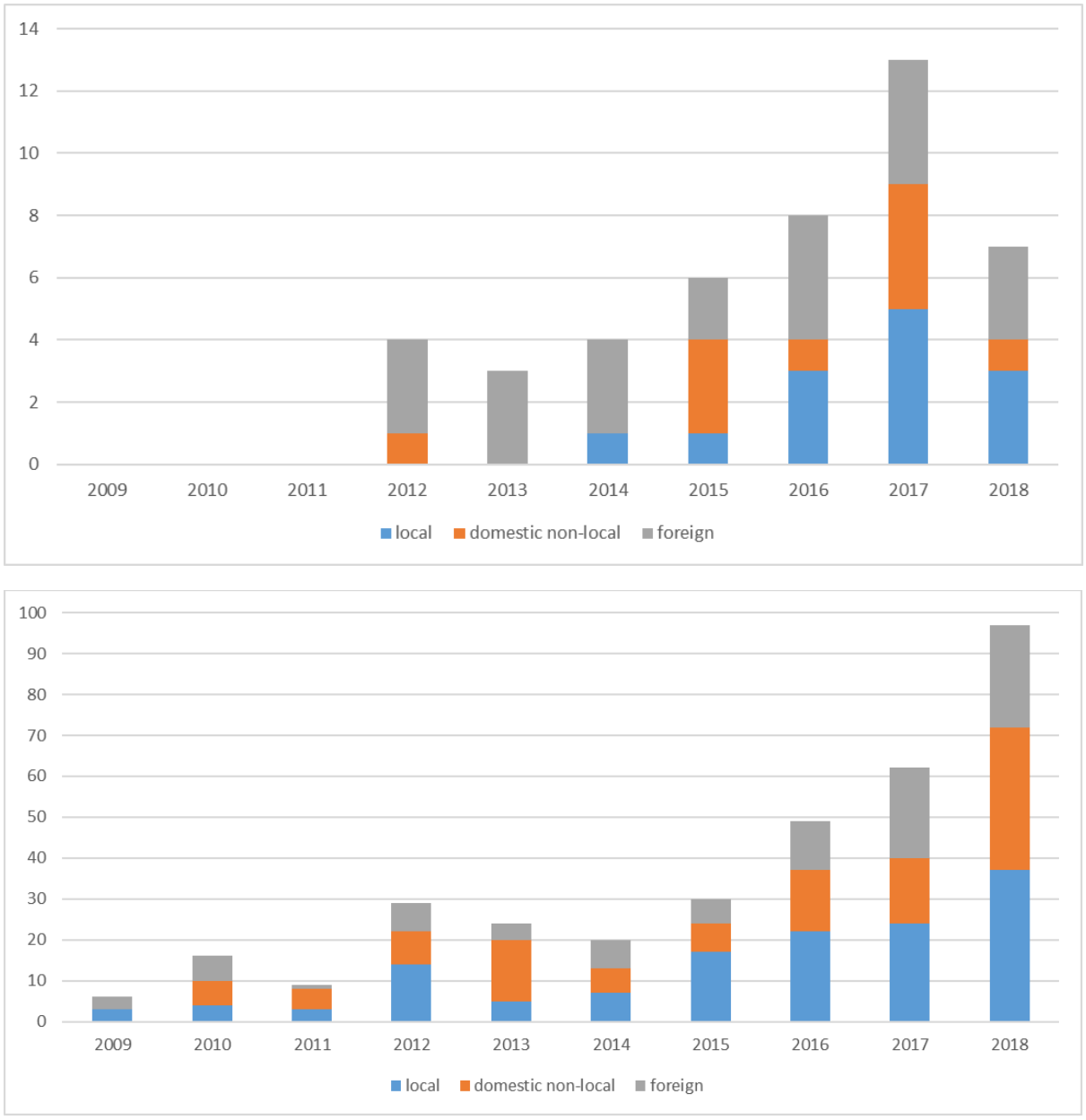


Figure 4-14 Breakdown of R&D expenditure by types of activity in Shenzhen (2009-2017); source: **Shenzhen Statistical Yearbook (2018)** and **Sharif et al. (2021)** Types of U-I co-publications involving SUSTech (above) and SZU (bottom) (2009-2018) based on the geographical origins of collaborating firms

We further divided these U-I co-publications into three types in accordance with the geographical origins of collaborating firms. The first category, 'local', refers to collaborating

enterprises that are headquartered within Shenzhen and other cities in the Greater Bay Area region, with the exception of Hong Kong and Macau; these municipalities include Dongguan, Guangzhou, Foshan, Zhongshan, Zhuhai, Huizhou, Jiangmen, and Zhaoqing.[159]

Table 4-31 below lists out the top-10 industry collaborators (in each of the three categories) for both SUSTech and SZU. In the case of 'local firm' category, most of the U-I co-publications – over 90% from our back-of-the-envelope calculation – were primarily with Shenzhen-based enterprises. Locally-based technology companies, notably BGI, Huawei, and Tencent, were among the most active collaborators with these universities, albeit bulk of the joint academic works were in conjunction with SZU-based scientists. In the case of domestic non-local firms, there is a diversity in the nature of companies with which Shenzhen university researchers collaborate with, as these entities range from SOEs (e.g. CNPC, COMAC, SINOPEC) to private-sector enterprises, such as BOE Technology Group. Once again, SZU, given their slightly longer history, had more co-publications than their SUSTech-based counterparts. In the 'foreign firm' category, we also found a larger number of co-publications involving SZU-based researchers than in those of SUSTech. Overall, while joint academic works with industries from the two universities have risen rapidly, SZU's scale happened to be bigger, given the relatively young age of SUSTech as a university.

Table 4-31 Top 10 collaborating firms with Shenzhen universities in U-I co-publications (2009-2018 period, number of co-publications indicated in brackets)

SUSTech		
Local firms (N = 15)	Domestic non-local firms (N = 11)	Foreign firms (N = 24)
SZ GeneHealth Bio (4)	BOE Tech Group (2)	SG Inst Manuf Tech (4)
Direct Genomics (3)	BJ Comp Sci R&D (2)	SOITEC (3)
Vienomics Biotech (2)	CNPC (1)	Waters Corp (2)
SZ Capchem Tech (2)	COMAC (1)	GlobalFoundries (2)
BGI (1)	CN Nonferrous Metals (1)	AECOM (1)
EFlexPV (1)	CNNC (1)	Alomone Labs Israel (1)
Rongxin Internet Fina (1)	SH Stock Exchange (1)	Array BioPharma (1)
Wanqian Technology (1)	Solargiga Energy (1)	Tega Industries SA (1)
-	Tianjin Zhonghuan (1)	Eni (1)
-	-	Facebook (1)
SZU		
Local firms (N = 145)	Domestic non-local firms (N = 118)	Foreign firms (N = 106)
BGI (28)	Yangtze Optic Fiber (19)	IBM (8)
Huawei (13)	Huaneng Clean Energy (4)	AstraZeneca (3)
SZ Zhenhua Microelec (6)	SINOPEC (3)	Microsoft (3)
Tencent (5)	Crystech (3)	GE Healthcare (2)
CN Construction Design (4)	Jiangsu Tenglong Bio (3)	Marvell Technology (2)
6Carbon Technology (4)	CapitalBio (2)	Novo Nordisk (2)
GD Huanxi Biological (3)	Fujian Building R&D (2)	PerkinElmer (2)

Adv Fiber Resource (2)	Hangzhou Zheda Dixun (2)	Qualcomm (2)
Dongjiang Enviro (2)	Ningbo Guoke Testing (2)	Samsung (2)
Foshan Nationstar Opto (2)	Novogene Bioinfo (2)	Alion Sci and Tech (2)

Unlike other hubs and universities, within Shenzhen we discovered very few U-I co-publications that involve firms that were spun off from academic research.[160] Here, we found 5 such journal articles from SUSTech that involve Direct Genomics and Vienomics Biotechnology, both of which were formerly university spin-offs founded by former professor He Jiankui, who garnered international notoriety in 2018 for his public claim of modifying genes of human beings, the first recorded instances in modern history. In the mini-box below, we will briefly summarize about the controversy surrounding He and his research, and implications on university technology transfer and the commercialization of science.

Box 2. The danger of unregulated university technology transfer: He Jiankui's gene-editing controversy

Thus far, much of our project has emphasized on the potential roles of universities in contributing to economic, innovation, and technology development of their surrounding regions, but we have yet to critically examine the multipronged societal impacts from knowledge/technology transfer (**Fini et al., 2018**), let alone potential downsides – or even perils – in the absence of proper regulation of such activities. For the remainder of this mini-box, we will summarize the narrative from a book by Walter Isaacson on the history of CRISPR-based gene-editing and one of its major pioneers, Jennifer Doudna (**Isaacson, 2021**), for which they dedicated several chapters on He Jiankui, a former SUSTech professor who gained notoriety for having created the first 'designer babies'.

Beforehand, we need to briefly summarize about what CRISPR is. An abbreviation for 'clustered regularly interspaced short palindromic repeats', CRISPR refer to a series of DNA sequences identified in the genomes of bacteria. A notable aspect of CRISPR relates to its anti-viral property (as in eliminating viruses), and its ability to both recognize and bisect certain DNA strands that complement the CRISPR sequence, thus its gene-editing specialty. Research on gene-editing experienced a significant boost with the discovery of Cas9 ('CRISPR-associated protein 9') enzyme, which enables CRISPR to perform its gene-editing operations. While research on CRISPR has taken place for decades (one notable example being the application of CRISPR by bacteria to destroy viruses during yogurt processing), it was the pioneering works by Jennifer Doudna and one of her co-collaborators, Emmanuelle Charpentier, that paved the way for a subsequent 'explosion' in academic research works pertaining to CRISPR-Cas9; both of them were subsequently awarded Nobel Prize in Chemistry in 2020 given this breakthrough.[161]

The breakthroughs surrounding CRISPR-Cas9 relate to their potential application in life-

changing treatments; examples include therapeutics for treating malignant cancer diseases, rare diseases, as well as the development of messenger RNA (mRNA) vaccines, for which the world has reaped significant benefits through COVID-19 vaccines produced by Pfizer-BioNTech consortium and Moderna Therapeutics. Indeed, a new generation of biotech companies and start-ups (led by BioNTech and Moderna) are refining the CRISPR gene-editing method to eventually develop mRNA vaccines against HIV/AIDS and cancer-related diseases in the future (**LaHucik, 2022**).

However, beyond its benevolent aims in treating diseases, there have also been fierce debates about the ethical, moral, and philosophical implications of applying CRISPR for enhancing human performance and/or physical appearance (e.g. embedding embryos with 'super-intelligent' genes, modifying the genetic codes relating to complexion, eye color, hair color, etc). These debates have been especially centered on its potential impacts on exacerbating social and wealth inequalities, as exemplified in scenarios where the well-to-do may invest to dramatically prolong their life expectancy or 'design' their babies to be embedded with genes relating to physical strength, intelligence, complexion, etc. While CRISPR-related trials have been performed on human beings on an experimental basis – and primarily to address debilitating diseases, no trials have been performed with the purpose of creating 'designer babies'.

That assertion changed in 2018 with the revelation by He Jiankui, then employed as a professor at SUSTech, that he had created the world's first designer babies by modifying their genes to be 'HIV-resistant'. A PhD graduate of Rice University with a postdoctoral research experience at Stanford, He was recruited as a professor at the newly-established university in 2012 under the Thousand Talents Program (TTP) scheme. Based on multiple conference-based exchanges between Doudna and He, as Isaacson elaborated in his book, the latter was described as ambitious, very driven, and highly motivated by reputation, money, and ambition to make China a CRISPR 'superpower'. Throughout his tenure at the university, He and his research team have had multiple articles on CRISPR published, as well as established at least two companies (Direct Genomics and Vienomics Biotech) to further commercialize their achievements.

A November 2018 report by MIT Technology Review would mark the apogee of He's research career (**Regalado, 2018**). The author, through a months-long investigation, chronicled a confidential project carried out by He – unbeknownst of the university – in which he listed pregnant mothers with HIV-positive spouses to participate in his 'clinical trial', by which these embryos would have their genes modified in order to make them eventually resistant to not only HIV, but also other diseases, such as smallpox and cholera. While the objective was seemingly benevolent, what became problematic was the near-absence of ethical consent mechanism provided to the participants, as well as no consideration over the potential long-term repercussions, or negative effects, from having such embryos gene-edited from their conception. Assessments on long-term risks, in particular, appeared to be missing from He's clinical trial with these patients. By November

2018, two babies – under the pseudonyms 'Lulu and Nana' – became the first human beings in history having undergone direct gene-editing methods straight from their conception as embryos.

What was initially intended as paean for the scientist's achievement immediately turned into widespread condemnation, both by international and mainland Chinese scientific communities (**Dvorsky, 2019**). Further investigation by Chinese scientists showed that He's methods were not only dangerous; they were also deemed 'medically unnecessary', as embryos from HIV-positive parents may sufficiently undergo through existing assistive reproduction protocols (**Dvorsky, 2019**).[162] Not long after He's revelation in a gene-editing conference in the University of Hong Kong (HKU) in November 2018, the scientist was dismissed from SUSTech in early 2019, and subsequently put to prison for scientific misconduct and 'misleading doctors to unknowingly implant gene-edited embroys into these women' (**Normile, 2019**). His two companies, Direct Genomics and Vienomics Biotech, were also subsequently shut down. He's case has demonstrated the need for proper discussions about formulating guidelines and regulations that are necessary to govern the boundaries of scientific research, as well as commercialization.

FINANCING SUPPORT FOR LOCAL TECHNOLOGY COMPANIES: EVIDENCE FROM CRUNCHBASE DATA

The third analysis in our case study here departs from the first two that we have conducted, in which we paid attention to both patent and publication data. Similar to our analysis in Hong Kong, we center our third analysis on studying the patterns of investment activities in Shenzhen, with a particular interest in examining the degree to which Shenzhen-based investors provide financial support to co-located technology companies, following **Sorenson and Stuart (2001)**. The co-location measure constitutes a strategic factor in determining the extent of resource regeneration within an entrepreneurial ecosystem, particularly in the form of successful, well-resourced entrepreneurs and/or institutions supporting their aspiring counterparts in building their potentially high-growth businesses (**Stam and Spigel, 2016**).

Our primary data source for this section was from Crunchbase, a subscription-only repository of over 1 million technology companies, as well as more than 200,000 investors, across the world. Having filtered our collection criteria to investors solely based within the boundaries of Shenzhen municipality, we managed to retrieve a total of 1,443 investors (institutional and individual). Afterwards, we further examined their cumulative investment records. In aggregate, these investors were responsible for a total of 6,470 financing and transaction deals, encompassing 5,777 technology firms headquartered within Shenzhen, across mainland China more broadly, and overseas. As a matter of comparison, their counterparts in Hong Kong collectively accounted for 5,520 investment deals in 4,742 such enterprises.

Table 4-32 Information about investors in Shenzhen (source: Crunchbase)

Size of investment activities	Number of investors
No information about investments	59
1 investment only	866
2-9 cumulative investments	429
10-25 cumulative investments	56
26-50 cumulative investments	15
51-99 cumulative investments	9
100-999 cumulative investments	9
1,000 or more cumulative investments	0
TOTAL	1,443

Table 4-32 above provides further details about these investors on the basis of their size of financing activities. Interestingly, only a small proportion (approximately 4%; N = 59) of them have no publicly known records; by contrast, the figure for Hong Kong within this category ('no information about investments') jumped to 40%. One-time-only investors, by contrast, constituted the biggest proportion of Shenzhen-based investment ecosystem; they accounted for 60% (N = 866) of the city's Crunchbase-listed investor population. With respect to Hong Kong, the figure was close to 31%. In other words, majority of Shenzhen-based investors were infrequently engaged in financing technology companies. Mid-sized investors, which we define as those having 2-50 cumulative deals, occupied close to 36% (N = 500) of the city's investor population, a share that was slightly larger than that of Hong Kong (about 27%). Shenzhen also has a somewhat smaller number (N = 18) of large-scale investors (those with experiences in at least 51 transaction deals) than their counterparts in Hong Kong (N = 21).

Once we narrowed down our analysis to the top 1,000 investors, we found that these actors, collectively, accounted for 6,086 such investments in 5,429 technology firms, both within Shenzhen and elsewhere; these figures represented approximately 94% of all existing investment records and cumulative portfolio by Shenzhen-based investors. Given our space constraints, we further limited our analysis to encompass only the 25 largest investors on the basis of total number of financing deals in a descending order. Financiers within this list, in aggregate, had been involved in 3,152 such deals across 2,690 technology companies and early-stage start-ups, both of which were equivalent to 48% of all cumulative deals and 47% of collective portfolio by Shenzhen-based investors.

For these top-25 investors, we investigated the extent to which they have channeled their resources and other types of support for co-located technology firms. Overall, they have been involved in 511 financing deals (16.2% of their cumulative transactions) in 463 such enterprises (about 17.2% of their collective portfolio). By contrast, with regard to their Hong Kong-based counterparts, the latter's top-25 investors only allocated 9.7% of their investment, as well as 10% of their portfolio, to support locally-based start-ups. In other words, the rate of co-located investments in Shenzhen was considerably higher than in the latter. Nevertheless, when these figures are placed in comparison with those in the remaining hubs (which we will

cover in detail in the next chapters), the co-located investment rate for the two cities remains relatively low.

An interesting finding from these top-25 investors is shown from the presence of major corporate VC (CVC) funds from technology enterprises, most notably from Tencent and TCL.[163] Tencent's case is particularly important, as 3 of these top-25 investors (the company's own CVC unit, a separate entity named 'Tengxun Touzi', and Tencent Industry Win-Win Fund) are operated by the firm. Nevertheless, very few of their VC funds are co-invested into Shenzhen-based technology companies. With regard to the over 650 investment deals committed by Tencent's internal CVC fund, the co-located investment rate was below 5% (N = 30), with most of these deals overwhelmingly flowing into incumbent corporations and early-stage companies currently emerging as the world's largest unicorn companies, such as unicorns within mainland China (e.g. Didi, Meituan, Kuaishou, JD Logistics, Pinduoduo, etc.), as well as globally, e.g. Flipkart (one of the largest e-commerce websites in India), Tesla (one of the world's largest, US-based electric vehicle automaker), Gojek (Indonesia's largest motorcycle-based ride-hailing platform), etc. Nevertheless, with regard to the co-located investees, a significant proportion of them have subsequently transformed into unicorn companies, namely WeBank, HeyTea, UBTech Robotics, and iCarbonX. The share of co-located investments by Tengxun Touzi and Tencent Industry Win-Win Fund is similarly low, as their remaining deals are channeled towards other mainland Chinese-based technology firms. The same pattern is also demonstrated by TCL Capital.

A no less significant finding from these top-25 investors is the prevalence of government-affiliated funds in the list. Inclusive of both government-run and public-private partnership (PPP) funds, we identified a total of 7 such entities from Table 4-32 below, namely: Shenzhen Capital Group, China Merchants Capital, CSC Group, CITIC Securities, Shenzhen Guozhong VC Management, Tencent Industry Win-Win Fund, and SZHTI Group. Shenzhen Capital Group is one of the two investment vehicles operated by the municipal government (the other being the lesser-known SZHTI Group), and is also the city's second largest investor. While majority of their investments are aimed for technology start-ups based in other mainland Chinese cities, a number of Shenzhen Capital Group's co-located investments (with 100 financing deals in 87 such enterprises) have resulted in some successful unicorns, mainly in Royole, Yunwang Wandian, and Naixuecha. China Merchants Capital and CITIC Securities differ from Shenzhen Capital Group, given that both entities belong to China Merchants and CITIC, two of China's largest, national-level state-owned enterprises (SOEs). The remaining entities in the list represent examples of public-private partnership, with CSC Group being the first fund in China with government certification to operate RMB-denominated large-scale investments, Shenzhen Guozhong jointly operated by private and state-owned firms as an investment vehicle for National SME Development Fund, and Tencent Win-Win Industry Fund partnering with government agencies to identify and support early-stage technology start-ups specialized in government-prioritized strategic emerging industries (SEIs).

Moreover, some of Shenzhen's top-25 investors happen to be China's earliest pioneers in the country's then-embryonic VC and PE industry. This could be attributed to the city's role as the country's 'laboratory' in experimenting with an industry that – until early-2000s – did not

receive complete support from the Chinese central government (**Zhang, 2012**); indeed, capital market-related sectors were originally perceived as forbidden by national regulators.[164] The city's subsequent success with this industry, nevertheless, would subsequently pave way for the country to gradually allow the replication of such model elsewhere across the country. Beyond Shenzhen Capital Group (which by itself was among the earliest investors), other similar examples include Tiantu Capital, Fortune Venture Capital, Share Capital, as well as Co-Stone Venture Capital.

One impact from the abundance of investment funds and supporting actors in Shenzhen has been the proliferation of start-up unicorns, or early-stage companies with valuation of at least US$1 billion. As of late-December 2021, based on the data we collected from **Failory (2021)** and **CB Insights (2021)**, we ended up retrieving a total of 26 current, former, and/or exited unicorn companies headquartered in the city. In turn, this figure made Shenzhen the third largest start-up unicorn hub in mainland China, after Beijing (N = 96) and Shanghai (N = 58), details on which we will further elaborate in our profiling of both hubs respectively. With this finding, Shenzhen also has a comparatively higher number of unicorn companies than Hong Kong does. The aggregate valuation of these 26 unicorn companies, in turn, is approximately US$114 billion, the third highest in mainland China after Beijing (about US$450 billion) and Shanghai (around US$130 billion).

Unsurprisingly, the most common industries associated with these unicorn companies are logistics (N = 4), e-commerce (N = 4), and robotics (N = 3), all of which reflect Shenzhen's competitive advantages in supply chain and electronics/ICT-related manufacturing. No less importantly, artificial intelligence (AI) and financial technologies/fintech are increasingly embedded into the sectoral specialization of these enterprises, as demonstrated by WeBank and DJI. Moreover, since 2015, we have observed the consistent 'minting' of new unicorns annually despite internal and external shocks (e.g. US-China trade war and technology tension, COVID-19 pandemic, and a series of restructuring action of China's technology industry). There has also been a gradual shift in investors' financing focus, from lifestyle-oriented start-ups to R&D-intensive firms (e.g. AI, semiconductor, biotechnology, etc).

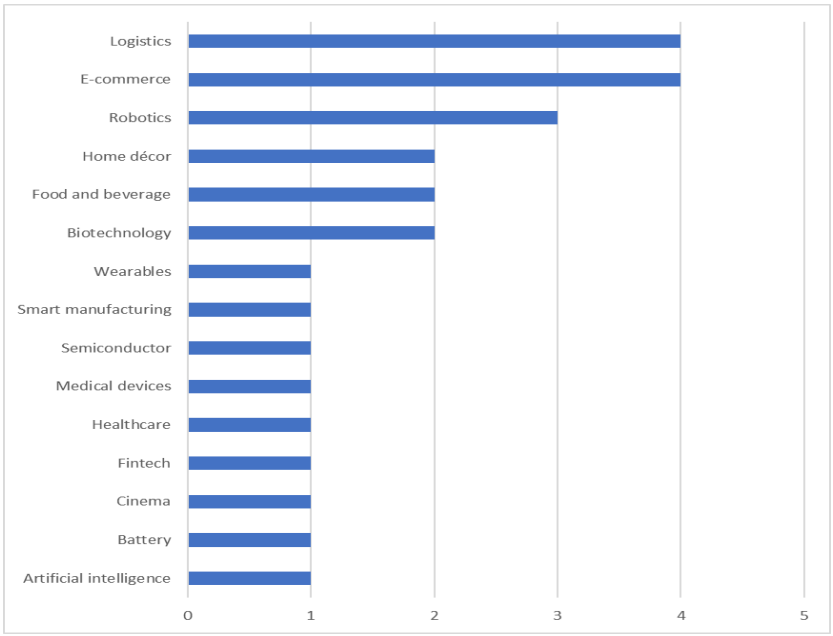


Figure 4-15 Breakdown of Shenzhen-based unicorn start-up companies (based on their main sectoral/technological specialization)

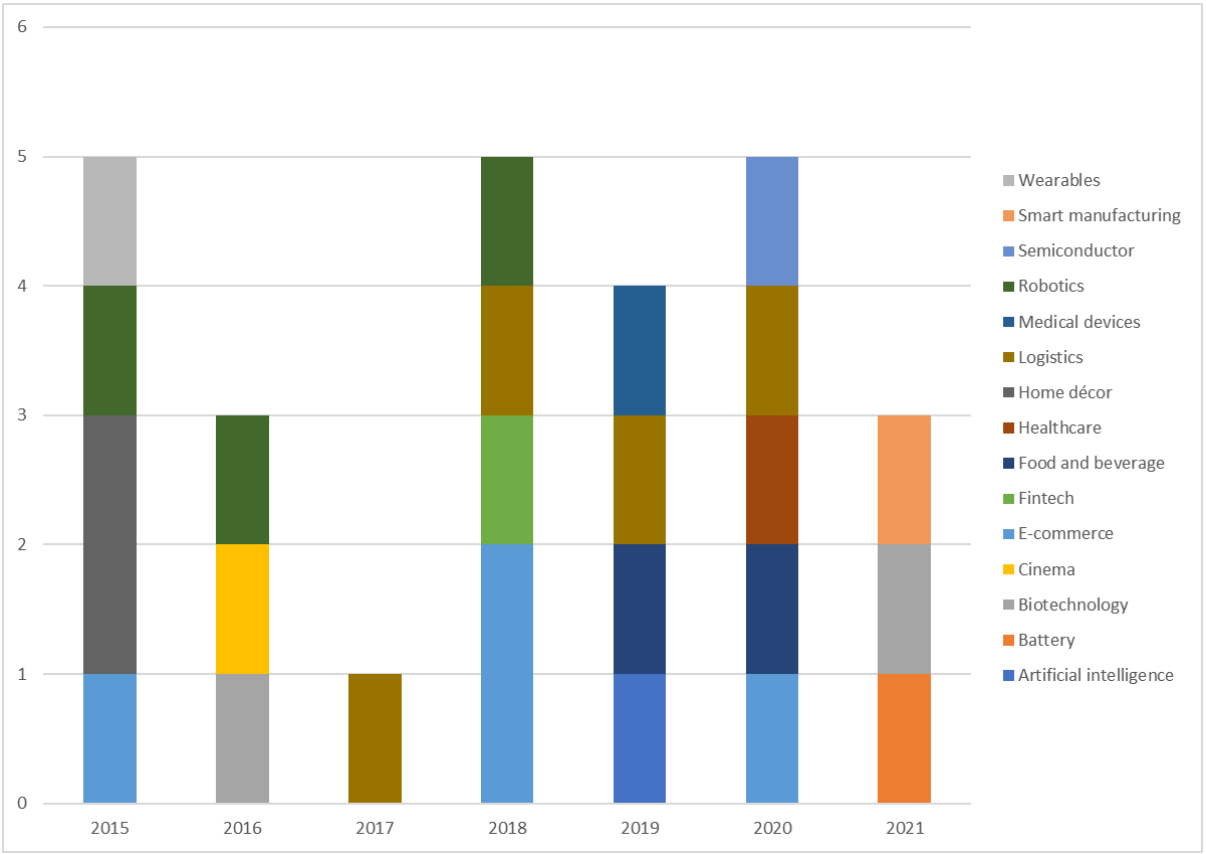


Figure 4-16 Unicorn start-up companies in Shenzhen based on their emergence year and main sectoral/technological focus

4.4.3.2.Discussion and conclusions

Throughout its four decades in existence, Shenzhen's transformation into a thriving innovation system has been nothing short of remarkable. Such historical process has been particularly outstanding in spite of the city's initial lack of education and research infrastructure to begin with (Mayer, 2011). In this regard, the city's innovation system, at present, is largely dominated by enterprises, specifically by different generations of 'anchor tenants' shaping Shenzhen's technological trajectory. This is evident from the first analysis, in which we focused on inter-organizational linkages by the proxy of USPTO patent data. With Hon Hai-Foxconn, a Taiwanese contract manufacturer, as the city's initial 'anchor firm' (Luthje et al., 2013), the company's importance eventually subsided with the rise of a new batch of 'domestic champions', notably exemplified by Huawei, ZTE, Tencent, CSOT, DJI, and some other firms we have mentioned in the introduction section, e.g. BGI and Kuang-Chi. Such dynamics also reflect the city's success in addressing vulnerabilities with regard to its reliance on few 'anchor firms' in driving the innovation ecosystem (Spigel and Vinodrai, 2020) through proactive government action. Given that the city has also been affected by ongoing technology and trade-related tensions in the US-China relations (for which Shenzhen firms rely substantially on imported technologies), it remains to be seen the extent to which Shenzhen authorities would be able to address such challenges in the coming years.

Unlike Hong Kong and the remaining hubs to be covered in this report, Shenzhen's education and research infrastructure is largely nascent. Until the last decade, Shenzhen University was the primary higher-education institution, and its mission orientation was centered on teaching, rather than research (let alone knowledge/technology transfer). It was only from mid-2000s onward that the city invested substantially in expanding their resources in this area (Chen and Kenney, 2007; Liu and Cai, 2018), as demonstrated by the establishment of SUSTech in 2009, followed by branch campuses and/or research institutes by leading universities from Hong Kong, mainland China, and overseas. Despite their comparatively small scientific research output, the growth in recent years has been significant, and these universities may emerge as future contenders in the coming years. On top of these has been the city's active efforts to encourage returnees, as well as research talents across the country, to establish scientific research institutions in Shenzhen, as exemplified by the cases of BGI and Kuang-Chi in the introduction. However, such impressive growth notwithstanding, we should also be aware about the adverse implications of unregulated knowledge/technology transfer resulting from such emphasis of rapid research outputs (Fini et al., 2018), as we have demonstrated from the notoriety surrounding He Jiankui's gene-editing of human babies (Isaacson, 2021).

We also studied the patterns of investment activities by Shenzhen-based investors, with a particular interest in examining the degree to which they have financially supported co-located technology firms (Sorenson and Stuart, 2001). With almost one-sixth (approx. 16%) of investment deals and portfolio centered on Shenzhen-based technology companies, the city's figure is comparatively higher than its southern, neighboring counterparts in Hong Kong. Nevertheless, and as we will further display from the analyses of the remaining hubs throughout the report, Shenzhen's co-located investment rate remains relatively low. The high proportion of investment deals contributed by Tencent – few of which ended up in Shenzhen technology

firms – partly explains such result. In recent years, the municipal government has also established their own VC funds (best demonstrated by Shenzhen Capital Group) which seek to provide financial capital and other forms of support for the city's early-stage start-ups and other aspiring technology ventures.

4.4.4. Shanghai

Introduction

Shanghai is located in eastern China, precisely on the western, coastal region of the Pacific Ocean, and sits on the alluvial plain of the Yangtze River Delta (YRD). The city, together with its neighboring provinces (Anhui, Jiangsu, and Zhejiang), constitute the broader YRD region, which has functioned as one of China's most dynamic nodes for economic/industry development and innovative activities (**Breznitz et al., 2011**). Geographically encompassing a total land area of 6,340 square kilometers, Shanghai, as of late-2020, has a total population of nearly 24.9 million people, representing an increase of 1.85 million people, or approximately 8 percent, over the past decade relative to its 2010 population of about 23 million (**National Bureau of Statistics of China, 2021**).

Despite the challenges and pressure exerted by the ongoing COVID-19 pandemic, Shanghai's economy continued to grow and perform fairly decently. In 2021, Shanghai's GDP increased by 8.1% to approximately 4.32 trillion yuan ($680 billion), ranking first in the country. Tertiary industry, as represented by service-related sectors, accounted for almost 3/4 (about 73%) of the city's GDP output, a figure that signifies the dominant role played by these sectors in driving the city's economic growth. While the service industries accounted for over 70 percent of the city's GDP, Shanghai has maintained a certain presence of key manufacturing sectors, as reflected in the rising industrial added value which surpassed CNY1 trillion in 2021 for the first time (**Shanghai Municipal Bureau of Statistics, 2021**). Three privileged industries, including integrated circuits, biomedicine, and artificial intelligence, have been viewed as potentially new economic growth engines, accounting for 12 percent of overall Shanghai's GDP. More R&D intensive industries are being developed as market demand increases, providing the basis for further specialization and scientific advancement(**Zheng & Bao, 2022**).

With regard to R&D investments, the city has, in recent years, invested about 4% of their GDP into such activities; about RMB160 billion (equivalent to US$25.4 billion) were dedicated to R&D expenditure in 2020. With respect to R&D-to-GDP ratio, Shanghai is on par with other globally leading innovative economies, notably South Korea and Israel. The findings on R&D activities, in turn, would lead us to discuss briefly about Shanghai's innovation system. In comparison with Beijing (which we will compare in the next chapter), Shanghai's development of innovation system commenced fairly late, with a comparatively smaller early-stage ecosystem to begin with. Nevertheless, the city enjoyed a unique competitive advantage relative to Beijing given the former's higher degree of exposure to economic globalization. In a way not dissimilar to the latter, Shanghai's innovation ecosystem expanded considerably due to the roles of foreign multinational firms establishing their business and/or R&D operations in the city, as notably demonstrated by the cases of IBM, Intel, and General Electric (GE), which we will further elaborate in the patent-based analysis of inter-organizational linkages below. Where the city diverges from Beijing relates to the city's first-comer advantage in attracting and hiring overseas Chinese returnees, especially those with substantial study, research, and/or work experiences abroad, to either work for leading technology firms in Shanghai or establish start-ups leveraging on their expertise. Some of these returnee-founded

firms would subsequently emerge into China's leading technology giants, such as SMIC, Wuxi AppTec, etc. Over time, in a pattern quite resembling what we observed in Shenzhen and Beijing, other domestic technology firms (notably Huawei) increasingly caught up with their foreign competitors with respect to their innovative outputs and capabilities.

4.4.4.1.Development of Shanghai's economic and social landscape

The city has acquired a historically long-standing metropolitan image since the mid-19th century, when it transformed into a bustling port for both Chinese and foreign merchants. In the aftermath of the first Opium War in 1842, Shanghai's territories began to be divided into 'foreign concessions' by various colonial forces (mainly British and French). While segregation occurred between native Chinese and the European population, a non-insignificant number of Shanghai locals and other settlers across China began to migrate into the city in search of a better life. Moreover, as a result of the Qing Empire's industrialization efforts – albeit done belatedly – Shanghai started to emerge as a heavy-industry and manufacturing hub, with a particular concentration on ship production (**Spence, 1990**). Beyond industrialization, Shanghai emerged as an education hub, with late Qing-era intellectuals and missionaries – particularly American-based missionary movements – establishing universities that would educate some of China's best and brightest, notably Fudan and SJTU (**Spence, 1990**). At one point, Shanghai was labeled as 'Paris of the East' given the strong imprint of Western culture and institutions on the city (**New York Times Archive, 2022**).

In the aftermath of the founding of the People's Republic of China in 1949, and throughout the first three decades, Shanghai's economic and social landscape underwent through considerable changes, as the city's linkages with the outside world became significantly restricted and experienced a series of historical and political events (e.g. Great Leap Forward, Cultural Revolution). Nevertheless, with the economic reforms and opening-up policy initiated from 1978 onward, Shanghai has once again 'reopened' itself to the outside world, and the city would soon experience – as well as contribute – to decades of rapid economic growth afterwards. One of the major impetus was in 1990, when Shanghai municipal government designated land plots to the east of Huangpu River for a new special zone known as Pudong District. Under this plan, the government would designate three priority sectors for the newly-established Pudong District, namely: 1) urban infrastructure; 2) financial services, and; 3) high-technology industries. Since its establishment in 1990, Pudong has served as a core 'hub' for Shanghai's innovation system, while its local GDP surged over 210-fold, from 6 billion RMB at the time of its establishment to more than RMB1.2 trillion (approximately US$190 billion) as of late-2020. The district has since served as one of the most important symbols of China's economic reforms and opening-up.

As one of the country's largest megacities, Shanghai currently hosts a total population of 24.87 million, representing an increase of 1.85 million people, or approximately 8%, over the past decade relative to its 2010 population of about 23 million (**National Bureau of Statistics of China, 2021**). Averaging this growth figure on an annual basis, we found that Shanghai's population growth has slowed considerably to 0.8%, one of the lowest rates the city has

witnessed over the last four decades. Figure 4-17 below visualizes the city's demographic trajectory from early 1950s to 2020, with blue bars denoting Shanghai's population across consecutive national surveys (figures on the left Y-axis, each for 10,000 people) and average growth rate on the right side of the Y-axis.

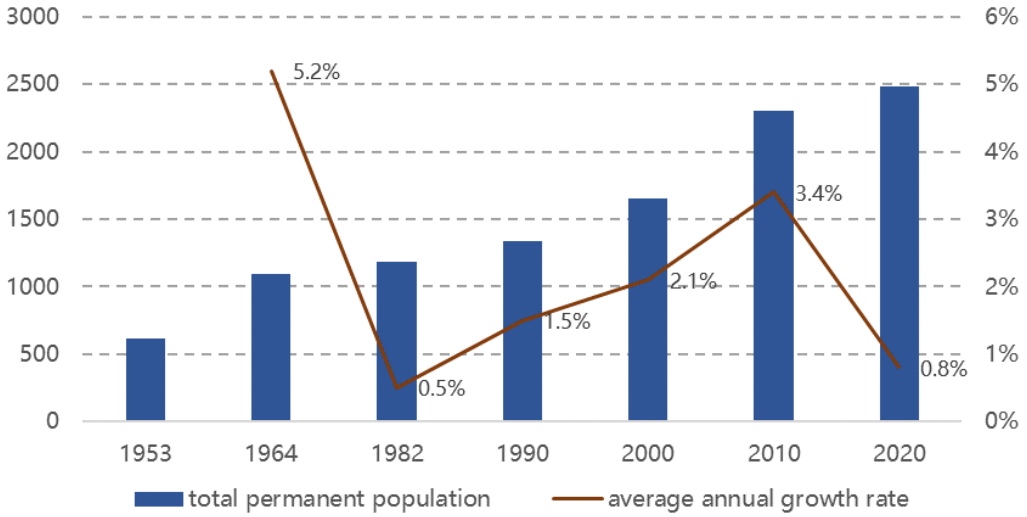


Figure 4-17 Shanghai's population growth trajectory (1953-2020)

One of the most remarkable characteristics of Shanghai's population is the rapid increase in the proportion of population with higher education degrees. According to the latest census data, close to 33.9% (approximately 8.4 million people) of the city's population had at least an undergraduate degree, endowing the first-level administrative division with the second highest share of university-educated population (the first position by which was filled by Beijing, with the figure approaching 42%).[165] Moreover, the average number of years of schooling for people aged 15 and above rose from 10.7 to 11.8 years, complemented by a drop in illiteracy rate from 2.74% to 1.61%.

Moreover, despite the challenges and pressure exerted by the ongoing COVID-19 pandemic, Shanghai's economy continued to grow and perform fairly decently. As an illustration, in 2020, the city's GDP grew by 1.7% and surpassed RMB3.87 trillion (approximately US$610 billion in nominal terms). Tertiary industry, as represented by service-related sectors, accounted for almost 3/4 (about 73%) of the city's GDP output, a figure that signifies the dominant role played by these sectors in driving the city's economic growth. Simultaneously, secondary sectors (dominated by manufacturing and related industries) accounted for nearly 1/4 of Shanghai's GDP, with 40% of the city's industrial output driven by strategic emerging industries, or high-technology industries included in the Chinese government's priority development list. Primary industry, as represented by agricultural sector, played a small – but no less important – role in the city's economy as well. With regard to R&D investments, the city has, in recent years, invested about 4% of their GDP into such activities; about RMB160 billion (equivalent to US$25.4 billion) were dedicated to R&D expenditure in 2020. With respect to R&D-to-GDP ratio, Shanghai is on par with other globally leading innovative economies, notably South Korea and Israel.

4.4.4.2.Technology transfer in Shanghai

The mode of technology transfer in Shanghai better reflects the combination of an effective market and a promising government.

In the first decade from 1978 to 1987, Shanghai stimulated the vitality of scientific research institutions through the pilot project of the scientific research contract system, the expansion of autonomy, the reform of the funding system, and other measures. The government also supported the set-up of private scientific and technological institutions by supporting research personnel to take part-time jobs and start their businesses. Exploring the establishment of technology markets promotes the connection between the supply and demand of scientific and technological achievements.

In the second decade, from 1988 to 1997, we introduced the concept of business incubation to build several science and technology business incubators, further explored the permanent technology market through the establishment of the Shanghai technology exchange, and issued the regulations of Shanghai on the technology market to creating an environment.

In the third decade, from 1998 to 2007, the famous policy on Promoting the Transformation of High-Tech Achievements, commonly known as "18 articles of science and technology," was released. It had made three major revisions in 1999, 2000 and 2004 respectively. The policy was positioned at the commercialization stage between R & D and industrialization, a series of supportive policies on finance, taxation, and talents were introduced and implemented, and government set up special service institutions and "one-stop" service windows to explore further ways to promote the technology transfer through policy innovation and service innovation;

In the fourth decade, from 2008 to 2017, concentrating on the core goal of the construction of the Shanghai Science and technology innovation center, the focus shifted to improving the mechanism of technology transfer. The change has successively issued a policy trilogy of technology transfer composed of implementation opinions, regulations, and action plans to promote the construction of the technology transfer framework and system.

By the end of 2020, 13785 high-tech achievements and transformation projects had been identified in Shanghai over the past 22 years. These projects have achieved a total sales of 1852.516 billion yuan, a total of 10.217 billion yuan of special financial funds, more than 2900 talents who had introduced and implemented high-tech transformation projects, and more than 10000 people with intermediate and senior titles in the transformation of achievements.

Educational resources are distributed more equitably through classification. By combining the three methods of government policy guidance, university independent selection, and social participation evaluation, Shanghai universities are classified and managed according to the differences between talent cultivation and scientific research. The universities are divided into four types: academic research, applied research, applied technology, and applied skills. With such classification criteria, schools have clearer development goals and the motivation to actively pursue internal reforms. Although some universities are less capable of scientific and

technological innovation, they can provide support in other aspects such as technology. Such classification has changed the single route of science and technology achievement transformation which is only chasing science and technology innovation, enriched the participation of many universities in achievement transformation, and helped to make full use of resources.

In the past years, the autonomy of universities to dominate scientific and technological achievements has been restricted. One of the impediments to the transformation of scientific and technological achievements - the right to legal personal property - has not been implemented. Although universities enjoy the intellectual property rights in financially funded projects, they are bound by the management system of state-owned assets in China and are equally not free to deal with their intellectual property rights under administrative intervention. Shanghai has continued to promote the reform of the institutional mechanism for the transformation of achievements, further releasing the transformation vitality of researchers by granting them ownership or long-term use rights of scientific and technological achievements, as well as other incentive policies. For example, the Shanghai Institute of Pharmaceutical Sciences of the Chinese Academy of Sciences has carried out an effective incentive revenue distribution policy: the team completing the scientific and technological achievements can choose to withdraw 0-50% of the transformation proceeds as a reward for those who complete them.

The autonomy of some applied universities has produced corresponding changes. The applied universities are able to promote the combination of technology and enterprises in all aspects with technology application as the core, so as to better promote the technological innovation of enterprises. Compared with the transformation of scientific and technological achievements in the past, the autonomy of local applied colleges and universities has obviously changed, which is mainly reflected in the following aspects. First, it independently decides to adopt transferring, licensing, and valued investment of scientific and technological achievements to carry out the activities of transferring and transforming scientific and technological achievements. This significant change has stimulated the potential and vitality of promoting scientific and technological achievements of universities. Second, the institutions for the transformation of scientific and technological achievements are established independently, which become separate functional departments and form the staff within the establishment, such as the Technology Transfer Center established by Shanghai University of Technology and the University Science and Technology Park established by Shanghai University of Applied Technology. Thirdly, all proceeds obtained from the transfer and transformation of scientific and technological achievements are retained by the unit, and the unit can independently decide to allocate them to the team. These three changes give local applied universities more autonomy, and local applied universities gradually set up institutions to support relevant personnel to transform scientific and technological achievements, and incubate cutting-edge scientific research technologies in science and technology parks to effectively promote the transformation of scientific and technological achievements of universities.

One of the competitive advantages of Shanghai relates to the abundance of higher education-supporting resources. 10 of Shanghai’s universities were listed in the 211 Project (a former

initiative by the Chinese government to enhance universities' research capabilities), and 4 of them were also double-listed in the 985 Project (another former initiative by the government to transform existing institutions into 'world-class universities'). Notable universities included within both projects were Fudan University, Shanghai Jiao Tong University (SJTU), East China Normal University (ECNU), and Tongji University. Given that we have extensively covered Fudan and SJTU in the Task 2 report, we will further elaborate about the broader links between the two universities and Shanghai's innovation ecosystem in the following sections in this case study.

In recent years, there have been ongoing large-scale efforts by authorities (from the central government down to Shanghai municipal authorities) to promote the transformation of state-registered 'scientific and technological achievements'. As an example, in the 2020 Shanghai S&T Achievement Transformation White Paper, which focused on blueprint for developing the city's market-for-technology ecosystem, Fudan, SJTU, along with 4 other universities (Tongji, East China University of Science and Technology/ECUST, Shanghai University, and Shanghai University of Science and Technology) would be reorganized by the Ministry of Education as core bases for pioneering commercialization of S&T achievements, as well as enhanced technology transfer. These universities would be provided significant autonomy in strategies on improving their management system, institutional structure, service support system, hiring of personnel, etc.

Throughout the next sections, we will further analyze the dynamics of Shanghai's innovation ecosystem using three different analyses. In the first analysis, we observe the dynamics of inter-organizational dynamics on the basis of patent data. The second analysis broadens our scope of investigation as we also seek to uncover the extent of knowledge exchange linkages, particularly between universities and industries, in basic scientific research. In the third, and final, analysis, we examine the extent to which Shanghai-based investors have provided financial support for technology companies co-located in the same municipality.

4.4.4.3. Three analysis

INTER-ORGANIZATIONAL NETWORKS: EVIDENCE FROM USPTO PATENT DATA

We first provided description on the top-10 patenting organizations based in Shanghai. Cumulatively, they have accounted for over one-third of all patent filings from the city. An interesting insight we learned from Table 4-33 below is that the list is entirely dominated by ICT-, electronics-, and semiconductor-oriented firms. What has become fascinating, in particular, is the rise of China's 'domestic champions', notably Huawei, SMIC (also known as Semiconductor Manufacturing International Corporation), and Tianma Microelectronics; three of them have been ranked as the most active patenting organizations, much of which was attributed to their 'patenting boom' in the 2013-2018 period (see Table 4-33 below).

Table 4-33 List of top-10 patenting assignees in Shanghai (all-time)

Name	Patent filings (26,134)
Huawei	1,982
SMIC	1,695
Tianma Microelectronics	1,073
IBM	924
Intel	868
General Electric	741
Inventec	651
Alcatel-Lucent	416
EMC Corporation	377
Delta Electronics	344
Share of top 10	34.7%
No. of organizations	2,189

In comparison to Beijing, another innovation hub we cover in the Task 3 report, Shanghai's innovation ecosystem produced – in aggregate – a smaller number of patent filings (as a matter of comparison, for the same period, a total of 36,000+ patent applications had been made from Beijing), but this finding did not make Shanghai any less innovative and/or dynamic than other innovation hubs within China. Indeed, the two cities have been singled out as the first-generation, and among the most vital, innovative clusters, thanks to the opening-up reform that initially favored cities and other localities in the eastern and southern coastal regions (**Breznitz and Murphree, 2011**). Moreover, both Beijing and Shanghai enjoy distinctive competitive advantages. The former excels in the form of strong government institutions, ICT industries, and a high density of research-performing organizations, whereas the latter has long enjoyed unbridled strengths in manufacturing, particularly in capital-intensive (e.g. chemicals, shipping, airplane components, etc.) and high-technology industries (**Yusuf and Nabeshima, 2010**), and more recently in financial services.

One characteristic that Shanghai's innovation ecosystem shares in common with Beijing lies in the historical and evolutionary trajectories of the city's inter-organizational networks. Until early 2000s, Shanghai's innovation landscape has been fairly 'barren', with affiliates of foreign research institutes and/or government agencies, as well as local research-performing entities, dominating the city's patenting activities. Indeed, no betweenness centrality scores could be assigned to these organizations in the first three periods (1983-2000) as majority of the inter-organizational networks were in the form of dyadic ties between pairs of nodes, all of which were disconnected from each other (see Table 4-34 in the following page). Local universities and/or research institutes (e.g. Fudan, SJTU, and Shanghai-based affiliate institutes of Chinese Academy of Sciences) played a very limited role in catalyzing the growth of Shanghai's innovation system.

Nevertheless, despite starting from a very low base, Shanghai's innovative output has been rising considerably, bulk of which was catalyzed by the local government's substantial support

in developing science, technology, and innovation-related (STI) infrastructure (**Breznitz and Murphree, 2011; Wu, 2007**). The city's aggregate number of patent filings multiplied from 31 in 1983-1988 to 76 in 1989-1994, and 278 in 1995-2000 period. In the aftermath of China's accession to WTO in 2001, the country began to experience a significant influx in foreign direct investment, particularly in technology-based industries that sought to exploit the country's low production costs and emerging consumer market; Shanghai's innovation system has been inevitably shaped by such historical events, with foreign MNCs – notably those in electronics and other ICT-related industries – starting to establish factories and research centers to take advantage of the city's strengths in science and technology (**Grimes and Du, 2013**).

A combination of economic globalization, advances in ICT-related sectors & technologies, as well as China's market reforms have, by and large, enabled patent outputs in Shanghai to multiply from one period to another. As an illustration, in 2001-2006, a total of 2,204 USPTO patent applications (an 8-fold increase compared to 1995-2000 figure) were made based on invention efforts in the city. The figure nearly tripled to 6,487 in 2007-2012, and increased by another whopping 80% to almost 11,600 in 2013-2018 period. A large proportion of such growth was attributed to the role played by foreign multinationals – especially those in ICT and electronics – that built their operations in Shanghai. Some illustrious examples included Intel, General Electric, IBM, Microsoft, Philips, as well as Taiwanese manufacturers, such as Delta Electronics and Inventec. In recent years, a select number of Chinese 'domestic champions' also began to challenge the longstanding dominance of these foreign MNCs. In a pattern similar to Beijing, by 2013-2018 period, almost half of the top-10 patenting organizations have been mainland Chinese firms, notably: Huawei, SMIC, Tianma Microelectronics, and On-Bright.

What about Shanghai's universities and public research organizations? This is where the city diverges from Beijing. In simple aggregate terms, none of Shanghai's major research-performing institutions, e.g. Fudan University, Shanghai Jiao Tong University (SJTU), Institute of Materia Medica, or Chinese Academy of Science (CAS)-affiliated centers, was included in the top-10 lists from the 1980s up to 2018, with the exception of Fudan in 1983-1988 period or CAS institutes in the 1980s and 1990s. Even when measured by betweenness centrality, a fairly limited number of such organizations would be ranked as among the most influential in the city's innovation networks. An exception was made in 2001-2006 period, when Institute of Materia Medica was ranked as the most influential bridging actor based on betweenness centrality position. Only SJTU recently made into the top-10 list in 2013-2018 period using this measure. Another university that was no less significant in its role was East China University of Science and Technology (ECUST).

Table 4-34 List of top-10 patenting assignees in Shanghai throughout different time periods (patent filings indicated in brackets)

1983-1988 (31)	1989-1994 (76)	1995-2000 (278)	2001-2006 (2,204)	2007-2012 (6,487)	2013-2018 (11,593)
Univ of Texas (6)	CSL Optoelec (6)	Inventec (37)	Intel (179)	SMIC (278)	Huawei (1,474)
Chin Acad Sciences (4)	US Dept of Commerce (6)	Regent Lighting Corp (12)	SMIC (119)	Huawei (262)	SMIC (870)
Univ New Mexico (4)	US DHHS (4)	US DHHS (10)	General Electric (106)	General Electric (229)	Tianma Micro (655)
Shanghai Lamp Factory (2)	Xerox (4)	Hoffmann-La Roche (9)	Inventec (77)	Alcatel-Lucent (221)	IBM (563)
US Dept of Commerce (2)	Allen-Bradley (2)	Eastern Michigan Univ (8)	Philips (59)	Intel (213)	Intel (286)
US Dept of Energy (2)	Chin Acad Sciences (2)	Eaton (8)	Alcatel-Lucent (58)	IBM (172)	EMC Corporation (190)
Ayetech Inc (1)	City Coll New York (2)	SINOPEC (8)	Microsoft (40)	Delta Electronics (134)	General Electric (174)
Fragrant Liq Butane (1)	Dana-Farber Inst (2)	Bio-Rad Gene (7)	SINOPEC (38)	Inventec (119)	On-Bright (170)
Fudan Univ (1)	Hoffmann-La Roche (2)	ExxonMobil (6)	Hoffmann-La Roche (27)	Philips (97)	Delta Electronics (159)
Harbin Res Inst Weld (1)	Int'l Med Research (2)	Microsoft (6)	Delta Electronics (26)	Dow (92)	Inventec (153)
Share of top 10: 77.4%	Share of top 10: 42.1%	Share of top 10: 39.9%	Share of top 10: 33.1%	Share of top 10: 28.0%	Share of top 10: 40.5%
No. of organizations: 17	No. of organizations: 42	No. of organizations: 107	No. of organizations: 441	No. of organizations: 1,104	No. of organizations: 1,272

Table 4-35 List of top-10 patenting assignees in Shanghai in terms of betweenness centrality scores (scores indicated in brackets)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
-	-	-	Inst Materia Medica (1388)	Huawei (19474)	Huawei (68389)
-	-	-	SMIC (1091)	Chi Acad Sciences (18779)	IBM (28610)
-	-	-	SINOPEC (1083)	Inst Mater Medica (18047)	SMIC (28570)
-	-	-	Intel (1079)	General Electric (16071)	Chi Acad Sciences (15677)
-	-	-	Alcatel-Lucent (1062)	Intel (12636)	General Electric (14493)
-	-	-	Chi Acad Sciences (805)	SMIC (11676)	SJTU (11555)
-	-	-	Ericsson (737)	Dow (10351)	Intel (10178)
-	-	-	Huawei (575)	Alcatel-Lucent (10208)	Tianma (9565)
-	-	-	NUS (557)	IBM (10159)	Delta Electronics (8727)
-	-	-	ECUST (545)	ECUST (8495)	Tyco (8719)

UNIVERSITY-INDUSTRY COLLABORATION IN SCIENCE: EVIDENCE FROM ANALYSIS OF JOINT PUBLICATIONS

In the second analysis, we further study about university-industry collaboration dynamics in Shanghai, this time by proxying our analysis on academics' joint publications with their industry counterparts ('U-I co-publications'), following **Tijssen et al. (2009)**. Similar to what we have performed in other hubs, we first collected publication data from Lens.org, with a particular focus on peer-reviewed journal articles involving at least one researcher from either Fudan University or Shanghai Jiao Tong University (SJTU), both of which have had their profiles examined in-depth at the Task 2 report. We limited our collection to academic works published from January 1, 2009 to December 31, 2018, covering a total of ten-year period. Through a combination of manual reviews and text mining, we identified U-I co-publications by analyzing the institutional affiliation of the co-authors, as well as checking for the existing company titles in their affiliation (e.g. 'Co.Ltd', 'Inc.', 'Corp.', etc). We also removed dataset entries with incomplete affiliation records, or with missing values for most of their variables.

Table 4-36 below provides summary statistics on the total number of peer-reviewed journal articles, as well as the smaller subset of U-I co-publications, that involve researchers from Fudan and/or SJTU. In aggregate, for the 2009-2018 period, the two universities were collectively responsible for over 138,000 academic publications, close to 5,500 by which were conducted in collaboration with industry researchers. Percentage-wise, this figure was equivalent to almost 4% of all journal articles originating from these two institutions. Benchmarking this figure with that of Hong Kong (of which, from the five research universities we covered, it was over 3.9%), we found the rate of industry co-publication for the two cities to be very closely similar.

Table 4-36 Publication data in Shanghai and information on U-I co-publications (2009-2018)

University	Total number of publications	Total number of U-I co-publications	U-I co-publications as % of all publications
Fudan	54,657	2,035	3.72
SJTU	83,763	3,449	4.12

From the above finding, one may perceive that the percentage score remained substantially below the annual global average, such as those estimated by **Tijssen et al. (2009)**. However, once we further break down the rates of U-I co-publication on an annual basis, as displayed below, readers may observe the substantial increase in collaborative works with industry actors over time. In this figure, we divide U-I co-publications into three types, by taking into consideration the geographical nature of their collaboration: 1) co-publications with local enterprises; 2) with domestic non-local enterprises, and; 3) with foreign firms. Regarding 'local enterprises', we operationalize this concept to encompass not only businesses based within Shanghai municipality, but also its neighboring cities, both in Jiangsu and Zhejiang provinces, given that increased accessibility (e.g. high-speed rail networks) have enabled easier mobility

across metropolitan regions (**Ma et al., 2020**).[166] Domestic non-local enterprises refer to mainland Chinese enterprises engaged in scientific research with these universities that are located outside the scope of localities qualifying for 'local enterprise' designation. Foreign firms refer to any enterprises based worldwide.

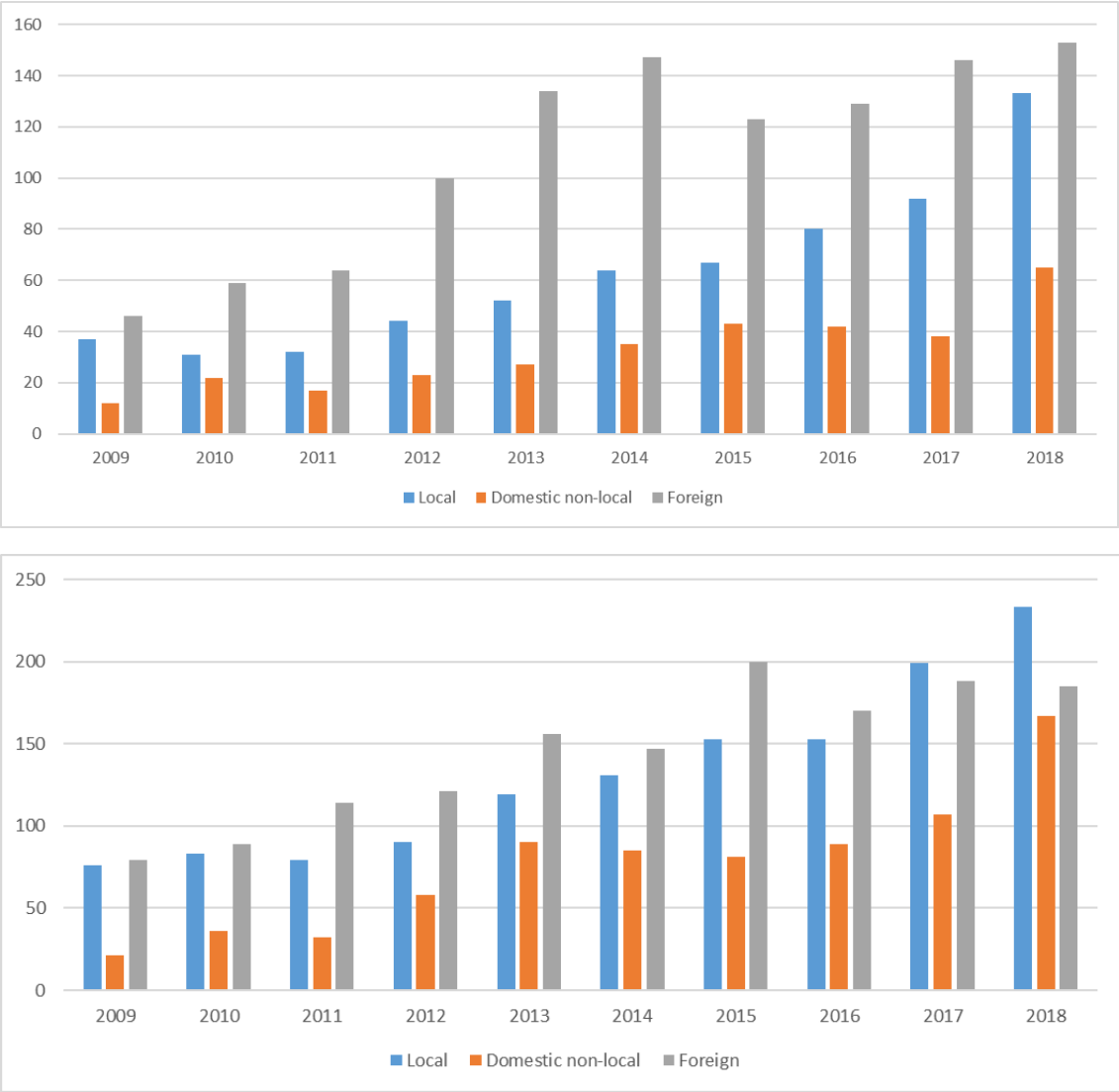


Figure 4-18 Types of U-I co-publications involving Fudan (above) and SJTU (bottom) (2009-2018) based on the geographical origins of collaborating firms

From Figure 4-18 above, we can observe considerable growth in the quantity of co-publication output with all three different types of enterprises over time. This phenomenon has been particularly substantial for U-I co-publications involving local enterprises, with the annual output for both Fudan and SJTU having multiplied significantly within the 10-year period. Indeed, specific to SJTU, the number of co-publications involving local firms in recent years has surpassed those with domestic non-local and foreign counterparts. The number of U-I co-publications involving domestic non-local firms, for both universities, somewhat lagged behind, but in the case of SJTU, the growth has been considerably higher, and has indeed rapidly closed their gap with co-publications involving local and foreign enterprises. Overall, the two universities – in terms of scientific collaboration – appear to be more closely linked with local

industry players than with those outside Shanghai.

Table 4-37 below further displays the top-10 industry collaborator lists with the two selected universities. With regard to Fudan, we found that a significant proportion of the companies in the top-10 lists are either pharmaceutical or biotechnology companies, particularly for the collaborating foreign firms; with the exception of IBM, the remaining enterprises in this list are major global drugmakers. The prevalence of biotechnology / pharmaceutical / chemical-related companies in the top-10 local and domestic non-local collaborator lists was also on display, with firms such as Hutchison MediPharma, 3D Medicines, Genesky Biotech, BGI, and Burning Rock Biotech being some of the major examples. Much of this was attributed to the presence of a large medical school in Fudan University, having been merged from Shanghai Medical University back in the early 2000s (**Wu, 2007**).

Table 4-37 Top 10 collaborating firms with Shanghai universities in U-I co-publications (2009-2018 period, number of co-publications indicated in brackets)

Fudan		
Local firms (N = 632)	Domestic non-local firms (N = 324)	Foreign firms (N = 1,101)
Baosteel (24)	SINOPEC (78)	Novartis (57)
Hutchison MediPharma (21)	BGI (12)	Siemens (52)
China Tobacco SH (18)	CNPC (10)	Hoffmann-La Roche (46)
Piaoxue Cultural Media (13)	Burning Rock Biotech (8)	AstraZeneca (35)
3D Medicines (12)	CNOOC (7)	Leidos (33)
CETC (12)	Huawei (5)	GlaxoSmithKline (28)
Givaudan (Shanghai) (11)	Tencent (4)	Pfizer (28)
Centennial Scientific (11)	Jiangmen Kanhoo (3)	IBM (25)
Genesky Biotech (10)	Agri Bank of China (2)	Eli Lilly (23)
Shanghai Chempartner (9)	FivePlus Molecular (2)	GE Healthcare (23)
SJTU		
Local firms (N = 1,316)	Domestic non-local firms (N = 766)	Foreign firms (N = 1,449)
Baosteel (127)	Huawei (55)	General Motors (83)
Shanghai Electric (93)	State Grid (45)	Ford Motor Co. (55)
COMAC Shanghai (33)	CNOOC (38)	Microsoft (52)
Shanghai Turbine (32)	SINOPEC (23)	Siemens (47)
Bright Dairy & Food (23)	CNPC (20)	IBM (39)
Shanghai Tool Works (23)	Jilin Electric (17)	Leidos (36)
Suzhou Origin Medical (22)	FAW (12)	AstraZeneca (32)
SAIC (15)	BGI (12)	Philips (32)
Jiaoyou Diamond Coat (14)	CGNPC (10)	Boehringer Ingelheim (30)
SH Superconduct Tech (13)	AVIC (10)	Novartis (30)

Another interesting pattern that we observed from Table 4-37 above is that SJTU appears to be

more active than Fudan in terms of engaging in scientific research collaboration with Chinese state-owned enterprises (SOEs). This was particularly evident when we looked into the top-10 local and domestic non-local industry collaborator lists. Regarding the former, 6 of the top-10 firms (Baosteel, Shanghai Electric, COMAC, Shanghai Turbine, Shanghai Tool Works, SAIC) are SOEs either operated by the Shanghai municipal government or the Chinese central government. In the case of the latter, with the exception of Shenzhen-based Huawei and BGI, the remainder are dominated by Beijing-headquartered SOEs. Moreover, judging from the collaborator profiles (e.g. State Grid, CNOOC, SINOPEC, FAW, AVIC, etc.), it appears that a significant proportion of U-I co-publications are linked to engineering-related topics in a wide range of sectors, from electricity, automotive, aerospace, to oil & gas. This finding seems to be driven by the fact that SJTU is a highly engineering-focused university, and has, since the onset of 21st century, more actively promoted collaboration with industry actors, especially in applied research (**Wu, 2007**).

Regarding U-I co-publications with foreign firms, the differences in the composition of top-10 collaborator lists for Fudan and SJTU are also worth mentioning. As we have shown for the former (Fudan), most of the frequent collaborators – with the exception of IBM – are pharmaceutical/life science multinational corporations. In the case of SJTU, 6 of the top-10 co-authoring foreign firms are either automotive-related (as displayed by General Motors and Ford), focused on ICT (e.g. Microsoft and IBM), or engineering/appliances-related (with Siemens and Philips being the prominent examples). Again, much of this could be attributed to the two universities' different specialization, with one leveraging their strengths in medicine-related studies (Fudan) and the other on engineering-related skills (SJTU).

Afterwards, we specifically turned our attention to the universities' scientific collaboration with spin-offs that were founded either based on their scientists' research ventures or by the affiliated students / staff / graduates / alumni. We focused our analysis on the subset of U-I co-publications involving local firms as our starting point in identifying these spin-offs. Regarding the designation of a local firm as a university spin-off, we relied primarily on desktop search of the authors' affiliated company names, and following **Powell et al. (2016)**, visited the websites of these respective enterprises, which was further complemented by additional search of the founders' profiles on LinkedIn and other similar websites. One limitation, however, is that we may overlook other spin-offs from Fudan and SJTU that may no longer be located either within Shanghai or its neighboring cities.

In total, we identified 24 such spin-offs from Fudan, and 20 from SJTU. As displayed in Table 4-38 below, these companies were responsible for a total of 155 U-I co-publications involving the two universities' researchers. Regarding the sectoral specialization of these enterprises, we identified an interesting pattern. Nearly 80% (N = 19) of Fudan's spin-offs are involved in life science-related industries, whether in bioinformatics, biotechnology, or drug development. Again, such finding is attributed to the substantial role of Fudan's medical school in pursuing research commercialization and collaboration with industry partners (**Wu, 2007**). By contrast, while biotech/pharma spin-offs occupied the biggest proportion of SJTU-affiliated spin-offs, they did not constitute a majority. A high percentage of such enterprises are specialized in science and engineering-related areas, such as material sciences, scientific instruments,

superconductor, renewable energy, physics-related applications, etc. Once again, this finding is seemingly driven by SJTU's strong engineering orientation (**Wu, 2007**). Another interesting observation relates to the high degree of involvement by overseas Chinese returnees in establishing and/or managing such enterprises; in some instances, we double-labeled collaborating local firms as 'returnee-founded' and 'university spin-offs' given their significant overlaps. Table 4-40 below provides examples of technology companies established on the basis of research activities taking place at both universities.

Table 4-38 Number of spin-offs & joint publications with Shanghai universities (2009-2018)

	No. of identified spin-offs	No. of U-I co-publications	% of local-firm co-publications
Fudan	24	74	12
SJTU	20	81	6

Table 4-39 Specialization of Shanghai university spin-offs identified from U-I co-publications (2009-2018)

	Fudan	SJTU
Bioinformatics	1	-
Biotechnology/pharmaceuticals	18	9
Blockchain	-	1
Consulting	1	1
Contract research organization (CRO)	1	-
Electronics	1	-
Foods and beverages	-	1
Material sciences	-	4
Nuclear-related technologies	-	1
Physics-related sectors	1	-
Renewable energy	-	1
Scientific instruments	-	1
Semiconductor	1	-
Superconductor	-	1

Table 4-40 Notable Fudan and SJTU spin-offs identified from U-I co-publications

Name	University	Profile
Shanghai Shines Clinical Laboratories	Fudan SJTU 2nd Mil Med Univ Tongji	Shanghai Sai'an (Shines) is a high-technology enterprise focused on R&D, clinical testing, and development of biomedicines. Their core services are primarily related to individualized diagnosis and medical treatment services, disease risk prediction and early screening, as well as medical testing services for healthy and disease-affilicted population. Shines closely collaborates with

		Fudan, SJTU, Second Military Medical University, Tongji, as well as various university hospitals in implementing these molecular diagnostic technologies. The company was established in 2010 by a group of professors, scientists, and researchers based in Fudan University, Shanghai Jiao Tong University (SJTU), Second Military Medical University, Tongji University, as well as overseas Chinese returnees formerly based in the United States.
Quanray Electronics	Fudan	Quanray Electronics is one of the largest firms in the global high-frequency RFID hardware solution industry. It is one of the first companies in the world to receive EPC Global chip compatibility/label interoperability dual certification. The company develops its expertise in a wide range of device product lines, such as RF circuit, micropower circuit, RF antenna design technology, software radio-based reader technology, etc. Its technologies have been used in many areas, e.g. asset management, health, education, anti-counterfeiting, retail, etc. The company actively collaborates with national key laboratories and institutes at Fudan University for both chip design and SOC architecture. Shanghai Quanray was established in 2005 by Hao Min and Qiang Li, both of whom are researchers based in Fudan University. Hao Min was an associate professor at the university, having obtained PhD also in Fudan. He was also a visiting professor at Stanford University for several years. Qiang Li was a PhD graduate of Fudan University in 2005, and founded the company after his graduation.
Biotecan Medical Diagnostics	Fudan City of Hope Med Ctr Stanford	Biotecan Medical Diagnostics is a company that offers diagnostics-related services, as well as individualized precision medicine solutions that are tailored to unique conditions of every patient. The company also runs a clinical laboratory for performing genetic analysis. Shanghai Biotecan was founded by a group of overseas Chinese returnees and scientists from Fudan and City of

		Hope National Medical Center in Nanjing. Leming Shi is currently a professor at Fudan and is also a lead principal investigator for the company. Hua Yu is also a professor at City of Hope Medical Center and is a co-founder. Cheng Xu is the company's vice president and was a PhD graduate from Stanford University. Shouxin Wu is also a professor at Fudan and currently heads medical R&D in the company.
VacDiagn Biotechnology	Fudan	VacDiagn Biotech is a biotechnology company currently based in Suzhou Industrial Park. It focuses on product R&D, manufacturing, and distribution of vaccines for influenza virus, hand-foot-mouth disease, as well as cancer tumors. It also provides technical services in evaluating the efficacy of major infectious-disease vaccines. The company's current R&D focus includes: immunogen design, immune strategy design to induce broad-spectrum protective response, and maximizing the efficiency of vaccine carriers. VacDiagn Biotech was established in 2008 by a group of researchers and scientists at Fudan University, many of whom are overseas Chinese returnees. Some of the scientific founders are Xu Jianqing (professor and researcher at the Institute of Biomedicine) and Zhang Xiaoyan (researcher at Biomedical Research Institute).
CARsgen Therapeutics	Fudan SJTU	CARsgen Therapeutics is a clinical-stage immuno-oncology company that focuses on developing CAR-T and antibody therapeutics for cancer disease-related treatments. Headquartered in Shanghai, with offices in China and the United States, the company is building a pipeline of CAR-T product candidates to address solid and blood tumors. It is also conducting clinical trials for their CAR-T technologies for various cancer diseases, such as hepatocellular carcinoma, squamous lung cancer, glioblastoma, multiple myeloma, leukemia, etc. Beyond CAR-T, CARsgen is building on a proprietary platform technology centered on antibody therapeutics,

		and their monoclonal antibody technology is currently awaiting approval. It was founded and is currently led by Zonghai Li and Huamao Wang. Zonghai Li was previously a full-time professor at SJTU and is currently the university's adjunct professor. He obtained his PhD from Fudan. Huamao Wang is a scientist with PhD from Fudan University.
Jiangsu Haoran Spray	SJTU	Jiangsu Haoran Spray Forming Alloy Co. Ltd., established and currently based in Zhenjiang National University Science and Technology Park, is the first high-technology enterprise in China to introduce and commercialize spray forming alloy technologies. Based on over 20 years of intensive academic research, the company has developed a complete set of spray forming production equipment and spray forming manufacturing processes, and extended the application to new-material technology development, leading the formulation of national and industry technical standards. Jiangsu Haoran was established in 2008, and is currently led, by Zhang Hao, based on his research as a scientist at the School of Materials Science and Engineering at Shanghai Jiao Tong University (SJTU).
Shanghai Longyao Biotech	SJTU	Shanghai Longyao is a biotechnology company committed to tumor immune cell technology and product development. Their scope of areas covers hematoma, solid tumors, and other cancer-related diseases. Another field of interest that the company is currently focusing on relates to the development of precision medicine. At present, Shanghai Longyao has been developing 12 product pipelines based on their core technologies. They also actively collaborate with universities, university hospitals, provincial hospitals, and military hospitals across China in research collaboration and joint development of tumor immunotechnologies. Shanghai Longyao Biotechnology was established to commercialize research by professor Xuanming Yang, also the

		company's chief scientist, who is based in the Shanghai Jiao Tong University (SJTU).
Asia Stem Cell Bank	SJTU	Asia Stem Cell Bank is a company that specializes in the isolation, extraction, culture and expansion of human uterine membrane stem cells (MenSCs), dental pulp stem cells (DPSCs), adipose stem cells (ADSCs), placental stem cells (PSCs), umbilical cord stem cells (UCSCs) and amniotic stem cells (ASCs). The company is located in Shanghai International Medical Park and Shanghai Biomedical Research Industry Base. The company's stem cell cryopreservation adopts an artificial intelligence (AI)-driven management and tracking system. Asia Stem Cell Bank was founded, and is currently led, by Qi Nianmin, currently a professor at SJTU and a PhD graduate from cell engineering from Oregon State University.

Overall, from the second analysis, it can be inferred that Shanghai-based universities, in terms of scientific research collaboration with industries, seemingly continue to prefer large-scale, incumbent corporations that are either national-level SOEs based in Beijing (e.g. State Grid, CNOOC, SINOPEC, etc) or other no less influential state-owned firms headquartered in Shanghai (as shown by Baosteel and Shanghai Electric), and to some degree with foreign multinationals. In comparison to other profiled Chinese-based hubs, while the U-I collaboration in scientific research is more well-established than in Shenzhen (and even Hong Kong), it pales behind their counterparts in Beijing, which we will further elaborate in the next hub profile. The number of spin-offs identified from U-I co-publications is also fairly small, although the trend is evolving and there exists a major overlap with firms established by overseas returnees (that also involve Fudan and/or SJTU researchers), which we have explained in the previous mini-box. To conclude, there remains space for the universities in further enhancing their scientific research networks with industry actors.

FINANCING SUPPORT FOR LOCAL TECHNOLOGY COMPANIES: EVIDENCE FROM CRUNCHBASE DATA

In the third analysis, we further expanded our scope of studies from patent and publication data to investment activities by Shanghai-based investors in the co-located technology companies (within the city), following **Sorenson and Stuart (2001)**. Replicating our approaches in other hub cases, we primarily relied on Crunchbase as our main source of data. In aggregate, the database has provided information on over 1 million technology companies across the globe, as well as more than 200,000 investors (both institutional and individual), ranging from venture capitalists (VCs) to private-equity (PE) firms, investment banks, trust funds, angel investors, etc.

From the Crunchbase dataset, we extracted a list of investors after specifying Shanghai as the headquarters and/or location where these investors are located. Through this approach, we were able to obtain a total of 2,479 Shanghai-based investors. From a thorough review of their size of cumulative investment activities, we calculated that these investors have, in aggregate, engaged in a total of 10,042 financing deals that were spread over 8,612 technology companies globally (some companies may have received multiple investment rounds from the same investors). When we further filtered the list into the top 1,000 investors, we discovered that they had been responsible for 9,007 investment deals (equivalent to 90% of financing activities by all investors) in 7,578 companies, both within and outside Shanghai, a figure close to 88% of the entire portfolio organizations accumulated by these financiers.

Table 4-41 Information about investors in Shanghai (source: Crunchbase)

Size of investment activities	Number of investors
No information about investments	284
1 investment only	1,274
2-9 cumulative investments	718
10-25 cumulative investments	129
26-50 cumulative investments	45
51-99 cumulative investments	12
100-999 cumulative investments	17
1,000 or more cumulative investments	0
TOTAL	2,479

Table 4-41 above provides descriptive statistics on the categorization of investors in Shanghai based on their cumulative size of investment activities. Unlike other hubs, we found that the proportion of investors with no discernible information regarding their past financing activities (N = 284, close to 12% of all investors) was relatively small. However, slightly above 51% of them (N = 1,274) would be considered as one-off investors, as they were shown to have participated in financing of technology companies only once. Large-scale investors (which we define as individuals and/or organizations with at least 50, or more, financing deals), however, were relatively scarce; we only identified 29 such entities, a figure that was equivalent to 1.2% of the entire Shanghai-based investor population. The number was only slightly larger than that

of Hong Kong (for which we identified 21 such investors).

As it is unlikely for us to cover the profiles of all these investors within this report, we will only specifically focus on the biggest 25 of them, which we ranked on the basis of their cumulative investment activities. The full list was presented in Table 4-42. All in all, Shanghai's biggest 25 investors were responsible for 3,449 investment deals in 2,563 firms, which was equivalent to slightly above one-third of all financing activities by Shanghai-based investors. Of these 3,400+ deals, about 849 of them (close to one-quarter of their financing) were allocated towards 617 Shanghai-based technology companies. These co-located technology companies, in turn, represented approximately 24% of the cumulative portfolio of these top-25 investors. In comparison to other innovation hubs within mainland China, Shanghai's rate of co-located investments was considerably lower than that of Beijing (which, in our estimation of their top-25 investors, was 39%), but was substantially higher than that of Shenzhen (about 16%, which we will cover in the Shenzhen case study), and especially Hong Kong (slightly below 10%). Here, Shanghai would still be considered to rank favorably in terms of the proportion of capital support going towards local enterprises, compared to other localities within the country.

One interesting pattern we identified from studying these 25 major investors was the presence of VC funds that are, or were, subsidiaries of foreign investment funds. Notable illustrations include: SIG China (SIG Asia Investments), Morningside Group, Chinaccelerator, Lilly Asia Ventures, SBCVC, and Meridian Capital. SIG China was established as a subsidiary of US-based Susquehanna Growth Capital, currently one of the world's largest private-equity and wealth-management firms. Nearly 30% of their investment portfolio, most of which was concentrated in China, has been – at present – committed for Shanghai-based technology companies and start-ups. Morningside Group (recently renamed as 5Y Capital in 2020), meanwhile, is a VC fund with close ties to the Gerald Chan family from Hong Kong; they have been also responsible for establishing Hang Lung Group, one of the largest real-estate developers in the city with a significant property portfolio in mainland China.[167] With regard to Chinaccelerator, it is a China-focused start-up accelerator program established by SOSV, an impact-investing fund based in Princeton, NJ, in the United States.[168] Next, Lilly Asia Ventures is a former corporate venture capital (CVC) fund of Eli Lilly, an American multinational drug company, but it has since been spun-off into an independent VC fund.[169] While it invests primarily in China-based biotechnology companies, they also gradually expand into US-based biotechnology start-ups with a strong focus on Chinese consumer market. Afterwards, SBCVC (Softbank China Venture Capital) represents another notable illustration. Established by the Japanese ICT company in 2000, it has reaped significant successes from early bets in Alibaba, Didi, Taobao, BGI, and other first-generation Chinese domestic technology firms that emerged in the late-1990s/early-2000s.[170] Last but not least, Meridian Capital – with dual headquarters in Shanghai and Singapore – is also actively investing in early-stage start-ups, primarily those in mainland China (and to a limited extent in Southeast Asia as well).

Moreover, we also identified a major corporate VC fund (Fosun International), in which the business group has participated in at least 100 financing deals in 88 companies within Shanghai, throughout the broader mainland China, and globally. We also identified two other major

investors (namely Fenbushi Capital and LD Capital) with a primary focus on supporting blockchain- and cryptocurrency-related technology start-ups in China and Asia more broadly. Overall, an obvious impact from the high concentration of VC funds in Shanghai has been the proliferation of unicorn start-up companies, as well as the evolutionary shifts in the sectoral concentration of these early-stage firms over time.

Table 4-42 Top 25 investment funds in Shanghai and proportion of investments in Shanghai technology companies

Name	Summary	No. of investments	Investments in Shanghai	No. of portfolio organizations	Portfolio organizations in Shanghai
Qiming Venture Partners	A VC firm investing in start-ups and companies focused on technology-media-telecom (TMT) and healthcare industries	717	152 (21.2%)	399	77 (19.3%)
SIG China (SIG Asia Investments)	A Chinese subsidiary of US-based Susquehanna Growth Equity, one of the world's largest private equity and investment funds	295	84 (28.5%)	218	62 (28.4%)
Chinaccelerator	A Shanghai-based accelerator set up by SOSV (a US, Princeton-based VC and investment fund) that invests in software-related start-ups	251	79 (31.5%)	202	62 (30.7%)
Morningside Group	Now renamed 5Y Capital, it is a VC fund with close ties to Gerald Chan family, one of Hong Kong's richest billionaires and founder of Hang Lung Group	169	19 (11.2%)	123	14 (11.4%)
Empower Investment	A VC fund investing in start-ups that focus on Internet, AI, big data, automation/robotics, fintech, ed-tech, materials, and healthcare	155	24 (15.5%)	133	19 (14.3%)
Lilly Asia Ventures	A former corporate VC (CVC) fund	146	40 (27.4%)	93	23 (24.7%)

Name	Summary	No. of investments	Investments in Shanghai	No. of portfolio organizations	Portfolio organizations in Shanghai
	of Eli Lilly, a US multinational drug company, that invests in biotech/pharma start-ups in China and Asia more broadly				
Yunqi Partners	A VC fund that offers and provides early-stage investments on Internet-related start-ups in China	135	36 (26.7%)	80	21 (26.3%)
SBCVC	Also known as SoftBank China Capital, it is a VC and PE firm that manages funds and insurance-related funds in USD and RMB	126	29 (23.0%)	96	22 (22.9%)
Lightspeed China Partners	A VC fund that focuses on offering early-stage investments in China's technology start-ups	118	36 (30.5%)	80	24 (30.0%)
Eastern Bell Capital	A VC fund that specializes in investing in technology companies that promote improvements in supply chain & industry efficiency	111	35 (31.5%)	79	23 (29.1%)
DT Capital Partners	An investment fund that promotes private equity (PE) deals in early-stage and expansion-stage technology start-ups	107	29 (27.1%)	93	24 (25.8%)
Meridian Capital	A PE fund with dual headquarters in Singapore and Shanghai that invests	107	41 (38.3%)	94	34 (36.2%)

Name	Summary	No. of investments	Investments in Shanghai	No. of portfolio organizations	Portfolio organizations in Shanghai
	in start-ups relating to films, arts, music, education, media, etc				
NewMargin Ventures	A VC fund that provides various types of investments for emerging-technology start-ups in China and beyond	102	32 (31.4%)	94	30 (31.9%)
Yonghua Capital	A shares-limited VC fund that offers investments in various technology companies in China and beyond	101	31 (30.7%)	85	26 (30.6%)
Fosun International	A corporate VC (CVC) unit of Fosun Group, one of China's largest industry conglomerates and manufacturers	100	20 (20.0%)	88	17 (19.3%)
Fenbushi Capital	The largest VC fund in Asia that is dedicated to investing in blockchain and cryptocurrency-related technology start-ups	99	3 (3.0%)	97	3 (3.1%)
Zhonglu Capital	An investment fund that offers VC and PE deals for technology start-ups in TMT, fintech, e-commerce, and other sectors	86	30 (34.9%)	85	30 (35.3%)
Capital Today	An investment fund that offers VC and PE financing support for SME-sized technology companies, mainly	77	17 (22.1%)	56	15 (26.8%)

Name	Summary	No. of investments	Investments in Shanghai	No. of portfolio organizations	Portfolio organizations in Shanghai
	in China				
Chengwei Capital	One of the earliest VC funds in China (established in 1999) that invests in various technology start-ups in China and beyond	72	17 (23.6%)	50	14 (28.0%)
Loyal Valley Capital	A private equity (PE) fund that focuses on investing in deep research-based middle-market technology companies	71	18 (25.4%)	64	16 (25.0%)
CMC Capital Group	An investment fund management company that offers investments in technology firms focused on media-related sectors	69	27 (39.1%)	58	21 (36.2%)
Ameba Capital	A VC fund that offers multiple-stage investments (from early-stage to growth-stage deals) in various technology companies	63	14 (22.2%)	53	12 (22.6%)
LD Capital	One of the largest VC funds in Asia that is dedicated for blockchain-focused technology start-ups in China, Asia, and beyond	59	0 (0.0%)	58	0 (0.0%)
Sky9 Capital	A VC fund that offers various types of investments (early-stage to growth-stage) at deep-technology	59	16 (27.1%)	42	10 (23.8%)

Name	Summary	No. of investments	Investments in Shanghai	No. of portfolio organizations	Portfolio organizations in Shanghai
	start-ups in China and beyond				
GP Capital	An investment firm that offers private equity (PE) deals at start-ups focused on financial services and fintech-related sectors	48	20 (41.7%)	43	18 (41.9%)
		3,443	849 (24.7%)	2,563	617 (24.1%)

4.4.4.4. Discussions and conclusions

Throughout the three different analyses, we have identified interesting findings about Shanghai innovation ecosystem that can be summarized in the following sentences. In the first analysis, by which we relied on USPTO PatentsView data to investigate the evolution of inter-organizational linkages within the city, we found that enterprises – and specifically foreign multinationals – played a major role in catalyzing the growth of Shanghai's innovative output, supporting the observation by Grimes and Du (2013). The roles of universities and research institutes, by contrast, were less significant, with a small number of such institutions appearing in the top-10 rankings in betweenness centrality and degree centrality positions; their roles only became more vital from 2013-2018 period onward. This finding also, by and large, aligns with the argument put forward by Wu (2007) about Shanghai universities' historical roles as 'suppliers' of graduates, with limited attention to knowledge/technology transfer in comparison to counterparts such as Tsinghua (Beijing).

As inter-organizational linkages cannot be solely identified through patent-resulting inventive ties alone, we carried out two additional investigations to complement the first. The second analysis, in this regard, is based on publication data we obtained from Lens.org. In further expanding the scope of analysis for universities already covered in the preceding Task 2 report, we specifically examine the broader scientific collaboration ties between Shanghai's two selected universities (Fudan and SJTU) and innovating industry actors within the city-level innovation system, which we proxied with the presence of U-I co-publications.

Through a close-up review of the top local, domestic non-local, and foreign industry collaborators, we obtained several interesting findings. First, it appears that with respect to scientific research ties, both Fudan and SJTU historically collaborated more often with their foreign-firm counterparts than with their mainland Chinese partners, but the pattern for these two institutions has been shifting quite considerably over time, with increasing shifts towards the latter. Second, the universities have engaged in recurrent knowledge exchange with their counterparts at state-owned enterprises (SOEs), with notable examples including Baosteel, Shanghai Electric, SINOPEC, CNPC, State Grid, etc. SJTU, in particular, appears to be more frequently engaged in such ties, most likely given their expertise in engineering-related fields. Third, there is a distinct specialization pattern with regard to the types of firms these universities collaborate with; Fudan's U-I scientific research landscape seemingly focuses on life sciences (given the presence of a large medical school, as Wu (2007) argued), whereas SJTU's landscape combines engineering-oriented firms as well as life science companies.

The third, and final, analysis focuses on patterns of financing activities by Shanghai-based investors, with a particular interest in investigating the extent of investments in co-located technology firms (Sorenson and Stuart, 2001). An interesting finding from this analysis is that a significant proportion of the city's 25 most-active investors happen to be VC funds affiliated with foreign entities, many of which possess a high degree of investments in locally-based technology firms. Moreover, the presence of investment communities within the city has enabled a proliferation of unicorn start-ups; based on Failory and CB Insights, we identified a total of 58 such companies, and the growth of unicorns also appears to be minimally affected by internal and external disruption, such as COVID-19 pandemic, massive restructuring of

China's economy and high-technology industries, etc. We also observe an increasing tendency for investors to financially support start-ups focused on emerging technologies that are deemed to be of the Chinese government's strategic interests, e.g. artificial intelligence, new materials, electric/autonomous vehicles, semiconductor, etc., while simultaneously shifting away from lifestyle-based sectors, e.g. e-commerce and fintech.

Furthermore, from these findings, we also identified two major lessons – concurrently serving as suggestions – for Hong Kong government and other innovation-related stakeholders to consider. The first relates to recommendation to the Hong Kong government to more proactively reach out to major foreign VC funds and other global investors to establish offices, as well as support the city's aspiring technology start-ups. As we have shown from the third analysis, nearly one-quarter of Shanghai's largest investors are affiliated with foreign investment funds, and these financiers – by and large – have enabled the proliferation of unicorn start-up companies within the city. It is not that Hong Kong lacks foreign-based VC funds; indeed, from our in-depth study of the city, a significant proportion of the largest investors are actually non-local entites, but almost none of these investments end up allocated for local technology companies. Given the significant presence of such funds, and the success already demonstrated by home-grown 'champions' such as SenseTime, it would be good for the Hong Kong government to proactively liaise with existing and/or prospective investors and connect them with some of the city's emerging technology start-ups.

With regard to the second suggestion, we also suggest that the government – acting in concert with relevant innovation and entrepreneurship-oriented stakeholders (e.g. entrepreneurs, community organizers, industrialists, etc.) – strengthen ties and outreach efforts with the overseas Hong Kong communities and the broader overseas Chinese diaspora, especially for those with expertise in STI-related fields. A major part of Shanghai's success as an innovation hub has been enabled by the strategic roles contributed by Chinese returnees, whether through working for multinational enterprises (Grimes and Du, 2013) – which have accounted for a significant proportion of the city's patent output, or by establishing high-technology firms to disseminate and commercialize their expertise (Kenney et al., 2013). Some of Shanghai's most influential technology companies and unicorns, such as SMIC, Wuxi AppTec, MicroPort, etc., were founded by some of these returnees. As Hong Kong's, and China's technological progress more broadly, continues to rely on strong linkages with the global STI ecosystem, innovation-relevant stakeholders can do better in strengthening such linkages.

4.4.5. Tokyo

4.4.5.1.Introduction

The contemporary, post-war Japan is traditionally synonymous with its rich culture and advanced technology development. Located in the center of the Japanese archipelago, Tokyo is one of the world's largest and most populous cities with approximately 14 million inhabitants. Tokyo, as the country's epicenter of economic and political activities, has played a particularly important role in Japan's both industrial and technological development. Relatedly, Tokyo has been widely perceived as a globally pre-eminent 'hub of creativity' (**Fujita and Hill, 2005**). The Tokyo model of innovation is also perceived to be vastly different from innovation hubs in Western countries, given their uniquely diversified industrial base, its distinctive cultural background, and its ability to maintain its outstanding characteristics while adapting to changes in the external environment (**Fujita and Hill, 2005**).

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At present, Tokyo serves as the headquarters to a great number of Japan's leading enterprises, some of which include Mitsubishi-affiliated firms (e.g. Mitsubishi Electric), Honda, SoftBank, Sony, Mizuho, Canon, etc. Moreover, the city's start-up ecosystem, which is highly specialized in ICT, robotics, manufacturing, financial technologies/fintech, and artificial intelligence (AI) among many others, is collectively valued at US$14 billion (Rocketspace, 2019). Such factors, in turn, enable the region to be highly productive in innovation-related activities. Based on the 2020 Global Innovation Index by WIPO, INSEAD, and Cornell (2020), the metropolitan region has consistently emerged as the world's top performing innovation cluster in terms of both science and technology activities; the Hong Kong-Shenzhen-Guangzhou region, for a comparative purpose, is an emerging runner-up. Tokyo's strong position in the index can be primarily ascribed to its strong performance in patenting activities, as well as in scientific publication outputs. Moreover, in the same index, Japan has consistently been placed in the world's top-5 position in terms of the quality of innovation. The quality of innovation, in this regard, is mainly assessed on three indicators, namely: 1) quality of local universities; 2) number of patents filed internationally, and; 3) the number of times a publication receives non-local citations. The Japanese companies have been investing in development and implementation of innovative technology solutions. According to Japan's National Innovation Survey 2020 Statistics Report, around 215,610 companies, i.e. 49% of the companies surveyed, carried out innovation activities during the three years from 2017 to 2019. In the year 2020, in response to the rising challenges from the covid pandemic, 14% of the companies (surveyed) had introduced a new innovative product. Additionally, covid-19 and related challenges had

hampered the research and development activities of only 10 percent of the surveyed companies in the year 2020.

The National Innovation System (NIS) of Japan has been inevitably shaped by decades of economic boom and targeted industrial policies by successive administrations. The country's NIS is well-structured and organized in accordance with the industrial specialization of different regions. For major cities, and Tokyo in particular, they continue to operate as major hubs for industry-oriented innovation (Fujita and Hill, 2005). One major implication has been the prevalence of a strongly hierarchical structure characterizing not only the workflow of an organization, but also cross-regional relationships. Specifically, Japan's industrial production system is geographically differentiated (Seki, 1994). As an illustration, large corporations establish their headquarters in Japan's most populous cities, mainly Tokyo, Osaka, and Nagoya. These cities serve as the primary hubs where majority of the firms' most vital management teams are headquartered. 'Mother' plants, R&D centers, and prototype creation processes are largely concentrated within these cities' broader metropolitan areas, oftentimes located within a distance of 50 km from the urban core (Seki, 1994). In turn, mass production and assembly plants are scattered in other prefectures across the country, and increasingly overseas. SMEs, and in particular those with expertise in niche technologies, are oftentimes closely affiliated with large corporations, whether in the form of prototype development, supplying of product parts, components, and/or technologies, or production outsourcing (Fujita and Hill, 2005).

Tokyo, in particular, has a strategic, comparative advantage that other hubs within Japan do not possess: the city plays a major role as a core node for Japan in connecting the country with the broader global economy and innovation ecosystem (Nonaka and Takeuchi, 1995). On one hand, the city is deeply engrained and embedded in a "product-pull system of relationships" given the presence of headquarters of multiple large corporations within Tokyo metropolitan region, as well as corporate R&D centers, production plants, and testing centers; all these features indicate a very dense inter-firm networking structure (Nonaka and Takeuchi, 1995). New products and/or technologies are primarily, and oftentimes rigorously, assessed in testing centers within the city. Only after testing is considered successful that these prototypes would be dispatched to other parts of the country, or the companies' overseas operational bases, for mass manufacturing. Such testing processes are frequently supported by additional networks of SMEs, suppliers, scientific research organizations, as well as government agencies. On the other hand, Tokyo also serves as a major gateway or entry point for other Japanese regional firms to enter the national and/or global market, even as most of their business operations are located outside the capital.

The discussion of Japan's NIS would be incomplete without highlighting the broader structure of employment relations characterizing most enterprises. In a typical Japanese firm, employment relations rest on three major pillars: lifetime employment, seniority-based system, and enterprise unions (Witt, 2014). Lifetime employment, by convention, refers to the promise – oftentimes implicitly stated rather than explicitly codified in contracts – to keep regular employees, primarily male (seishain), until retirement age. Nevertheless, in recent years, this trend has been gradually fading due to the emergence of a short-term, contract labor-based employment system that increasingly paves the way for a dual labor market structure within

Japan. Seniority-based system, which complements the lifetime employment approach, refers to the practice of raising salaries for employees in accordance with their age, and duration of employment, within the company. However, with the introduction of a series of corporate governance reforms from 2000s onward, this pillar is – across an increasing number of firms – being replaced by performance-based pay structure, in which salary raise is strongly contingent on employee performance instead of seniority. Enterprise unions, for decades, have been instrumental in assisting company workers in seeking rights, better pay, and/or compensation from firm management, but since the 1970s, the role and influence of such unions in dealing with employment relations has also been on a decline.

4.4.5.2. Characteristics Of the Japanese Industry

The culture of the Japanese is deeply embedded into the country's industry practices. A key characteristic of Japan is the dominance of certain business groups or industry conglomerates, also known in Japanese as 'keiretsu,' which are central to Japan's economic history (Gilson and Roe, 1993). An interesting characteristic of such keiretsu relates to the affiliation structure of constituent companies under these business groups, in the sense that 'member' companies' ownership is centered on a financial-services group (usually in the form a bank) and a trading company (sogo shosha) (Colpan et al., 2010; Miyashita and Russell, 1994). In this regard, each of these banks and/or the trading companies controls a proportion of shares in a large number of companies across diverse industries, albeit the degree of ownership shares varies considerably from one company to another.

The progenitors of these contemporary keiretsu groups could be traced to the pre-war zaibatsu business groups, which dominated Japanese economy both before and throughout the duration of World War II (Addicott, 2017). In an organizational model relatively similar to that of chaebol business groups in South Korea – which we will elaborate in more depth in the Seoul case study, the zaibatsu business groups were originally controlled by the founding families, primarily by means of holding companies as proxies for exerting control. With notable examples of Mitsubishi, Mitsui, and Sumitomo, these zaibatsu were responsible in promoting mass industrialization, from Meiji restoration in 1868 to Japan's entry into the World War II.

Nevertheless, in the aftermath of the war, which resulted in Japan's near-total destruction and military defeat, the zaibatsu – most of which provided economic, industrial, and weaponry-related assistance to the Japanese military regime – were severely affected when the United States established a military occupation authority in the country (Addicott, 2017). While the US military authorities attempted to dissolve all of the zaibatsu business groups, the process ended up incomplete due to Korean War and Cold War, with the occupation authorities eventually relying on the remaining business groups for wartime production. Despite the incomplete dissolution, the occupation had a lasting effect on Japan's post-war economic and business landscape, with most of the founding families required to relinquish most of their ownership shares in their holding companies and controlling banks; as a result, there is a marked difference between zaibatsu and keiretsu, in the sense that the latter are no longer dominated by founding families, but rather by banks and trading companies (with most of these

affiliate companies eventually also publicly traded in Tokyo's stock exchange).

Two major phenomena explained how the keiretsu business group structure continued to be retained in the postwar era, particularly during the period of rapid economic growth. First, the Japanese government played an explicit role in encouraging the formation of inter-firm consortia, particularly in technologies and industries deemed to be of the country's competitive advantages (Noland, 2007; Witt, 2014); such linkages were often pushed through the indirect provision of subsidies to large financial institutions, many of which had historical links to the dissolved zaibatsu groups. Secondly, the cross-shareholding practices, often through 'friendly firms' owning some portions of other companies, were commonplace (Witt, 2014). Nevertheless, in recent years, given corporate governance issues, the Japanese government has been involved in successive reforms to reduce cross-shareholding, mainly through allowing ownership by foreign investors and having foreigners and/or corporate outsiders sitting in the boards of directors to monitor firm performance. Over time, in the face of intensifying global competition, an increasing number of business groups have embarked on a series of mergers and acquisitions (M&As) to transform themselves into even larger industry players.

Key Policies And Their Impact

Policies central to Japan's industrial development

Enterprises, historically, have played a core, driving role in promoting the development of Tokyo's innovation system. Much of this was also driven by the presence of a strong developmental state that enabled Japan's post-war economic boom (1945-1990). In the aftermath of World War II, through effective industrialization policies, Japan was able to achieve a rapid economic recovery and sustained a high growth rate for several decades. One of the major government actors, namely Ministry of International Trade and Industry (MITI), contributed significantly to Japan's economic miracle through a systematic series of plans on target-based development of new industries with which Japan had competitive advantages (**Noland, 2007**). Nevertheless, in the aftermath of the 1990 economic bubble, Japan's economic growth has slowed considerably, and its innovation system began to lose its vitality. A successive number of prime ministers have made attempts with structural reforms with some improvements, but the overall impacts remain too gradual to be assessed at its present stage, given the tendencies for government bureaucracies and major enterprises to stick with their path-dependent approaches (**Noland, 2007; Witt, 2014**). Gradually, the government has begun to play a less interventionist role in regulating the economy, a major departure from its previously proactive approach in the second half of the 20th century.

The linkages between Japan's keiretsu business groups and the country's economic miracle should not be understated. Japan's postwar economic boom began in the early 1950s when these enterprises – partly encouraged by the then-US military occupation authority – resumed their production of textiles, food and beverages, steel, chemicals, as well as other metal products within this period. Under a strong, top-down catch-up development agency promulgated by the Japanese government (chiefly by MITI), Tokyo began to focus on the development of chemical and heavy industries by virtue of its location advantage and

availability of low-cost labor force. Gradually, as their absorptive capacities improved, these enterprises began to diversify into other industries, such as automobile and electronic products (**Noland, 2007**). In the aftermath of oil crisis in the mid-1970s, both the Japanese government and major corporations began to make adjustments in their economic policies and industrial structure, gradually focusing on high-technology sectors and service industries. With the country's increasing involvement in international trade, these keiretsu enterprises diversified into a wide range of sectors, ranging from logistics, financial services, insurance, information service, marketing, etc.

4.4.5.3.Policies central to the formation of industry-academia relations

According to Mgonja (2017), in Japan, there was a "longstanding tradition of cooperation" between universities and various industry players, even though the partnerships among them was not active in the years of 1960s and 1970s. Also, Motohashi and Muramatsu (2012) highlighted that in the pre-war Japan era, several university academicians had a pivotal role in establishing businesses. Post-war, there was a decline in the collaboration between academicians and industry bodies due to concerns pertaining to the involvement of military, government, industry players and universities in Japan's militarization. The formation of Act on Research and Development Partnership concerning Mining and Manufacturing Technology in 1961 enabled university and industry collaboration activities in the mining and manufacturing industries. Further, industry bodies and universities formed a contract system for research in 1970. Gradually, around 1980s, the Japanese government saw the need for policies that would facilitate university industry collaboration. In 1983, a formal scheme of joint research was created, thereby marking the commencement of collaborative research activities between universities and industry bodies, as against the previous method of contract research between industry players and academicians. Thereafter, in 1987, the government established Collaborative Research Centres in national universities, which enabled the formation of joint research centres. As a result, funding for joint research increased significantly, which was visible in growth of patents applications.

As highlighted above, since the early 1990s, Japan's economy – and its innovation system – have been dramatically altered in the aftermath of the economic bubble. This issue can be summarized into the two major following issues. First, there has been a weakening the impact of the government's strategic industrial policies on stimulating industrial development and upgrading (**Noland, 2007**). A major consequence, in this regard, has been the gradual stagnation of Japan's industrial production system. Second, changes in the global economic landscape (e.g. creation of World Trade Organization / WTO, China's rapid economic ascent, globalization of industrial supply chains, etc) was hastening the necessity for the Japanese government, as well as large industrial players, to adopt reforms. Such action received increased urgency with stricter rules set by WTO, on top of trading disputes and pressures from the United States and countries in Europe.

Similar to the observation we have seen from other hubs covered in this report, external pressures necessitated the government to urgently transition from a development strategy

centered on industrial development (and oftentimes manufacturing) to one increasingly driven by knowledge production and utilization. In the face of such challenges, the government began to reform their industrial policies, from encouraging industrial upgrading, promoting university-industry collaboration, to the adoption of rules encouraging the formation of technology start-ups and commercialization of scientific research, the details by which we will elaborate in the coming sections (**Noland, 2007; Harada and Mitsuhashi, 2011**).

From the late 1990s onwards, the Government of Japan came to be influenced by the progress that the United States had experienced from the implementation of policies for university and industry collaboration. The Japanese government adopted some of these policies from the United States for promoting university and industry collaboration to give a boost the country's economy which was "stagnant" at the time. A primary factor for the extended stagnation in Japan's economy, despite availability of financing opportunities, was the fall in productivity. Around the same time, the government identified universities as a key driver of innovation and economic growth (Nagaoka et al., 2009). The Japanese government believed that technology transfers from universities in areas such as information technology and biotechnology were the growth drivers of the United States economy. Additionally, private corporations in Japan acknowledged that scientific findings of universities had become applicable in corporate research and development processes in areas such as biopharmaceuticals and recognised a need for university and industry collaboration (Motohashi and Muramatsu, 2012 and Kyoung-Joo Lee, 2017). These measures were focused on removing regulations that limited or prohibited relations between national universities and private industrial sectors as well as develop organizational and legal platforms that enable intellectual property rights and technology transfer in universities.

Hence, in 1995, the Science and Technology Basic Law was introduced, which aimed to reform the existing STI policy in Japan by explicitly pushing for greater collaboration among nationally leading universities, government-funded public research organizations, as well as the private-sector enterprises (**Harayama, 2001**). Following this, The First Science and Technology Basic plant of 1996 to 2000 was developed. Moreover, Japan began to initiate a series of five-year strategic plans in STI development, as well as reformulated existing laws and policies to encourage innovative activities among Japan's incumbent SMEs (**Noland, 2007; Harada and Mitsuhashi, 2011**). Subsequently, in 1998, the the Ministry of Economy, Trade and Industry (METI) and the Ministry of Education and Science (MEXT) implemented the Act on Promotion of Technology Transfer, which allows for transfer of technology from universities to private industry bodies. Under this law, technology licensing offices, which manage university-generated intellectual property rights, were established as private entities outside of universities due to legal restrictions. In 1999, the government adopted another law, known as the Japanese version of the Bayh-Dole Law, which permitted universities to seek ownership of their patents (Ohta, Lee and Kazuhiko, 2008). Following these policies, several patents held by the university academicians were included. Consequently, several universities and industry organisations leveraged inter-organizational alliances to enhance university and industry collaboration.

Despite the policies, the needed acceleration for university and industry collaboration was

lacking. On the basis of Japanese publication data, Sun and Negishi (2010) identified that it was easier for universities and industry organizations in Japan to collaborate with foreign researchers and as a result, the linkages between universities, industry and government (within the country) had become weaker. Prior to 2000, the universities acted as a bridge connecting the government and industry with foreign researchers. However, even as the Japanese government pushed for university industry collaboration, since 2000, the country's research networks aligned more with foreign researchers.

In 2000, the government established the Law to Strengthen Industrial Technology, which allows university researchers to manage funded and joint research and development projects with industry. It also enables universities to launch start-ups (Kyoung-Joo Lee, 2017). Thereafter, in 2003, MEXT of Japan introduced a policy for the establishment of Intellectual Property Headquarters in universities, which were focussed on promoting collaborations between industry bodies and universities. The policy called for formation of formal rules and procedures to manage the intellectual property rights of universities and paved the way for university industry liaison offices in Japan. However, as the universities in Japan were government organisations, they were unable to pursue collaborations with industry bodies. The joint research projects were small and were unable to generate concrete results for applications in the industry (Kyoung-Joo Lee, 2017). Hence, in 2004, the National Universities Incorporation Law was introduced, thereby removing the legal hurdles of collaboration between universities and industry bodies. As a result, the University of Tokyo became a national university corporation and a Division of University and Corporate Relations (DUCR) was created consisting of three units, namely; the University-Industry Collaborative Research Promotion Unit, the Intellectual Property Unit, and the Business Incubation Unit. As a result, the University of Tokyo's entrepreneurial performance grew significantly from the year of 2004 onwards (Ohta, Lee and Kazuhiko, 2008).

Scholars indicated that the policies adopted by the Japanese government for promoting collaboration between industry and universities have shaped various businesses and innovation hubs in the country. Following these reforms by the Government of Japan, several universities and industrial organisations in the country revised their approach to establish inter-organizational alliances (Kyoung-Joo Lee, 2017). Ranga, Mroczkowski, and Araiso (2017) noted that over the years, the university and industry collaboration policies have become more complex and encompass all aspects of the innovation chain. They noted that the number of joint research contracts more than doubled to around 23,000 in 2014. Also, there was a significant increase in the number of patent applications and joint research projects. The number of joint research projects almost doubled to 17,638 in the financial year of 2009 from 9,225 noted in the financial year of 2003 (Motohashi and Muramatsu 2012). Also, from 2001 to 2008, around 65 universities in Japan reported establishing nearly 442 alliances including 220 with manufacturing firms and around 222 with financials services (Kyoung-Joo Lee, 2017).

The impact of these extensive policies, which were inspired from those implemented by the United States, varied in several aspects due to the different structure of Japan's innovation system. Research and development in high-technology fields, such as automobile, electronic and medical, is usually undertaken by large companies in Japan. These large companies restrict

their research to in-house capacities or affiliated companies. Even though they have connections or linkages with certain universities, they do not necessarily absorb the sizeable technology developments arising from university based startups (Ranga, Mroczkowski, and Araiso, 2017). Additionally, in Japan, the corporates or industry players involved in joint research with the universities have not either clearly established their objectives or do not recognize the varied roles that the latter could hold in a joint research. Additionally, joint authorship of research papers is a result of close social connections of academicians with corporates in Japan. Also, some corporates send their researchers to work in laboratories of certain universities in order to identify joint publication opportunities (Hicks, Isard et al. 1995). Contrarily, the industry bodies in the United States categorize universities into those with which they conduct joint research for advanced science and those which they can contract to conduct research for developing practical technologies (Bercovitz and Feldman 2005). The proof lies in the findings of a recent survey conducted by Japan's National Institute of Science and Technology. According to the National Innovation Survey 2020 Statistics Report, the most common channels used in the industry-academia collaboration for acquiring knowledge were "professional or industry associations" and "scientific or technical journals, or trade publications." Further, the least common challenges for knowledge acquisition through the collaboration was "published patents" and "reverse engineering."

Also, Nakamura and Ueda (2006) noted that since the 1990s, the Japanese government has been formulating policies to encourage university and industry collaboration to reach one of the ultimate goals of advancing industrial competitiveness, However, they believe these policies may not have had the desired impact. Some of the reasons could include that the researchers in Japan's universities maybe considered to be "intrinsically of low commercial value" or there may not be adequate incentives to encourage collaboration for high quality research. (Nakamura and Ueda, 2006). Also, some of the private companies in Japan may not have adequate infrastructure or abilities to understand and apply the results from the joint research with universities.

Scholars also noted that the series of policy reforms introduced to enhance university industry collaboration led to sizeable growth in commercial activities, specifically among small and medium sized enterprises. However, Japan is still highly dependent on the research and development capabilities of large companies. According to Japan's National Innovation Survey 2020 Statistics Report, 3% of the innovation-active organisations (around 215,610 enterprises) in the country had collaborated with universities or higher education institutes. Of these industry bodies collaborating with the universities, 20% of them were large-sized organisations. Further, these policies have paved way for establishing large government research labs and have enabled universities to undertaken extensive science research, specifically in areas such as Nano-technology, physics and chemistry. However, the overall development in applied research has been slow as the academic system in Japan is relatively less involved and appears to be isolated from the industry. Additionally, the universities in Japan drive a hard bargain when it comes to intellectual property, which is not desirable by the industry research partner (Okamuro and Nishimura, 2013). Inflexibility in intellectual property policy and isolation from the industry in certain research fields results in publication secrecy, low contribution to open science by academicians or university-based entrepreneurs and weak linkages between

patenting and commercial productivity.

In addition to the aforementioned policies, specifically within Tokyo, the metropolitan government enacted a series of initiatives, such as the establishment of ***Invest Tokyo program***, development of innovation labs and co-working spaces, special schemes to attract foreign talents, etc.

One area where the Japanese government has been actively promoting in this area is start-up incubation (**Ibata-Arens, 2014**). In the last three decades, the government has made conscious and deliberate efforts towards reducing their economic reliance on large, incumbent corporations. Since the early 1990s, the government has been embarking on the widespread development of start-up incubators not only within Tokyo, but also across the country. In aggregate, **Ibata-Arens (2014)** identified four types of incubators as follows:

- "Winner-picking" incubators: these refer to incubators with high selection threshold, but oftentimes assistance to start-up companies by such programs tends to be limited, whether in financial resources or networking support
- "Facilitating", landlord-based incubators: such incubators, in turn, have low selection criteria, and simultaneously limited support for incubatees. These incubators operate no more than as co-working spaces for these companies
- "Coaching-based" incubators: many incubators under this category were essentially reformed from the "winner-picking" type; nevertheless, one major feature from such incubators is their low selection criteria, but high degree of assistance for incubated start-ups
- "Hybrid" (joint public-private) incubators: such facilities represent the 'rarest' type of incubator, given their high selection threshold and simultaneously high degree of support. Indeed, due to the limited number of admitted incubatees, the resources they dedicated were also more comprehensive than those in "coaching-based" incubators. Moreover, they bypassed existing limitations with Japan's highly notorious bureaucratic rigidity

Overall, numerous types of organizational entities, ranging from large corporations, government-funded PROs, universities, to even government agencies have participated in the 'incubator boom' described by **Ibata-Arens (2014)**. Nevertheless, thus far the outcomes from such programs have been mixed. While the incubator 'boom' has, to some degree, stimulated some degree of entrepreneurship across the country, there have been complaints by such companies regarding policy restriction and funding availability, especially by incubators affiliated with large firms, universities, and/or government institutes. Two such cases are:

- Tsukuba Incubator: based in Tsukuba, a planned 'science city', the incubator has competitive advantages that its counterparts do not possess, namely a close proximity to numerous leading research institutes within the city. Nevertheless, the incubator – as of the 2010s – has remained small-scale, and given that most of its shareholders are incumbent corporations, its primary function is limited to providing technical advisory

services to these firms, more so than incubating early-stage start-ups

- The University of Tokyo Incubator: it was established under the two special coordinated funds of the university. However, up to early 2010s, the incubator is more involved in providing one-to-one consultation with university start-ups, while comprehensive assistance of such companies was limited. Nevertheless, such trend may be shifting, as our analysis in the upcoming sections demonstrates that the university is becoming more embedded within the city's innovation system, as well as more supportive of high-risk, high-technology ventures

In addition, According to Baba, Yarime and Shichijo (2010), a success case of university industry collaboration in Japan includes the research and development of TiO2 photocatalyst in the field of advanced materials. Few of the key players in the photocatalyst case include Akira Fujishima and Kazuhito Hashimoto, reputed chemists in Japan who have worked as professors at the University of Tokyo. These professors have been attributed with scientific breakthroughs and acquiring numerous patents through university industry collaboration (Baba, Yarime and Shichijo, 2010).

One consequence from such mixed outcomes is the country's consistently low rates of entrepreneurial activities, especially in comparison with other developed countries/regions (**Global Entrepreneurship Monitor, 2019**). Such low performance is highly cultural, and is primarily attributed to the ingrained fear of failure within Japanese society, on top of the need for conformity (**Suzuki et al., 2002; Hemmert et al., 2019**). With regard to education and career growth, many Japanese are risk-averse, and they constantly pursue higher education with the expectation of gaining stable employment in large corporations in the long run. Relatedly, an individual's decision to establish a company is often highly contingent on opinions by family members and friends, as well as peer pressure to attain social status through gaining employment, and possibly prestigious posts, in large firms (**Ohe et al., 1991**). Such impact is strongly reflected from our upcoming, patent-based analysis of inter-organizational linkages, which demonstrates the persistence of such entities within Tokyo's innovation networks throughout the last three decades.

Main entities/organisations in fostering the university-industry linkage

In Tokyo, the two main institutes, that are driving innovation and have benefited from the series of policies introduced for university and industry collaboration, include the University of Tokyo and the Tokyo Institute of Technology. Besides these institutes, Kyushu University, Hiroshima University, Osaka University, Hokkaido University and Tohoku University have also formed collaborations with industries. These universities have formed alliance with major manufacturing firms including Hitachi, NTT, Mitsubishi Heavy Industries and Fujitsu Laboratories, Panasonic, and Sanyo Electric (Kyoung-Joo Lee, 2017).

The policies in Japan pertaining to university industry collaboration as well as promoting innovation have been developed and implemented by the Ministry of Education, Culture, Sports, Science and Technology (MEXT). This government body is the primary funding

organisation for universities and some national labs and supports basic science and technology policies. The Ministry of Economy, Trade and Industry (METI) is responsible for industrial competitiveness and industrial technologies as well as certain measures pertaining to human resources. The other ministries that are involved in the University and Industry Collaboration policies or the policies for innovation system in Japan include Ministry of Health, Labour and Welfare and the Ministry of Defence. Also, the Ministry of Internal Affairs and Communications promotes the policies pertaining to development of information and communications technologies. The primary research funding institutes in Japan are the Japan Society for the Promotion of Science, the Japan Science and Technology Agency and the New Energy and Industrial Technology Development Organization (Woolgar, 2011). A study by Walsh et al. (2008) noted that the increased activities in university and industry collaboration was not a result of research commercialization but is in response to the policies and willingness to align with new expectations of productivity and compliance.

4.4.5.4.INTER-ORGANIZATIONAL NETWORKS: EVIDENCE FROM USPTO PATENT DATA

The first analysis we will perform is to identify the historical dynamics and evolution of inter-organizational innovation networks in Tokyo by making use of USPTO patent data. The methodological approach in conducting this analysis is similar to what we have performed in other innovation hubs covered in the Task 3 report: we consider at least two organizations as directly linked when an inventor (proxied by his/her inventor ID) has filed two, or more, patents on behalf of these organizations, regardless of their actual motives – which could range from career mobility, informal knowledge exchange, formal collaboration, U-I collaboration, etc., following **Laforgia and Lissoni (2009)** and **Casper (2007)**. Through these networks, we are able to measure the centrality properties of these nodes, of which we are interested in two types: betweenness centrality (proxied by the potential number of dyads directly linked by the node of interest) and degree centrality (the total number of direct connections that a node builds with others in a network), following **Freeman (1977)**.

In total, we were able to collect nearly 293,000 US patent filings originating from Tokyo. One interesting insight that distinguishes the city's innovation landscape – and Japan's more broadly – is the near-total dominance of Japanese domestic industrial groups. The top 10 patenting organizations, in aggregate, were collectively responsible for almost half (close to 46%) of Tokyo-based patent applications, as shown from Table 4-43 below. Many of these companies are synonymous with consumer appliance products, e.g. Sony and Canon (one of the pioneers of modern photography cameras), as well as household and electronic products, e.g. Mitsubishi Electric, Toshiba, Hitachi, and Panasonic.

Table 4-43 List of top-10 patenting assignees in Tokyo (all-time)

Name	Patent filings (292,990)
NEC	25,975
Sony	22,910

Canon	20,999
Mitsubishi Electric	15,389
Toshiba	14,804
Hitachi	11,113
Ricoh	7,852
Oki Electric	5,657
Panasonic (Matsushita)	4,696
TDK	4,671
Share of top 10	45.8%
No. of organizations	8,676

We further break down our analysis into six different 6-year periods, the details by which are shown in Table 4-44 in the next page. An interesting pattern we gleaned from this table was that majority of the top-10 patenters in 1983-1988 period remain largely unchanged in the 2013-2018 list, as demonstrated by the ongoing dominance of Canon, Sony, Hitachi, Toshiba, NEC, Ricoh, and Olympus after more than three decades. Much of this reflects the country's ongoing competitive advantages from their collective industrial firms (**Noland, 2007**), but this trend also simultaneously evinces Japan's lackluster shifts in business and innovation landscape. Moreover, the proportion of patent output by Tokyo's top-10 patenters (relative to all patents filed from the city) across different periods rose sharply from over 39% in 1983-1988 to nearly 56% in 1995-2000, before their share steadily dropped to 46% as of 2013-2018 period. While this finding demonstrates a gradual decrease in the degree of concentration of innovative activities by Tokyo's incumbent corporations, these enterprises can be expected to continue playing a major role for the foreseeable future. Another caveat, however, is that the total number of patent filings in 2013-2018 (N = 54,560) has been significantly lower than those of the preceding 2007-2012 period (N = 63,873); one possibility that explains this trend could be linked to Japanese firms' shifts in innovative activities beyond patents (e.g. reliance on trade secrets or overseas investments to acquire relevant technology companies), or that the technological bases that lay the foundation for these incumbent firms' competitive advantages have been maturing. Nevertheless, from another angle, we can infer that Tokyo's inter-organizational innovation networks – and Japan's more broadly – have largely revolved around the same corporate actors that have dominated the country's innovation landscape for decades, an indication of what **Witt (2014)** described as 'structural inertia' in Japan's economy.

Another characteristic of Tokyo's innovation ecosystem has been their highly dense inter-firm networks, so much so that they were often described by **Lincoln (1990)** as being representative of a 'network economy'; bulk of this was largely attributed to the common practices of joint patenting among R&D consortia of incumbent corporations centered on specific technologies (**Hagedoorn, 2003**). Table 4-45 and Table 4-46 in the following pages provide description on the most influential organizations based on betweenness centrality and degree centrality properties. With regard to the former, throughout the 36-year period (1983-2018), more than half of the organizations listed in the top-10 rankings have consistently been occupied by the same companies (namely Toshiba, Hitachi, NEC, Sony, Mitsubishi Electric, Canon, and Panasonic).

Evidence of dense inter-firm networks could also be observed when we examine the degree centrality scores of Tokyo's most pivotal innovation actors; given the abundance of organizations with high degree centrality, we limited our observation in Table 4-46 to those with degree centrality scores of at least 100, or above. Once again, based on this category, the top rankings, over time, were almost consistently occupied by the same corporate actors (Toshiba, Hitachi, NEC, Sony, Mitsubishi Electric, Canon, and Panasonic), with only minor alterations in the position taking place among these industry giants. In other words, a high proportion of direct inter-organizational linkages in Tokyo's innovation ecosystem involved any of the above-listed enterprises, or close collaboration among these firms, alternatively, in the form of horizontal business groups (keiretsu), R&D consortia, or cartels (**Witt, 2006**).[171] The number of organizations with 100-plus degree centrality scores also resembled an inverted-U curve over time, beginning from 8 such entities in 1983-1988, peaking at 52 in 2001-2006 period, before gradually declining to 44 in 2007-2012 and 27 in 2013-2018 period. One possible interpretation from our finding is that inter-organizational relations are becoming less dynamic over time, due in large part to persistent institutional and structural inertia in Japan's economy (**Witt, 2014**).

What roles have research-performing institutions (both universities and public research organizations) played in Tokyo's innovation ecosystem historically? Judging from the absolute numbers of patenting output alone, these entities have been basically 'absent'. Indeed, existing literature provided some degree of support regarding the indirect role played by these organizations in stimulating Japan's entry into high-technology industries; instead of wholesale subsidies to support these technology firms, Japanese government's support was largely limited to providing R&D subsidies for emerging-technology development projects, coupled with massive investments in human capital-supporting infrastructure, e.g. expanding enrolment into schools, universities, colleges, and vocational institutes (**Noland, 2007**). Specific for universities, and the University of Tokyo (which we have covered in Task 2 report), their role was historically limited to supplying graduates to the labor market.

Based on betweenness and degree centrality measures, only a small handful of research-performing organizations were listed on the top-10 lists, as indicated by the italicized actors in Table 4-44 in the following page. This was demonstrated with the entry of Japan Science and Technology Agency (JSTA), as well as National Institute of Advanced Industrial Science and technology (NIAIST), a government-funded research agency that supports R&D activities in strategic technologies in collaboration with domestic industries, beginning in 2001-2006 period. JSTA's influence – from a network perspective – was considerably larger, both from betweenness and degree centrality dimensions. Over time, their influence began to subside as two major universities (University of Tokyo and Tokyo Institute of Technology) saw their betweenness and degree centrality scores increase significantly, both in 2007-2012 and 2013-2018 timeframes. Although neither university achieved the top-10 lists in terms of absolute number of patent filings, they have been instrumental in 'bridging' the inter-organizational innovation networks within Tokyo, in terms of increased U-I collaboration and/or resulting spin-offs (**Motohashi, 2005**), or enhanced career mobility linkages in the forms of university researchers working for enterprises, etc.

Table 4-44 Most frequent direct inter-organizational linkages involving Tokyo-based HEIs (number of recurrent linkages in brackets)

	2001-2006	2007-2012	2013-2018
Univ of Tokyo	Japan S&T Agency (104) Nissan (67) Chisso (50) Daiichi Sankyo (45) NIAIST (43) NTT (34) Nanocarrier (30)* NIRS (21) IHI Corporation (21) Johnson & Johnson (20)	Hitachi (304) NEC (256) IHI Corporation (194) Toshiba (172) Dowa Holdings (117) Sony (117) Mitsubishi Electric (98) Fujitsu (97) Kyocera (97) Panasonic (97)	Fujitsu (2031) Azabu Vet Med (301) Unizeo (209) Fujifilm (181) Nikon (162) Hitachi (129) Seiko Corp (113) Stanley Electric (91) Ricoh (90) IHI Corporation (83)
Tokyo Inst of Tech	Canon (81) Honda (30) Japan S&T Agency (25) Olympus (15) Toshiba (12) Hitachi (11) Sony (10) Circle Promote S&E (10) Eisai (8) Fuji Electric (7)	Mitsubishi H I (85) Mitsubishi Electric (84) Olympus (81) Ricoh (76) Honda (72) Canon (57) NTT (57) Sony (55) SBI Pharma (53) Sharp Corporation (45)	Japan S&T Agency (205) NEC (71) Sony (53) Olympus (41) ENEOS (37) Toshiba (28) JNC Corp (27) Mitsubishi H I (27) Univ of Tokyo (26) NTT (20)
NIAIST	NEC (160) Sony (115) Japan S&T Agency (106) TDK (98) Yamatake Corp (88) Panasonic (75) Canon (73) Hitachi (69) Sanyo (69) Renesas (64)	Toshiba (118) Mitsubishi Electric (78) Sony (63) Dainichiseika (61) Seiko Corp (51) NEC (42) Ricoh (37) Furukawa Electric (36) GS Yuasa (36) TDK (34)	NEC (37) Sony (29) Toshiba (23) Photonics ETRA (21) Mitsubishi H I (19) Renesas (19) Toyota (19) Fujitsu (17) Mitsubishi Electric (17) Sicoxs Corp (16)

* indicates that the organization of interest is a spin-off of the university

We further investigate the types, and composition, of organizations with which Tokyo's three major research-performing entities (University of Tokyo / Todai, Tokyo Institute of Technology / TokyoTech, and NIAIST) have had the most frequent direct linkages with. We limited our attention to the top-10 organizations with the most recurrent ties with these universities and research institutes for 2001-2018 period, given that these institutions only recently rose in their centrality rankings from early 2000s onward. The basis for obtaining recurrent linkages was taken from calculating the number of times inventors affiliated with an organization are also registered in the patents of another organization; repeated ties may occur

due to: 1) talent mobility (e.g. Todai researchers moving to a company, or vice versa); 2) multi-applicant patenting (**Ter Wal and Boschma, 2009**), and/or; 3) companies contracting their research to university scientists given their expertise.

Results for this analysis are displayed in Table 4-44 above. Here, we can observe the dynamic changes in the composition of top-10 organizational actors with which these three entities have the most frequent direct relationships with. The latter's linkages are not limited to the big-7 corporate actors that have consistently dominated Tokyo's innovation ecosystem (Toshiba, Hitachi, NEC, Sony, Mitsubishi Electric, Canon, and Panasonic), but also a diverse set of other enterprises, e.g. Fujifilm, Nissan, Nikon, Daiichi Sankyo, Ricoh, Renesas, etc. Nevertheless, the proportion of direct linkages with scientific research-based spin-offs is rare; with the exception of Nanocarrier (based on medical research at Todai), we could not identify any other enterprises within the top-10 lists that were spun off from activities at Todai, TokyoTech, or NIAIST. Based on the interpretation of our finding, we can argue that university-industry knowledge exchange has been predominantly concentrated by ties between top universities/research institutes and incumbent corporations.

Overall, from patent analysis alone, it can be deduced that inter-organizational linkage networks in Tokyo, as combined proxies for career mobility, inter-firm consortia, and/or U-I collaboration, have been historically very dense (**Lincoln, 1990**), but these networks have been – by and large – primarily driven by the same set of large corporations that contributed to Japan's postwar economic boom from the 1980s to the present day, an indication of the country's innovation 'inertia' (**Witt, 2014**). Despite the gradual decline in concentration of innovative activities by the major patenters – an indication of the dispersion towards other smaller enterprises and start-ups, Tokyo's innovative output has been considerably slowing down since the early 2000s.

Table 4-45 List of top-10 patenting assignees in Tokyo throughout different time periods (patent filings indicated in brackets)

1983-1988 (19,788)	1989-1994 (31,514)	1995-2000 (50,387)	2001-2006 (61,457)	2007-2012 (63,873)	2013-2018 (54,560)
Canon (1,712)	NEC (3,410)	NEC (9,505)	Sony (5,829)	Sony (6,682)	Canon (4,239)
NEC (1,324)	Canon (2,845)	Mitsubishi Electric (4,292)	NEC (5,203)	NEC (4,319)	Sony (4,146)
Toshiba (1,228)	Toshiba (2,082)	Sony (3,735)	Mitsubishi Electric (4,184)	Canon (4,205)	Mitsubishi Electric (2,990)
Hitachi (820)	Sony (1,349)	Canon (3,167)	Canon (3,902)	Toshiba (3,581)	Hitachi (2,872)
Sony (703)	Hitachi (1,107)	Toshiba (2,526)	Toshiba (2,725)	Mitsubishi Electric (3,348)	Toshiba (2,271)
Honda (559)	Asahi Kogaku (948)	Oki Electric (1,330)	Hitachi (2,459)	Hitachi (2,305)	NEC (2,199)
Fujifilm (490)	Oki Electric (550)	Hitachi (1,136)	Ricoh (1,753)	Ricoh (2,123)	Ricoh (2,037)
Olympus (357)	Ricoh (530)	Asahi Kogaku (1,012)	Oki Electric (1,640)	Renesas (1,349)	Japan Display (1,669)
Oki Electric (333)	Fujifilm (500)	Nikon (724)	TDK (1,434)	Panasonic (1,338)	Renesas (1,383)
Ricoh (330)	Olympus (499)	Panasonic (720)	Panasonic (1,311)	TDK (1,311)	Olympus (1,103)
Share of top 10: 39.7% No. of organizations: 1,757	Share of top 10: 43.9% No. of organizations: 2,256	Share of top 10: 55.9% No. of organizations: 2,772	Share of top 10: 49.5% No. of organizations: 3,141	Share of top 10: 47.8% No. of organizations: 2,682	Share of top 10: 45.7% No. of organizations: 2,269

Table 4-46 List of top-10 patenting assignees in Tokyo in terms of betweenness centrality scores (scores indicated in brackets)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
Toshiba (63554)	NEC (170082)	NEC (332077)	NEC (307379)	Sony (246993)	Sony (138453)
Hitachi (59658)	Toshiba (111333)	Mitsubishi Elec (223126)	Sony (301276)	Hitachi (147096)	Hitachi (131743)
NEC (46487)	Canon (87348)	Sony (213017)	Mitsubishi Elec (238956)	NEC (140177)	Mitsubishi Elec (106995)
Sony (45839)	Sony (85009)	Toshiba (134145)	Panasonic (158560)	Mitsubishi Elec (130515)	Toshiba (79754)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
Mitsubishi Electric (41310)	Hitachi (83738)	Panasonic (102340)	Canon (158418)	Toshiba (123103)	NEC (62945)
Honda (39755)	Mitsubishi Electric (59956)	Canon (81762)	Hitachi (148096)	Panasonic (114794)	Panasonic (53935)
Canon (36365)	Panasonic (44973)	Hitachi (77017)	Toshiba (129849)	Univ of Tokyo (107157)	Mitsubishi Heavy I (53691)
Fujifilm (25021)	Honda (40775)	Fujitsu (58710)	Ricoh (82023)	Canon (83186)	Ricoh (49868)
Nissan (21650)	NKK (40101)	Oki Electric (51926)	Honda (80488)	Ricoh (71951)	Canon (46418)
AIST Japan (19749)	Toyota (29185)	Honda (47640)	Japan S&T Agency (77528)	Nippon Steel (69840)	Univ of Tokyo (45701)

Table 4-47 List of patenting assignees in Tokyo with the degree centrality scores above 100 (scores indicated in brackets)

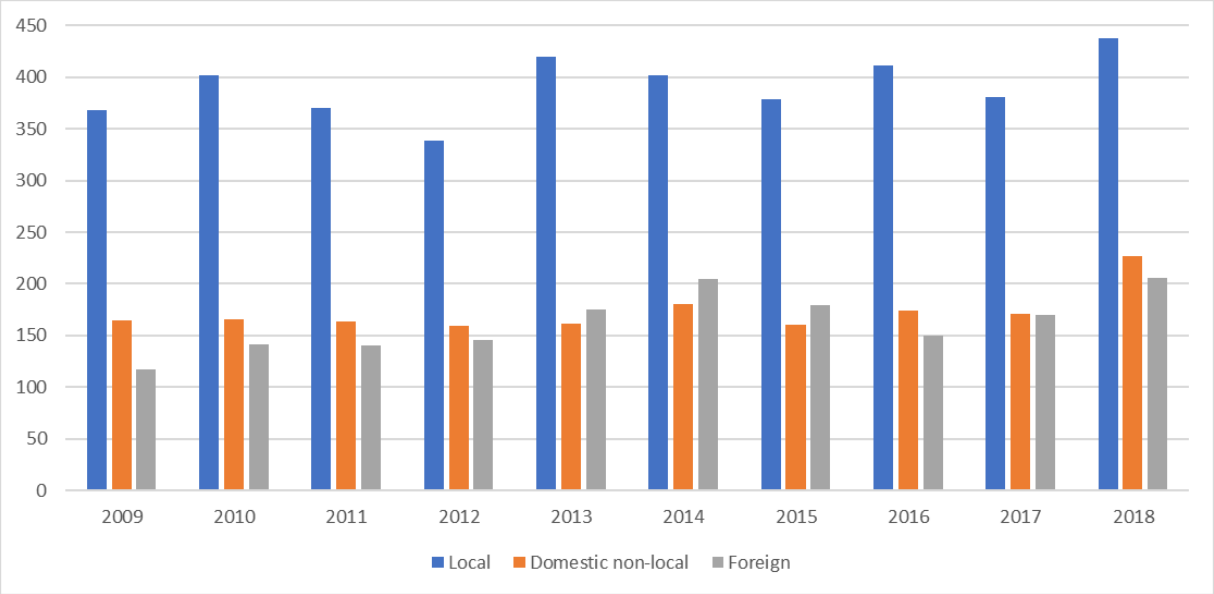
1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
Toshiba (164)	NEC (360)	NEC (595)	NEC (636)	Sony (616)	Sony (421)
Hitachi (162)	Toshiba (304)	Mitsubishi Electric (469)	Sony (635)	Panasonic (462)	Hitachi (403)
NEC (156)	Sony (282)	Sony (461)	Mitsubishi Electric (549)	Hitachi (461)	Mitsubishi Electric (341)
Mitsubishi Electric (137)	Hitachi (265)	Toshiba (345)	Panasonic (519)	NEC (439)	Panasonic (278)
Sony (132)	Canon (244)	Panasonic (336)	Canon (497)	Mitsubishi Electric (435)	NEC (272)
Honda (125)	Mitsubishi Electric (210)	Hitachi (273)	Hitachi (457)	Toshiba (413)	Toshiba (271)
Canon (107)	Panasonic (198)	Fujitsu (246)	Toshiba (405)	Ricoh (362)	Ricoh (255)
Fujifilm (103)	Honda (157)	Canon (241)	Ricoh (334)	Canon (329)	Canon (244)
	Pioneer Electronics (141)	Oki Electric (227)	Honda (331)	Renesas (302)	Mitsubishi Heavy I (234)
	Seiko Corp (135)	Honda (198)	Renesas (314)	Honda (295)	Nippon Steel (203)
	Fujifilm (132)	Seiko Corp (194)	TDK (284)	Mitsubishi Heavy Ind (290)	Renesas (202)
	Toyota (123)	TDK (191)	Seiko Corp (280)	*Univ of Tokyo (287)*	TDK (185)
	Tokyo Electron (117)	NTT (172)	*Japan S&T Agency (260)*	TDK (275)	*Univ of Tokyo (177)*
	Sharp Corp (112)	Fujifilm (170)	Oki Electric (260)	Nippon Steel (256)	Japan Display (157)
	Nippon Steel (110)	Ricoh (166)	Tokyo Electron (247)	Sharp Corp (241)	Tokyo Electron (157)
	Asahi Kogaku (108)	Sharp Corp (143)	Sharp Corp (242)	Seiko Corp (209)	Olympus (146)
	Oki Electric (108)	Asahi Kogaku (137)	Fujitsu (236)	Olympus (201)	Honda (141)
	Fujitsu (107)	Sanyo (123)	NTT (232)	Tokyo Electron (199)	Fujifilm (125)
	NKK (106)	Nissan (120)	Fujifilm (223)	Fujifilm (197)	Konica-Minolta (125)
	NTT (106)	Nippon Steel (117)	Pioneer Electronics (205)	Oki Electric (189)	Seiko Corp (117)
	Konica-Minolta (104)	Yazaki Corp (106)	Xerox (204)	Xerox (187)	Furukawa Electric (109)
	Olympus (103)	Mitsubishi Heavy I (105)	Nissan (199)	Furukawa Electric (179)	Dai Nippon Printing (108)
	Xerox (101)	Pioneer Electronics (102)	Furukawa Electric (192)	Asahi Kasei (174)	IHI Corporation (106)
		Showa Denko (102)	Konica-Minolta (186)	NTT (172)	*Tokyo Inst Tech (102)*
		Sega Enterprise (100)	Dai Nippon Printing (183)		

Nissan (100)	Sanyo (181)	Konica-Minolta (158)	Xerox (102)
TDK (100)	Olympus (177)	*NIAIST (157)*	Kyocera (101)
Kawasaki Heavy I (100)	Toyota (164)	Toyota (153)	Nissan (100)
Sumitomo Elec (100)	Nippon Steel (154)	Fujitsu (152)	
	Kao Corporation (149)	Dai Nippon Printing (150)	
	Kyocera (143)	Asahi Glass (146)	
	Hoya Corporation (142)	*Tokyo Inst Tech (144)*	
	Ebara (136)	Elpida (142)	
	Mitsubishi Chemical (133)	JFE Holdings (141)	
	Fuji Heavy Industries (132)	Kyocera (138)	
	Fujikura (128)	Advantest (122)	
	Asahi Kasei (128)	Sanyo (117)	
	NIAIST (127)	IBM (115)	
	JSR Corporation (124)	Ebara (112)	
	Advantest (122)	Stanley Electric (112)	
	Sega Enterprise (119)	Hoya Corporation (109)	
	Mitsubishi Heavy Ind (115)	IHI Corporation (109)	
	Omron (113)	Fuji Heavy Indus (106)	
	Shinko Electric (107)	Daiichi Sankyo (105)	
	Rohm Co Ltd (107)	Toppan (102)	
	Asahi Glass (106)		
	TOPCON (105)		
	Fuji Electric (105)		
	Denso (103)		
	Mitsubishi Pharma (102)		
	Teijin (101)		
	Daiichi Sankyo (100)		

Note: for organizations that are italicized, these refer to non-industry entities, e.g. universities, research institutes, hospitals, government agencies, etc.

UNIVERSITY-INDUSTRY COLLABORATION IN SCIENCE: EVIDENCE FROM ANALYSIS OF JOINT PUBLICATIONS

In the second analysis, we shifted our unit of analysis from patent data to publication data. We are specifically interested in the linkages between the University of Tokyo/Todai, which we have covered in Task 2, and the broader Tokyo innovation system, particularly with regard to scientific research landscape with industry actors. Similar to our coverage of other innovation hubs regarding this subsection, we relied on Lens.org dataset in collecting the publication data, covering a ten-year publishing period from January 1, 2009 up to December 31, 2018. In identifying joint university-industry publications (or simply described as 'U-I co-publications'), we closely examined the institutional affiliation of co-authors in Todai-linked peer-reviewed journal articles. In aggregate, we managed to collect 82,140 journal articles involving Todai-based researchers, in which 7,160 of them (equivalent to 8.7% of the entire observations) were U-I co-publications. This figure placed Todai above the global annual average of 6-7% as estimated by **Tijssen et al. (2009)** with respect to this indicator.



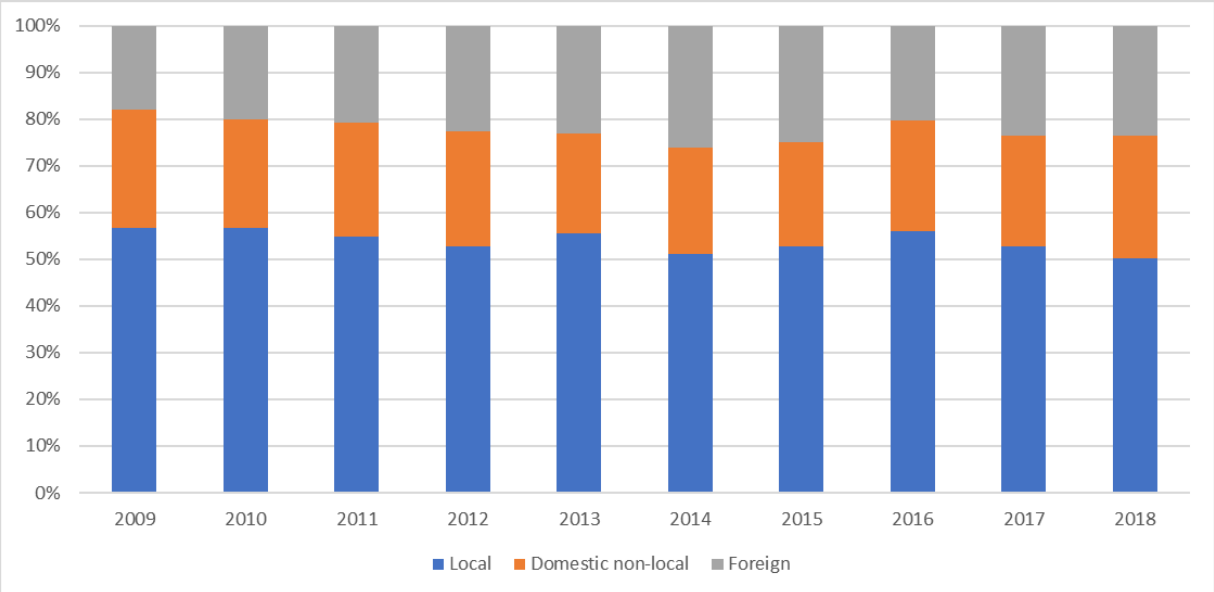


Figure 4-19 Types of U-I co-publications involving Todai (2009-2018) based on the geographical origins of collaborating firms

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Local	368	402	370	339	420	402	379	411	381	438
Domestic non-local	165	166	164	159	161	181	160	174	171	227
Foreign	117	142	140	146	175	205	179	150	170	206

Similar to the approaches we have conducted in other hub-related case studies, we further divided these U-I co-publications into three types based on their geographical location context: 1) local; 2) domestic non-local, and; 3) foreign. In the first category, collaborating firms were categorized and proxied as 'local' when they are located within the vicinity of Greater Tokyo Area, an agglomeration defined by the Japanese government as inclusive of Tokyo, its neighboring cities (Yokohama, Kawasaki, Saitama, Chiba, and Sagamihara), as well as the prefectures surrounding the capital, namely: Gunma, Ibaraki, Shizuoka, Tochigi, and Yamanashi.[172] Domestic non-local firms, in turn, represent collaborating Japanese-based firms that are headquartered outside the Greater Tokyo Area (e.g. companies based in Osaka-Kobe-Kyoto metropolitan area, Hiroshima, Fukuoka, etc). Finally, for collaborating enterprises with non-Japanese origins (as in located outside Japan), we would label them as collaborating foreign businesses. Description regarding the total number of U-I co-publications divided into these categories is displayed in Figure 4-19 above.

From this figure alone, we can observe the persistent tendency for most joint academic works with industry actors to be overwhelmingly dominated by domestic enterprises, a pattern that has remained stable since the early 1990s, when **Hicks (1995)** conducted a comparative study of corporate research landscape in European and Japanese firms. Interestingly, more than half of Todai's U-I co-publications were primarily with enterprises based within Greater Tokyo Area, although the share has been dropping throughout the years, from 57% in 2009 to 50% as of 2018. Simultaneously, the share of U-I co-publications with domestic non-local enterprises only increased slightly from close to 25% in 2009 to somewhere around 27% in 2018. The proportion of joint academic works with foreign firms rose from 18% to 23% within the same period.

Table 4-48 Top 10 collaborating firms with the University of Tokyo in U-I co-publications (2009-2018 period, number of co-publications indicated in brackets)

Local firms (N = 3,910)	Domestic non-local firms (N = 1,728)	Foreign firms (N = 1,630)
Hitachi (270)	Toyota (152)	Nat'l Presto Indus (149)
NTT DoCoMo (150)	Panasonic (40)	Hoffmann-La Roche (51)
Subaru (143)	Denso (38)	Saga Group (48)
Toshiba (135)	Hamamatsu Photonics (31)	IBM (41)
Fujitsu (122)	JP Fine Ceramics Ctr (27)	Pfizer (36)
Mitsubishi Group (105)	Canon Inc (26)	Microsoft (34)
NEC (65)	Kobe Steel (23)	Novartis (27)

Nippon Steel (63)	Shimadzu (22)	Analysis Group (22)
Daiichi Sankyo (57)	Dai Nippon Printing (21)	Merck (21)
Eisai (50)	Japan Tobacco (13)	Nestle (19)

Overall, while there has been a slight alteration in the composition of U-I co-publications, the landscape of academic-industry collaboration in scientific research has remained remarkably consistent, with Todai-based researchers continuing to exchange knowledge more frequently with their counterparts based in Tokyo metropolitan region. Once we take into consideration the profiles of top industry collaborators across all the three categories (shown in Table 4-48 above), we can better understand what accounts for the high degree of concentration in U-I collaboration within the Tokyo metropolitan region. In the case of the first column (with local firms), we found that the top-10 local enterprises accounted for approximately 30% of all U-I co-publications within this category. Many of the major collaborators (in this regard, Hitachi, Toshiba, Mitsubishi, and NEC) comprised some of the 'Big Seven' patenting innovators we have highlighted in the first analysis. Contrasting this finding with the limited linkages between Todai and these firms in inventive activities, we could observe that these firms, in general, are more interested in obtaining the latest scientific insights from university researchers than in technological development-related matters. Other notable enterprises within the top-10 list include: NTT DoCoMo (a major affiliate of Nippon Telegraph and Telephone/NTT Group), Subaru, Fujitsu, Nippon Steel, Daiichi Sankyo, and Eisai.

Hitachi's collaboration with Todai, in particular, has been particularly interesting. The company's very high number of journal articles published in collaboration with their Todai counterparts may have been attributed to the presence of a major joint research center between the two organizations. Known as H-UTokyo Lab (with the link retrieved from http://www.ht-lab.ducr.u-tokyo.ac.jp/en/), the laboratory has – since its inception in 2017 – launched a total of 17 projects with researchers from Todai and Hitachi jointly serving as principal investigators (PIs) for each of these projects. These projects span a wide range of areas, ranging from: 1) urban policies to support UN Sustainable Development Goals (SDGs); 2) big data for policy-making optimization; 3) next-generation energy systems and decarbonization; 4) healthy-aging society through supporting assistive technologies; 5) sustainable regional development through smart-city technologies, and more recently; 6) data infrastructure sustainability. Moreover, the laboratory spans over 90 faculty members, research assistants, as well as industry scientists from Hitachi.

Regarding Todai's scientific collaboration with Japanese domestic non-local enterprises, we found that over 22% of such U-I co-publications were dominated by these top-10 firms. The most active among these enterprises was Toyota, with a total of 152 journal articles in collaboration with Todai-based researchers. Other notable firms include Denso (an affiliate of Toyota Group specialized in truck production), Hamamatsu Photonics, Japan Fine Ceramics Center, Kobe Steel, Shimadzu, Dai Nippon Printing (DNP), and Japan Tobacco. Specific to Panasonic and Canon, the university's scientists primarily collaborate with researchers located in their R&D centers outside the Tokyo metropolitan region.[173] In the following paragraph below, we will elaborate on Todai's knowledge exchange with Toyota.

As already mentioned in the previous paragraph (and highlighted in Table 4-48 above), Toyota has the second largest number of U-I co-publications with Todai researchers after Hitachi. Based on our analysis from Lens.org dataset, the two organizations' collaboration has been taking place for decades, spanning a period of four decades from early 1980s. Over time, the number of published journal articles annually has shown a significant increase, from only 2 in 1982 to 47 as of 2021. These publications are concentrated in a diverse range of fields, such as chemistry, crystallography, chemical engineering, composite material, computer science, mechanical engineering, optical and magnetic materials, etc. In recent years, their linkages have been concentrated in two major areas: 1) development of next-generation electricity systems, and; 2) battery resources and recycling. Regarding the former, the two parties are engaging in pilot projects on peer-to-peer, blockchain-enabled electricity trading for homes, office buildings, and electric vehicles/EV (**Toyota, 2019**). Furthermore, in January 2022, as part of Toyota's pledge for carbon neutrality, the company is working closely with Todai scientists in developing new methods for lithium-ion battery recycling.[174]

Last but not least, in the case of Todai's scientific collaboration with foreign firms, we found that approximately 27% of all U-I co-publications under this category were conducted with the top-10 firms listed on the third column of Table 4-48. These enterprises are specialized in a wide variety of sectors, such as manufacturing (as demonstrated by US-based National Presto Industries), pharmaceuticals (e.g. Roche, Pfizer, Novartis, Merck), ICT-related areas (exemplified by Microsoft and IBM), as well as food science and chemistry-related fields (Nestle and Analysis Group). Overall, from this category, it can be deduced that the university's collaboration is not limited to firms of a particular sector, but rather reflecting the diverse expertise – and interests – of the researchers.

Table 4-49 Specialization of Todai spin-offs identified from U-I co-publications (2009-2018)

Sector	Number (N = 60)
Biotechnology/pharmaceuticals	24
Artificial intelligence	3
Consulting	3
Big data and data analysis	3
Food sciences	3
Scientific instruments	3
Bioinformatics	2
Chemicals	2
Engineering-related services	2
Medical devices	2
Nanotechnology	2
Renewable energy	2
Software	2
Information and communication technologies (ICT)	1
Material sciences	1
Microelectronics	1
Photonics	1

Robotics	1
Semiconductor	1
Wearables	1

Todai's U-I collaboration landscape, nevertheless, is not limited to incumbent corporations. Faculty members and scientists at the university have also continued to maintain close ties with companies spun off originally from research taking place at the institution. In order to identify such spin-offs, we engage in further 'site visits' of company websites (specifically from the subset of collaborating firms based in Greater Tokyo Area) to ascertain the profiles of company founders and scientific advisory board (SAB) members, following the approach suggested by **Powell et al. (2016)**. Using this approach, we are able to identify, and extract, a total of 340 U-I co-publications involving 60 university research-based spin-off companies.

Table 4-49 above provides details on the sectoral specialization of these companies. Quite interestingly, close to half of these spin-offs are concentrated in life sciences, namely biotechnology/pharmaceuticals (N = 24), bioinformatics (N = 2), as well as medical devices (N = 2). This reflects the findings by **Murray (2002)** of persistent tendencies of life-science companies to continue maintaining knowledge exchange linkages with their academic progenitors even long after these companies have been spun off. Beyond life sciences, these spin-offs are also engaged in as many as 17 sectors, such as artificial intelligence (AI), big data/data analysis, scientific instrument development, material sciences, etc. Indeed, one of these firms (Preferred Networks) is at present one of Japan's few unicorn companies, which we will elaborate in the third analysis. Table 4-50 below provides some further examples of notable spin-offs originating from Todai.

Table 4-50 Notable Todai spin-offs identified from U-I co-publications[175]

Name	University	Profile
Advanced Softmaterials (ASM)	Univ of Tokyo	Advanced Softmaterials, abbreviated as ASM, is an early-stage material-science technology start-up that seeks to commercialize their breakthrough innovation, "SeRM", which is the first-ever polymetric material with movable cross-links, as well as a supermolecule that provides new features to polymers, namely toughness, impact resistance, extensibility, and resilience. Its innovation enables polymer materials to achieve better durability, shape restoration, vibration absorption, as well as heat radiation. It was established to commercialize the SeRM technology developed at the research lab of Kohzo Ito, a professor of material science at the University of Tokyo (Todai). It receives VC support

		from University of Tokyo Edge Capital (UTEC), the university's VC fund.
Alnair Laboratories	Univ of Tokyo	Alnair Laboratories is a company that manufactures scientific research instruments, namely products which include picosecond optical sampling osilloscopes, bandwidth-variable and wavelength-tunable optical bandpass filters, polarization-maintaining femtosecond fiber lasers, alignment-free autocorrelators, short-pulse optical generation. It was established in 2001 by Dr. Goh Chee Siong (a Tokyo-based Malaysian scientist-entrepreneur) and Professor Kazuro Kikuchi of the University of Tokyo, based on Goh's PhD research on photonics in the university.
Autonomous Control Systems Laboratory (ACSL)	Univ of Tokyo Kyoto University	ACSL is a start-up company focused on robotics technology, with a specific interest in autonomous control technology. The company aspires to have these technologies applied in order to increase the productivity of economic activities, as well as to replace low-value-added and dangerous work activities with robots, and reorient human society for other activities. ACSL was established in 2013. It is currently led by Hiroaki Ohta (as the company's CEO, formerly an assistant professor at Kyoto University), Satoshi Washiya (now the company's COO, formerly a consultant for McKinsey Japan), Kensuke Hayakawa (now the company's CFO, formerly an analyst for Kohlberg Kravis Roberts Japan), and Chris Raabe (now the company's CTO, a PhD alumnus of University of Tokyo and former assistant professor of aeronautics at the same university). It is currently invested by University of Tokyo Edge Capital (UTEC).
Exergy Power Systems	Univ of Tokyo	Exergy Power Systems is a company promoting innovation in flexible energy service, with a focus on managing fluctuation of renewable energy generation in Japan, the US, and also European countries. At present, they are researching and developing next-generation energy storage systems for hydrogen cells, by taking advantage of the ultra-

		fast charging and discharging nature of these cells. At present, they are deploying an energy storage system pilot project in the state of Hawaii (US) and Europe. Within Japan, the company is piloting large-scale energy storage systems at port facilities and railway systems. The company was established to commercialize research on energy-saving technologies developed at the University of Tokyo's next-generation battery lab. Exergy was founded with the support of UTEC (University of Tokyo Edge Capital).
IDAC Theranostics	Univ of Tokyo	IDAC Theranostics (for which IDAC stands for 'Inflammatory Diseases And Cancer') is a biotech company that offers both therapy-related and diagnostics-related services. The company dedicates their R&D efforts to address incurable diseases, mostly in collaboration with established pharmaceutical companies. One example is their licensing of humanized anti-CD4 mAb (monoclonal antibody) in collaboration with Kyowa Hakko Kirin, one of the largest pharmaceutical companies in Japan, and the world. They also focus on other drug development projects that are intended to address solid tumor-related disorders and HIV eradication (for AIDS). IDAC Theranostics was established in 2012 to commercialize research on cancer treatment at University of Tokyo (Todai). It is based in University of Tokyo Entrepreneur Plaza in Yokohama.
Lily MedTech	Univ of Tokyo	Lily MedTech is a biotechnology company whose core innovation relates to ultrasonic CT techniques to accelerate the detection of potentially malignant cancer tumors, especially for those relating to breast cancer. Lily Medtech was established in 2015 by husband-and-wife Takashi Azuma and Shiho Azuma. The company was established to commercialize research by Takashi as a professor at the University of Tokyo (Todai). It was established partly given the couple's past experience of having Shiho's mother succumbing to advanced-stage, highly malignant brain cancer.

Nanocarrier	Univ of Tokyo Tokyo Women Med	NanoCarrier is a biotechnology company that seeks to develop nanomedicines. Their core innovation lies in utilizing polymeric micelles (micellar nanoparticles) as drug deliver systems, for which they are aiming to apply as potential new approaches in cancer therapies through nanoengineering. The company is also aspiring to apply these as platform technologies that can be utilized in collaboration with other biotechnology and pharmaceutical firms (in Japan and beyond) seeking to develop new therapeutic treatments on the basis of polymeric micelles. NanoCarrier was established in 1996 to develop drugs which utilize the nanotechnology researched by Dr. Kataoka Kazunori, now Professor Emeritus at the University of Tokyo (Todai), Teruo Okano, now Emeritus Professor at Tokyo Women's Medical University, and their colleagues.
Perseus Proteomics	Univ of Tokyo	Perseus Proteomics is a biotechnology company focusing on medical application of antibodies to address diagnostic and therapeutic targets, particularly in the fight against cancer-related diseases. The company's core innovation lies on developing oncological antibody drugs. Beyond antibody drugs, Perseus Proteomics also focuses on screening technologies and has in possession one of the world's largest collection of phage antibody libraries. These technologies are particularly useful in the discovery of drug targets in affected cells, and offering treatments that are different from conventional methods. The company has also collaborated actively with other pharmaceutical firms worldwide in the development of antibody drugs and therapeutic treatments. Perseus Proteomics was established in 2001 based on the technologies of protein expression and antibody generation, which were developed by the Laboratories for Systems Biology and Medicine (LSBM) of the Research Center for Advanced Science and Technology at the University of Tokyo (Todai). It is now a subsidiary of Fujifilm.

Preferred Networks	Univ of Tokyo	Preferred Networks (PFN) is an artificial intelligence company that aims to apply insights from deep learning and AI-related emerging technologies to solve challenging real-world problems. Their core innovation is linked to applying these technologies and fusing them with software and hardware to create smarter devices, vehicles, and interfaces through real-time sensing of the physical world. The company's core innovation is on developing their deep-learning framework, 'Chainer', as well as building large-scale computing clusters, to applying their technologies in various fields, e.g. robotics, life sciences, etc. Preferred Networks was established in 2006, and is currently led, by Toru Nishikawa, based on his PhD research at the University of Tokyo (Todai). He graduated in 2007. It is currently one of Japan's few unicorn start-up companies.
ReproCELL	Univ of Tokyo Kyoto University Chiba University Osaka University Juntendo University Nat Ins Biomed Inno Keio University Tokyo M&D Univ	ReproCELL is a biotechnology company established in 2003 by a group of professors in Japan's top universities and research institutes. It is one of the leading stem-cell research companies in the country, and also globally. One of its core innovations is induced pluripotent stem cell (iPSC)-derived human cardiomyocytes, hepatocytes, and neuronal cells for research applications, which have been used by Professor Shinya Yamanaka at Kyoto University for his research, in which he would win a Nobel Prize in 2012. The company has also made use of their stem-cell expertise to expand further into drug-discovery and regenerative medicines. Their other expertise includes: human tissue acquisition, iPSC reprogramming, cell differetiation, in-vitro tissue modeling with 3D technology, assay development for drug development, etc. It is publicly listed at JASDAQ Growth Market in 2013. Reprocell was established in 2003 by a group of preeminent Japanese professors, namely Norio Nakatsuji (Kyoto University), Hiromitsu Nakauchi (University of Tokyo / Todai), Atsushi Iwama (Chiba University), Hiroyuki Mizuguchi (Osaka University), Wado

		Akamatsu (Juntendo University), Naoki Nishishita (National Institute of Biomedical Innovation), Hiroshi Yagi (Keio University), and Taeko Naruse (Tokyo Medical and Dental University).

To conclude, from the second analysis, we observed that Todai-based researchers primarily engage with large, incumbent (and mostly Japanese) corporations with respect to their scientific research collaboration and knowledge exchange. This was evident from the high number of U-I co-publications with major firms such as Hitachi, Toyota, NTT, Toshiba, Fujitsu, Mitsubishi, etc. Nevertheless, the university has – quite surprisingly – collaborated fairly often with firms formerly spun off from research at the former's laboratories, with a total of 340 journal articles involving 60 such spin-offs. As attested from the previous table, some of these spin-offs have received significant support from venture capitalists (VCs), and one of them (Preferred Networks) has even seen its valuation surpass US$1 billion, effectively transforming itself into a unicorn company.

Nevertheless, we caution about the generalizability of spin-offs originating from university research, as past surveys by government agencies and academics have shown that this phenomenon was largely limited to a small number of elite, mostly publicly-funded research universities, such as Todai, Kyoto, Osaka, and Tsukuba (**Harada and Mitsuhashi, 2011**), and concentrated in few large municipalities. Moreover, despite the proliferation of policies by the Japanese government to further encourage the commercialization of scientific research (e.g. Science and Technology Basic Law of 1995, which enacted the five-year plans on S&T development for Japan, 1999 Law on Special Measures for Industrial Revitalization – also known as Japan's Bayh-Dole Act, and the 2003 National University Incorporation Law that converted universities' status into 'corporations'), there remains limited normative encouragement within academic communities to further enhance faculty members and researchers in knowledge/technology transfer activities (**Harada and Mitsuhashi, 2011**). Furthermore, the ongoing population decline has posed another indirect challenge for Japan in revitalizing their economic dynamics through this route, as attested by the dropping enrollment for students in universities nationwide. It remains to be seen, in the future, whether such tendencies will change.

FINANCING SUPPORT FOR LOCAL TECHNOLOGY COMPANIES: EVIDENCE FROM CRUNCHBASE DATA

The third analysis will entail an examination of financing activities by Tokyo-based investors in technology companies co-located within Tokyo metropolitan region, following the approach by **Sorenson and Stuart (2001)**. Studying the patterns of investor-local firm co-location (and subsequent investment ties) has been an important indicator in proxying for the existence of 'resource regeneration' within an entrepreneurial ecosystem (**Stam and Spigel, 2016**), particularly in nurturing the next generation of disruptive, innovative businesses.

Replicating our approach already conducted in other hubs, we made use of Crunchbase dataset in extracting a complete set of investors that listed Tokyo as their headquarters. In aggregate, we identified a total of 3,062 such investors having been cumulatively involved in 17,930 financing deals that involve 15,048 technology companies in Tokyo, within Japan more broadly, and worldwide. Nevertheless, approximately 62% of these investors either have unknown records or were publicly involved in only one-time investment. Close to 36% of these investors would be classified as small-to-medium-sized, given their non-sizable scope of deals (from 2 all the way up to 50 cumulative investments). Once we further limited our analysis to the top-1000 investors, we found that these entities accounted for 16,491 deals in 13,899 firms, equivalent to over 91% of the accumulated deal volume and portfolio organizations of all listed Tokyo-based investors.

Given the space limitation, and in accordance with our approach for other hubs, we would concentrate primarily on the 25 largest investors in terms of their size of financing deals. None of them had a record of below 100 cumulative investments, similar to the initial findings from London and Silicon Valley (which we will profile in the coming sections). In aggregate, they were responsible for 5,674 cumulative financing deals in 4,459 technology companies and early-stage start-ups, equivalent to 31% of all existing deals and 29% collective portfolio of all Tokyo-based investors. The paragraphs below will describe some of the interesting findings we observed from studying these top-25 investors.

Table 4-51 Information about investors in Tokyo (source: Crunchbase)

Size of investment activities	Number of investors
No information about investments	790
1 investment only	1,097
2-9 cumulative investments	867
10-25 cumulative investments	167
26-50 cumulative investments	67
51-99 cumulative investments	37
100-999 cumulative investments	31
1,000 or more cumulative investments	0
TOTAL	3,062

A very interesting finding from our analysis relates to the very high proportion of corporate venture capital (CVC) funds dominating the top-25 list. In this regard, 12 out of the 25 largest investors are CVC affiliates of Japan's incumbent corporations. Major funds under this category are listed in the following bullet points below:

- SMBC Venture Capital
- Mitsubishi UFJ Capital
- Mizuho Capital
- SoftBank
- JAFCO
- Nissay Capital
- Mitsui Sumitomo Insurance Capital
- Globis Capital Partners
- Itochu Ventures
- DG Ventures
- DBJ Capital
- YJ Capital (partially owned by LINE Ventures)

With the exception of SoftBank (which invests bulk of their capital on technology start-ups across the globe), all of these CVC funds dedicate an overwhelming majority of their financial resources to support technology companies co-located within the Tokyo metropolitan region. Start-ups supported by these funds are also concentrated in a wide range of emerging-technology sectors, such as biotechnology and life sciences, robotics, artificial intelligence, agricultural technology/agtech, new materials, Internet of Things (IoT), etc. To a certain extent, our finding challenges the existing proposition about Japan's historically lagging entrepreneurial drive, given the strong dynamics in Tokyo's innovation ecosystem and the widespread availability of VC funds in the capital region.

Nevertheless, in comparison with other remaining innovation hubs in the Task 3 report, we also identified a very small number of unicorn start-ups – or early-stage companies with valuation of at least US$1 billion. Based on the latest data we obtained from CB Insights as of December 2021, we were only able to retrieve a total of 6 such unicorns across the country, 5 of which are based in Tokyo (as listed in

Table 4-52 below).[176] One of these unicorns, Preferred Networks, also happens to be a former spin-off that commercializes research taking place in the University of Tokyo (Todai). While the number of unicorn companies remains very low, **Nikkei Asia Review (2021)** reported that the figure masks a large number of promising start-ups that may possibly acquire billion-dollar-valuation status in the future; indeed, the number has actually doubled from the prior figure in 2020. Some of these prospective unicorns include Hirotsu Bioscience (a cancer-diagnostics start-up), Astroscale (a space debris removal company), Ispace (another aerospace-themed start-up developing robots for lunar exploration), etc.

Table 4-52 List of unicorn start-up companies in Tokyo

Name	Valuation (US$ billion)	Sector
Preferred Networks	2.0	AI, IoT, robotics, biotechnology
SmartNews	2.0	Mobile app, news, content aggregation
SmartHR	1.6	Fintech, insurance, healthcare
Liquid	1.0	Cryptocurrency, trading, platform
Playco	1.0	Gaming, platform, content creation

In recent years, the Japanese government – in collaboration with universities, major corporations, and established VC funds – has begun formulating plans to develop new large-scale innovation funds to nurture the country's next-generation technology start-ups. One of these channels includes the establishment of university-affiliated VC funds. We will discuss it together with other university-affiliated VC funds in Task 4.

Table 4-53 Top 25 investment funds in Tokyo and proportion of investments in Tokyo technology companies

Name	Summary	No. of investments	Investments in Tokyo	No. of portfolio organizations	Portfolio organizations in Tokyo
East Ventures	A VC fund focusing on early-stage investments in promising technology start-ups in Japan and Southeast Asia, with 4 unicorns on portfolio	450	171 (38.0%)	335	144 (43.0%)
SMBC Venture Capital	A corporate VC (CVC) unit of Sumitomo Mitsui Banking Corp. (SMBC), one of the largest banks in Japan and the world	425	317 (74.6%)	335	243 (72.5%)
Mitsubishi UFJ Capital	A corporate VC (CVC) unit of Mitsubishi UFJ, member of Mitsubishi Group, and one of Japan's, and world's largest, banks	417	266 (63.8%)	349	221 (63.3%)
Global Brain Corporation	A Tokyo-based VC fund offering seed-stage and early-stage investments in pre-IPO tech start-ups in Japan and globally	367	193 (52.6%)	282	140 (49.6%)
Mizuho Capital	A corporate VC (CVC) unit of Mizuho Financial Group, one of the largest financial services groups in Japan and the world	353	283 (80.2%)	286	224 (78.3%)
SoftBank	A corporate VC (CVC) unit of Softbank, one of the world's largest	291	28 (9.6%)	231	21 (9.1%)

Name	Summary	No. of investments	Investments in Tokyo	No. of portfolio organizations	Portfolio organizations in Tokyo
	mobile telephone, Internet, and ICT firms, founded by Masayoshi Son				
JAFCO	The earliest, and largest, VC fund in Japan; it also serves as a private equity firm and incubator for promising technology companies	267	176 (65.9%)	207	133 (64.3%)
Nissay Capital	A corporate VC (CVC) unit of Nissay (Nippon Insurance Life), one of the largest insurance groups in Japan and the world	258	183 (70.9%)	196	136 (69.4%)
Incubate Fund	A start-up incubator + VC fund that provides incubation and investment services (at seed and early stage) for technology start-ups	248	193 (77.8%)	184	139 (75.5%)
CyberAgent Capital	A VC firm that offers financial support and other investments specifically for Internet-related technology companies	232	112 (48.3%)	202	95 (47.0%)
Japan Finance	An investment firm that offers VC, PE, and other types of financial support for SMEs from various sectors in Japan	185	141 (76.2%)	167	126 (75.4%)
ANRI	A VC firm that offers seed-stage and early-stage investments for IT and	177	147 (83.1%)	140	111 (79.3%)

Name	Summary	No. of investments	Investments in Tokyo	No. of portfolio organizations	Portfolio organizations in Tokyo
	emerging-technology start-ups in Japan and beyond				
Nippon Venture Capital	A VC fund that provides investments in various technology companies and early-stage start-ups in Japan	177	113 (63.8%)	144	89 (61.8%)
Innovation Network Corporation of Japan	A joint public-private partnership (PPP) between various companies and the Japanese government to support technology companies	169	108 (63.9%)	111	67 (60.4%)
Mitsui Sumitomo Insurance Capital	A corporate VC (CVC) unit of Mitsui Sumitomo Insurance Group, one of the largest financial services and insurance groups in the world	161	115 (71.4%)	121	87 (71.9%)
Globis Capital Partners	A corporate VC (CVC) unit of Globis Group, a Japanese business conglomerate involved in various business services-related sectors	147	128 (87.1%)	104	87 (83.7%)
Itochu Corporation	An internal corporate VC (CVC) unit of Itochu, one of the largest general trading and industry conglomerates in Japan, that invests in various companies	142	56 (39.4%)	121	50 (41.3%)
Samurai Incubate	A start-up incubator and VC fund that invests in technology start-ups in	137	85 (62.0%)	125	75 (60.0%)

Name	Summary	No. of investments	Investments in Tokyo	No. of portfolio organizations	Portfolio organizations in Tokyo
	Japan and overseas (ranging from fintech, logistics, HR-tech, etc)				
UTEC (University of Tokyo Edge Capital)	A VC fund by the University of Tokyo (Todai) that invests in research spin-offs and deep-tech start-ups from the university	135	74 (54.8%)	90	54 (60.0%)
STRIVE	A VC fund that offers multiple-stage investments (seed to A-series) in early-stage Internet and mobile-related technology start-ups	133	84 (63.2%)	92	57 (62.0%)
Mitsui and Co	An internal investment unit of Mitsui Group, one of the largest general trading and multi-sector industry conglomerates in Japan	132	33 (25.0%)	118	31 (26.3%)
Itochu Technology Ventures	Another separate corporate VC (CVC) unit of Itochu Group, one of Japan's largest business groups, that invests in technology start-ups	130	87 (66.9%)	109	70 (64.2%)
DG Ventures	A corporate VC (CVC) unit of Digital Garage, one of Japan's largest Internet conglomerates, that invests in Internet start-ups globally	126	62 (49.2%)	108	50 (46.3%)
DBJ Capital	A corporate VC (CVC) unit of Development Bank of Japan (DBJ), a	124	94 (75.8%)	103	78 (75.7%)

Name	Summary	No. of investments	Investments in Tokyo	No. of portfolio organizations	Portfolio organizations in Tokyo
	bank partially owned by the government of Japan that invests in technology companies				
YJ Capital	A VC fund partially owned by LINE Ventures, a corporate VC (CVC) unit of LINE, one of the largest social media app companies in Asia	121	88 (72.7%)	89	64 (71.9%)
		5,504	3,337 (60.6%)	4,349	2,592 (59.6%)

4.4.5.5.Discussions and conclusions

We first summarize about the analyses we performed and the findings that we subsequently obtained. First, we investigated the evolutionary dynamics of inter-organizational linkages in Tokyo's innovation ecosystem by utilizing USPTO PatentsView data, covering patent filings from 1983 up to 2018. Having split our data subset into various six-year periods, we found that the innovation networks within Tokyo metropolitan region have remained largely consistent and centered on the same set of incumbent corporations (mainly Toshiba, Hitachi, NEC, Mitsubishi Electric, Sony, Canon, and Panasonic) that have dominated Japan's innovation landscape since the 1980s. Inter-organizational linkages have also, by and large, been dominated by dense inter-firm networks, confirming the observation by **Lincoln (1990)** and **Witt (2014)**. By contrast, the roles of universities and public research organizations (PROs) have been limited, with these organizations only gaining more prominence, specifically from mid-2000s onward. Interestingly, back in the 1980s and early 1990s, patenting output in Tokyo exceeded the total filings from Silicon Valley region, but in the aftermath of post-1990 economic bubble, Japan's innovation performance began to weaken, with Tokyo's patent filings stagnating considerably beginning from early 2000s.

Given the limited amount of information revealed from patent-based analysis alone (**Ter Wal and Boschma, 2008**), we complement the first analysis with our study of publication data – covering a 10-year period from 2009 to 2018 – involving Tokyo's leading university, the University of Tokyo (Todai), which we obtained from Lens.org. Following **Tijssen et al. (2009)**, we specifically examined the degree of U-I collaboration in scientific research and knowledge exchange, using the proxy of U-I co-publications. Through this analysis, we found that journal articles in collaboration with researchers from Tokyo-based enterprises have consistently formed the largest proportion of all U-I co-publications from Todai, although their share has been gradually diminishing over the years. A significant share of these journal articles, in turn, reflected close knowledge-exchange ties between Todai-based scientists and their counterparts in some of Japan's leading corporations, such as the 'big seven' mentioned in the previous paragraph. Nevertheless, we also identified a significant number of spin-offs (N = 60) through this indicator, many of which develop niche expertise in science-driven industries and/or technologies. These findings demonstrated to us the preponderance of inter-organizational linkages not only driven by incumbent corporations, but also those involving SMEs and/or start-ups with niche specialization; in turn, they support the observation by **Fujita and Hill (1998)** regarding the dense inter-firm networks in Tokyo.

In the third analysis, by which we investigate the degree to which Tokyo-based investors provide financing support to technology firms located within the same metropolitan region, we found the city's rate of co-located investments (about 60%) to be the highest relative to all the other remaining hubs we included in the Task 3 report. Simply inferring from this figure alone, we can argue that the degree of resource regeneration within Tokyo's innovation ecosystem is highly salient; nevertheless we advise caveats with such interpretation. Slightly over half of Tokyo's top-25 investors are corporate VC funds of Japan's largest corporations, many of which provide financing support to – and in some instances, subsequently acquire – these

invested companies. Moreover, in spite of the high per-capita population of SMEs and other businesses within the country, the rate of start-up formation has slowed considerably in recent decades (**Suzuki et al., 2002; Whittaker et al., 2009**). This finding is also partially reflected from the infinitesimal number of start-up unicorns currently present in the country; out of 6 such companies, 5 of them are based in Tokyo. However, in recent years, there has been a revival in the city's – and the country's – entrepreneurial ecosystem, as a new generation of high-technology companies began to emerge, and a series of innovation and university VC funds started to proliferate.

Given the unique configuration of Tokyo's innovation ecosystem – as demonstrated by the presence of large, incumbent corporations in tandem with numerous specialized SMEs and the subsequently dense inter-firm networks, most of the insights from this case study may not be necessarily replicable in the context of Hong Kong. Nevertheless, we suggest at most one major lesson that stakeholders in Hong Kong's innovation system can learn from Tokyo, and that is the risk-taking attitude of a growing number of Japan's universities in investing, and financially supporting, the new generation of high-technology start-ups.

4.4.6. Seoul

4.4.6.1.Introduction

Located in the northwest of South Korea, Seoul is the capital and largest metropolis of the country with approximately 10 million inhabitants. Echoing the rapid transformation of South Korea, the city has experienced great economic growth and technology boom, transitioning into one of the most innovative global players. According to the **Global Innovation Index 2021**, Seoul have remained in the top 10 active cluster in science and technology, while in the meantime, the South Korea came top among the Asian economies and joins the top five GII place for the first time. High-growth economic activities are also concentrated in the regions surrounding Seoul. A high density of international brands, information and communication companies, universities, public research institutes, and venture capitalists are located in the Seoul Capital Area (hereinafter referred to as SCA), which includes Seoul capital city, Incheon, and Gyeonggi Province(**OECD, 2018**). In 2020, Seoul alone accounts for 22.7% of the national GDP, with SCA representing 52.5% of the national GDP and almost half of the national population (**Statistics Korea, 2021**). With strong digital infrastructure and start-up friendly policies, Seoul is also emerging as a global startup city, concentrating more than half of the technology startups in South Korea (**Startup Genome, 2021**).

The story of Seoul's emergence as an innovation hub is inevitably intertwined with the rapid transformation of South Korea, from one of the world's poorest countries in the early 1960s into the world's tenth largest economy by 2020. Since the late 1990s, the Korean government has invested heavily in R&D to enhance the national economic development and research capabilities. As an illustration, South Korea's ratio of R&D expenditure to GDP grew from 2.27% in 2001 to 4.81% in 2020, ranking second among the OECD's nations. The country has now been positioned as the most innovative countries and shown outstanding performance in R&D intensity, manufacturing capacity, researcher concentration, and high technology density, ranked 1st in the "2021 Bloomberg Innovation Index" among sixty nations. Much of the success stories of Korea's economic development has also been attributed to aggressive, collective catch-up and technological/industrial leapfrogging efforts, primarily by the industries, and to a certain extent by government research institutes and universities (**Lee and Lim, 2001**). The Korean national innovation system, as described by **Eom and Lee (2010)**, have been characterized by "two dominance" of big businesses (*Chaebols*) and the government.

The Korean national innovation system, as described by Eom and Lee (2010), have been characterized by "two dominance" of big businesses (Chaebols) and the government, which implies a relatively weak role played by universities. In South Korea, national and public universities accounted for less than 20% of all universities. Universities have been considered as hotbeds for promising innovation technologies and startups, with the trend led by the country's best-known education institutes like Seoul National University (SNU) and Daejeon-based Korea Advanced Institute of Science and Technology (KAIST.) The following paragraphs below briefly summarize Korea's economic transformation given the succession of different policies adopted by the government across multiple decades. We then provide briefs of recent policy instruments issued by both national and Seoul metropolitan government to

illustrate what has been implemented by the government, particularly, how the government has turned Seoul into such a start-up incubation place.

The following is a short description of the historical development of economic development strategies in South Korea. We then provide briefs of recent policy instruments issued by both national and Seoul metropolitan government to illustrate what has been implemented by the government, particularly, how the government has turned Seoul into such a start-up incubation place.

Historical development of South Korea's economic development strategies

The characteristics of the Korean developmental path are well explored in the literature (**Amsden 1989; Wade 1990; Kim, E. M. 1997; Woo-Cumings 1999**). Broadly speaking, the goal of Korean developmental policies was to develop the country by using administrative means to accelerate the progress of Korean industries from labour-intensive to capital intensive, and ultimately to technology-intensive industries (**Witt & Redding, 2014**). In its effort to catch up with the world's leading economies, South Korea has witnessed several major shifts in the country's economic development strategies.

At the early stage, the Korean government's strategy was to increase the country's capabilities to assimilate, adopt, and improve technologies introduced through foreign direct investment (FDI). During the 1960s, its economy was driven by import-substitution industries (ISI), mainly agriculture and labor-intensive light-industry manufacturing sectors. Korea's deficit in absorptive and technological capabilities were addressed by the government's selective import, followed by reverse-engineering and assimilation, of technologies overseas through the establishment of the Ministry of Science and Technology (MOST) and the Korea Institute of Science and Technology (KIST), the latter by which was one of the country's first-generation research institutes (**OECD, 2009**).

From the decade of 1970s onward, South Korea's economy – and the government's overall development strategies – began to rapidly shift toward heavy industries, primarily in chemicals, machinery, and shipbuilding. Simultaneously, the government allocated an increasing amount of resources to set up industry-oriented public research organizations (PROs). Nevertheless, in spite of the establishment of such institutes, Korea remained highly dependent on imports of foreign technologies, while the absorptive capacities of most local firms had yet to be enhanced. Despite such limitation, these enterprises were protected by the government's protectionist policies that denied foreign companies access to South Korea's consumer market, on top of subsidies and support by state-funded R&D institutes.

Efforts to substantially improve local firms' absorptive capacities and reduce collective dependence on imported foreign technologies did not commence until the mid-1980s, when Korean firms found themselves deeply vulnerable to external shocks from international markets. Instead of turning to domestic research institutes or universities for two-way knowledge exchange and/or collaboration, many of these local enterprises embarked on the pathway of developing their own indigenous, homegrown knowledge bases (**OECD, 2009**).

This was further accompanied by winner-picking industrial policies, through which the most successful firms in an industry were provided with virtually unlimited supplies and resources by the government in assimilating new technologies, expanding their scale of business operations, and subsequently increasing their shares in the global market; such successive policies, in turn, led to the rise of a new generation of 'chaebols' (business groups) – the most notable examples being Samsung, Hyundai, LG, and SK – that would significantly shape South Korea's phenomenal industrial growth in the following decades (**OECD, 2014**).

It is also worth noting that, throughout the 1970s and 1980s, South Korean government utilized 'industry consortia' model to rally, and exert pressure, on major enterprises to enhance their absorptive capacities in mastering technologies deemed by the authorities to be of 'national interest'. We demonstrated such approach with the two following illustrations as follows. In the former, the government introduced 'Heavy Industry Promotion Program' (HCI), which, in the aftermath of 1973 oil crisis, aimed to reduce the country's dependence on foreign imports and pushed the industry actors to master more advanced technologies; one such technology would be semiconductor. Moreover, specific consortia heavily focused on large airline and steel-producing companies were also established, in which these firms were provided by the government with significant preferential treatment. Regarding the latter, in the 1980s, South Korea's then-Ministry of Trade and Industry led the establishment of Korea Electronics Industry Alliance, in which some of the country's largest electronics/ICT firms, notably Samsung, Hyundai, LG, and Daewoo, participated as some of the core founding members. Such alliances were primarily centered on industry-building approaches, instead of targeted mastery of core technologies. Essentially, with such alliances, these firms were pressured to build whole-new industries, together with their supply chains. While the approach sort of resembled the Japanese model of industrial consortia, the South Korea's version differed in the sense that the former focused on targeted R&D, whereas the latter implemented their strategies by acquiring foreign companies or establishing joint ventures with foreign multinational corporations (MNCs).

By early 1990s, South Korea has begun to bear fruits from decades of economic and industrial policies. This decade was characterized by a rapid expansion in the enrollment on the country's higher education system, and the transition towards high-technology industries and their supporting innovation policies (**OECD, 2014**). Simultaneously, Korea's largest companies moved up the value-added manufacturing chain by diversifying into electronics and ICT-related industries, given the increasing global proliferation of Internet. Nevertheless, this was the same decade in which Korea was severely affected by the 1997-1998 Asian financial crisis, which resulted from a massive accumulation of debt by the country's major corporations (and, indeed, most chaebol business groups). Faced with persistent, and chronic, current deficits, as well as rapidly depleting foreign exchange reserves, the South Korean government launched a series of reform programs to rescue the economy, as well as redirect the country to be driven by an advanced knowledge-based economy model (**OECD, 2014**). The Gangnam district in Seoul symbolized a "boomtown" for the country's growing IT-related start-ups, and an increasing number of individuals, especially among the young population, engaged in more risk-taking ventures, such as establishing start-ups and/or working for early-stage technology companies (**Hemmert et al., 2019**).

Throughout the 2010s, support measures for promoting entrepreneurship and start-up creation in South Korea intensified; part of this was attributed to the government's strategies to make the economy gradually less dependent on chaebol firms. Some of the recent major initiatives are highlighted in the following bullet points below:

- In 2011, Korean government – in partnership with Gyeonggi provincial authorities – officially launched testablishment of Pangyo Techno Valley Industrial Park, which aims to host a growing number of technology start-ups that relocated from Seoul, and partly as a strategy to address regional disparities between Seoul and the rest of the country (**Lee et al., 2017**)
- In 2018, the Ministry of SMEs and Start-ups (MSS) and the Financial Services Commission (FSC) launched a US$12 billion innovation fund in September to provide financing support for promising early-stage technology start-ups. As a follow up, the Seoul municipal government announced that an additional US$1.2 billion will be invested up to 2022 to support aspiring SMEs within the city
- In 2020, MSS and the Korea Institute of Start-up and Entrepreneurship Development (KISED) launched COMEUP Korea, the latest government-driven entrepreneurship event that centers on competitions, sharing sessions by experienced entrepreneurs, and information portals on entrepreneurship-related opportunities. The program targets eight major sectors, namely: 1) mobile apps; 2) food and beverages; 3) entertainment; 4) fashion and beauty; 5) financial technologies (fintech); 6) life sciences and biotechnology; 7) cutting-edge technologies, and; 8) lifestyle.

Worth mentioned, elimination of regional disparity is more highlighted. The Rho government in 2004 initiated the Industrial Complex Cluster Program (ICCP) to balance the development of different regions by transferring some ministries, public agencies and industrial complex to different regions. Seoul only maintains its specialized IT complex. In particular, building collaborative and open network of industry-university-government is one of the major strategies for the program. It is further facilitated by various funding and e-cluster infrastructural projects to support for management, promotion, and database establishment (**MKE, 2010**).

R&D

The country has now been positioned as the most innovative countries and shown outstanding performance in R&D intensity, manufacturing capacity, researcher concentration, and high technology density, ranked 1st in the "**2021 Bloomberg Innovation Index"** among sixty nations. As an illustration, South Korea's ratio of R&D expenditure to GDP grew from 2.27% in 2001 to 4.81% in 2020, ranking second among the OECD's nations. 75% of total Korean R&D spending is accounted from industry sources which also explains why more of R&D spending goes to applied rather than basic research (Nature, 1 June 2016). Moreover, South Korea is a global outlier for its high proportion of researchers moving from industry to academia, Cross-sectoral moves between industry and academia per 1,000 researchers 2017-

2019 are shown for the top 10 countries by Share in the Nature Index. This suggests that a significant proportion of South Korean trained researchers will head to its industrial sector.

4.4.6.2.Government policies and programs

In order to catch up with the development of modern industrial economies, starting 1960s, Korean government embraced the "promotion of science and technology" as one of the key matters in the agenda (STEPI, 2008) and adopt the national system of innovation, which is a system connecting private sector, universities and government agent to promote the domestic capacities of science and technology development at the national level. At the early stage, the Korean government's strategy was to increase the country's capabilities to assimilate, adopt, and improve technologies introduced through foreign direct investment (FDI). This strategy set the foundation that the R&D development from the 1960s to the mid-1990s was to be driven by private sectors, especially in big companies. Its strategy was export-led economic development based on the combination between low-wage and high-quality labor and the introduction of latest technologies from outside Korea by large corporations. From mid-1990s, Korean government has sought new engines for national innovation—strengthening new discoveries in the research institutes and universities. Based on the governmental R&D survey and analysis , nearly 23% of the government R&D budget contributes to the university sector.

Table 4-54 GOVERD by performance sectors in Korea

	2015		2016		2017		2018	
	GOVERD (100 million KRW)	Percentage (%)	GOVERD (100 million KRW)	Percentage (%)	GOVERD (100 million KRW)	Percentage (%)	GOVERD (100 million KRW)	Percentage (%)
Research institutes	87,814	46.5	88,188	46.4	88,853	45.8	90,747	45.9
Universities	42,617	22.6	42,727	22.5	44,052	22.7	45,365	22.9
Business enterprise	40,310	21.4	41,286	21.7	45,382	23.4	46,694	23.6
Ministries	6,181	3.3	6,281	3.3	4,692	2.4	2,993	1.5
Others	11,825	6.3	11,562	6.1	10,948	5.6	11,960	6.0
Total	188,747	100.0	190,044	100.0	193,927	100.0	197,759	100.0

Source: **MIST & KISTEP, 2019**

Emergence of technology transfer offices and vitalization plan for industry and academia cooperation

The Technology Transfer Promotion Act (TTPA) 2000 was the first law to encourage the development of science and technology and the commercialization of public research by benchmarking the Bayh–Dole act (**Han, 2018**). TTPA specified that university researchers were eligible to obtain Through TTPA, it is also possible to manage intellectual property

through technology transfer offices (TTOs), and this law encompasses not only universities but also the TTOs of government research institutions.

The technology licensing offices (TLOs) were established by the Ministry of Science and Technology in 2001 in five research institutes (KIST, KAIST, KITECH, RIST, GIST). Meanwhile, the number of TTOs in universities and PRIs, showed a marked increase due to the enactment of TTPA, from 42 in 2000 to 158 in 2005. In 2006, the TTPA was amended to increase the incentives for the technology commercialization of universities and PRIs. In addition, SNU established SNU R&D Foundation which played a role in stimulating university-industry technology transfer. The government has enacted various laws for the protection of intellectual property rights, the promotion of university-industry collaboration, support for the development of new technology, the creation of a proper ecosystem, and participation by private companies.

The Technology Transfer and Commercialization Plan (TTCP) was implemented in 2001. The plan aims to integrate the management of the details of various ministries involved in technology transfer and commercialization activities. At the beginning, the plan focused on building infrastructures (e.g., the technology trading market, National Technology Bank) and establishing intermediary organizations such as an industry–academia cooperation foundation, TTOs, and technology evaluation institutions. In 2006, MOTIE has amended national law as "Act on Promotion Technology Transfer and Commercialization (TTCP Act)," which indirectly promotes the increase of the technology transfer from university to industry. The primary contents of the TTCP Act are (1) detailed plan and projects to encourage the technology transfer and commercialization to private companies and increase the liquidity of the technology assets through setting up TLO at research agents; (2) provide corresponding financial support and supervision to ensure the smooth transaction and contracts during technology transfer and commercialisation.

Besides, there were only a few instances of formal long-term collaboration between university-based research and entrepreneurs. The reason behind is the lack of regulated classification of the ownership of the patent and lack of financial incentives to achieve the technology transfer. MSIT (which was previously Ministry of Science, ICT and Future Planning between 2013 and 2017) built infrastructures and support departments, such as special R&D Zones and lab-based venture companies, to support the technology transfer among private sectors, university, and government agencies. At the same time, MSIT revalued and upgraded the R&D projects to ensure the market demand of technology has been linked to the university research.

MOE also set the follow-up long-term support laws as "Industry Education Enhancement and Industry—Academia—Research Cooperation (IARC) Promotion Act." The role of university is defined as to strengthen agency that provides high-skilled labor force. This act shifted the policy emphasis from the industrial innovation to the commercialization of educational research. IARC promoted for the Industry-Academia Cooperation Foundation to acquire legal status and handle integrated issues such as intellectual property rights management, affairs of technology transfers, and researcher compensation. During 2006 and 2010, Ministry of Knowledge Economy and MOE (Ministry of Education, Science, and Technology) implemented the "Connect Korea" project (by benchmarking the CONNECT program of the

University of California, San Diego) that governing academic's involvement in the business activities. University is required to create the TLOs, which is regarded as a connect between firms' demanded R&D products and research prospects in universities.

In 2006, Korean Intellectual Property Office amended the Invention Promotion Act. The act allowed teaching staff of a national or public school to have a non-exclusive license for employee invention according to the detailed policy instruments that were devised were related to the laws that originated from the spirit of the Bayh–Dole Act. In accordance with the TTCP and IARC, Industry-Academic Cooperation Foundation became a party to the agreement of an UIC and took on the role of the intermediary organization that connects funding support provided by private companies. At the same time, it took over the patent rights to inventions by faculties and staffs on behalf of the Invention Promotion Act and carries out the role of licensing them to private companies (**Park, 2014**).

Technology transfer and commercialization through transition from GFRIs to universities

The position of GFRIs became ambiguous as the research capabilities of universities increased and private research institutes in large corporation became competitive. In the 1990s, the government began supporting collective and large-scale basic science research. During this period, the government research expenditures were increased, and the R&D for universities grew quantitatively, but mainly focused on the applied research that can help industrial development. After 2000s, as innovation activities began to shift toward corporates, GFRIs began to emphasize complementary roles to support them. As the post catch-up innovation system was emphasized, universities were increasingly asked not only to cultivate human resources through education, but also to strengthen basic research activities (**STEPI, 2013**). In addition, as academic entrepreneurship spread to universities, universities played a role in cultivating competent scientific and technological human resources, creating new knowledge, and diffusing new knowledge through technology transfer.

The government, which has been developing economic growth and technology development centered on GFRIs, initiated and amended national policies for technology transfer and commercialization focusing on universities and corporates since 2000s. The government has implemented national plans for the promotion of university-industry collaboration (UIC) and technological commercialization as shown in Table 4-55.

Table 4-55 National plans for technology transfer and commercialization

National Plan	**Year**	**Responsible Organization**
The Technology Transfer Promotion Act (TTPA)	2000 – 2005 (1st)	Ministry of Trade, Industry and Energy (MOTIE)
The Technology Transfer and Commercialization Plan (TTCP)	2006 – 2008 (2nd) 2008 – 2010 (3rd) 2011 – 2013 (4th) 2014 – 2016 (5th)	

	2017 – 2020 (6th) 2021 – 2023 (7th)	
The Industry Education Enhancement and Industry—Academia—Research Cooperation (IARC) Promotion Act	2003 – Present Amended in 2007	Ministry of Education (MOE)
The Invention Promotion Act	2006 – Present	Korean Intellectual Property Office (KIPO)
Leaders in Industry-University Cooperation (LINC)	2012 – 2016 (1st) 2017 – 2021 (2nd)	Ministry of Education (MOE) National Research Foundation (NRF)

University-level profit-making business operations

Despite efforts of ministries to implement policy for promoting technology transfer, TTOs suffered from operational and organizational inefficiency. According to Han (2018), this obstacle was from structural problems such as lack of experience and specialists, and insufficient funding for operation of TTOs. For resolving these obstacles, the government initiated the "Leaders in Industry-University Cooperation (LINC)" in 2012, which focused on R&D, company support, workforce training, and marketing, among others (Kim et al, 2012). The government supported KRW 1535 million (HKD 11 million) to 57 universities in 2011, KRW 1820 million (HKD 13 million) to 80 universities in 2012, and KRW 2350 million (HKD 16.8 million) to 80 universities in 2013 for promoting business programs to cultivate capabilities and build a creative economy ecosystem for leading industries in regional businesses. At the same time, the government began to implement "Leading TTO Cultivation Project" which support the operating expenses and subsidize the labor cost, technology discovery, evaluation, marketing, and business expenses for enhancing the capabilities of TTOs. At the time of the project in 2011, leading TTOs received KRW 150 million (HKD 1 million) to KRW 300 million (HKD 2 million), and the TTOs of the consortium received KRW 50 million (HKD 0.5 million).

In 2011, with the introduction of the "University Faculty enhancing UIC", the recruitment of 'collaboration professors' began to expand. As for collaboration professors, they focus on education, research, and startup/employment support activities through UIC. As a faculty who is evaluated based on the achievements of UIC. The collaboration professor requires at least 10 years of experience in the industry and, national and public institutions. For enhancing the capabilities of major actors in UIC, universities hire collaboration professor and identify those who can be appointed as technical research professor (tenure track or non-tenure track positions) based on the standards for hiring collaboration professors by MOE. In addition, as the MOE implemented the LINC project in 2012, the number of collaboration professors at all universities from 2,20 in 2011, surged to 2,000 in 2012, and increased to 4,400 in 2019. Through the human resource management policy, the universities expect to improve the system of collaboration professor and bring the stability and expertise of dedicated staff. In addition, it can transform awareness and enhance competency through the operation of educational

programs for teachers.

4.4.6.3.Universities in Seoul

Evolution of universities in South Korea

Universities in South Korea have been strongly influenced by the Korean government's university and innovation policies(**Cho, 2014**). Initially, in the 1960s and early 1970s, universities' roles were primarily in teaching and supplying the trained labor force to the country's growing job market, while research activities were concentrated in government-funded PROs (**Sohn and Kenney, 2007**). The highly centralized institutional structure – through which the Ministry of Education (MOE) exerted tight control through strict regulation in research funding, faculty recruitment, and faculty promotion – meant that most universities had limited incentives to conduct research, let alone in building strategic linkages with industry actors for knowledge exchange (**Sohn and Kenney, 2007**). University faculty were only expected to educate students or provide consultation to industry rather than directly participate or invest in R&D projects (**Sohn & Kenney, 2007**). In 1962, the first Five-Year economic development plan was drafted and the Korean government started to initiate various technology-push policy measures to promote science, innovation and technology(**Acha & Martin, 2011**). Supporting programs for overseas training were initiated and encouraged by the government with its aim to cultivate and foster highly qualified scientists and engineers during this time(**Kwon, 2015**). In other words, the government implemented science and technology policy by recruiting foreign talents to GFRIs and establishing research-centred graduate schools, rather than growth of university-oriented research. Moreover, to facilitate the economic development plan, Korean government established the Korean Institute of Science and Technology, which carried out R&D activities especially related to the automobile promotion, mechanical engineering, material science, and the electronics industry.

From mid-1970s to the 1980s, in the face of growing perception about Korea's vulnerability given their dependence on foreign imports, the government began to enact various strategic, national-level R&D programs to boost collaboration between both university and PRO researchers. While the initial focus was on absorbing imported technologies to assist local manufacturers, over time the orientation shifted towards basic science and developing homegrown technologies. In the 1970s, the Korean government established various government research institutes (GRIs) in heavy and chemical industries, such as Korea Institute of Machinery and Materials (1976), Korea Research Institute of Chemical Technology (1976), and the Electronics and Telecommunications Research Institute (1976). Based on the *Special Research Institute Promotion Law* of 1973, the main purpose of these government-funded research institutes (GFRIs) was to conduct research for the introduction, improvement, and diffusion of industrial technologies. Together, the GFRIs has contributed to not only satisfying the demand for industrial technology, but also complementing the universities and companies that lacked a research base by supplying human resources.

Korea started to boost university-industry cooperation in the late 1980s by providing universities with funds to establish three types of R&D centers: Science Research Centers,

Engineering Research Centers, and Regional Research Centers. MOST in particular is responsible for the distribution of funds, while research centers are expected to be managed by researchers. UIC in R&D contracts, technical training, and technology consultation fall under this policy support (**Sohn & Kenny, 2007**). From 1990s onward, given the intensifying corporate R&D investments, university-institution linkages began to emerge as well (**Park & Leydesdorff, 2010**). During this time, private sector started to carry out a substantial proportion of R&D, which by facilitating product development and commercialization, contributed to the international competitiveness of the private sector.

In order to build indigenous innovation capability, a national R&D program was launched by the Ministry of Science and Technology to promote private R&D activities by providing tax-based incentives and competitive , "means of funding R&D, providing tax benefits and other incentives, and emphasized the companies' competitiveness in international markets." "Universities and private firms could both participate in such a programme, competing against Government Research Institutes (GRIs) to acquire. R&D project funding. These policies targeted balanced development of research capabilities within universities, GRIs and private firms, and the fostering of networks among researchers, but decentralisation policy from the early 1980s was primarily focused on expanding the Seoul macro-cluster to include proximate regions (Sohn and Kenney 2007)"

Korea started to boost university-industry cooperation in the late 1980s by providing universities with funds to establish three types of R&D centers: Science Research Centers, Engineering Research Centers, and Regional Research Centers. MOST in particular is responsible for the distribution of funds, while research centers are expected to be managed by researchers. UIC in R&D contracts, technical training, and technology consultation fall under this policy support (Sohn & Kenny, 2007). From 1990s onward, given the intensifying corporate R&D investments, university-institution linkages began to emerge as well (Park & Leydesdorff, 2010). During this time, private sector started to carry out a substantial proportion of R&D, which by facilitating product development and commercialization, contributed to the international competitiveness of the private sector. Noticeably, from the mid-1970s to 1990s, Chaebols have started to grow rapidly aided by the "government-led public–private research consortia in achieving key R&D goals, with such examples of TDX (a system of telephone switches), memory chips development, and digital TV projects(Eom & Lee, 2010). While the initial focus was on absorbing imported technologies to assist local manufacturers, over time the orientation shifted towards basic science and developing homegrown technologies. Moreover, from 1990s onward, given the intensifying corporate R&D investments, U-I linkages began to emerge as well (Park and Leydesdorff, 2010).

More details will be elaborated through analyses in the upcoming sections. The first analysis centers on identifying and observing evolutionary dynamics in the inter-organizational linkages within Seoul innovation ecosystem over time, by proxy of USPTO PatentsView database. The second analysis complements the first by focusing on scientific collaboration landscape between academia and industry using U-I co-publications from Lens.org. Finally, the third analysis explores the degree to which investors in Seoul support co-located start-ups.

4.4.6.4.INTER-ORGANIZATIONAL NETWORKS: EVIDENCE FROM USPTO PATENT DATA

In the first analysis, we engaged in the analysis of inter-organizational networks in order to build a better understanding of evolutionary changes in Seoul's innovation ecosystem. We first collected USPTO patent data, and filtered our data collection to patent filings based on inventions taking place in Seoul. Replicating our previous approaches in studying other hubs in this report, we identify the presence of inter-organizational networks by proxying for patents by two, or more, applicant organizations that involve researchers with the similar inventor ID. Afterwards, we utilized the subsequent resulting network data to identify and select the most influential organizations based on betweenness centrality and degree centrality measures. Before we elaborated about these two network properties, we would first provide description on the most actively patenting organizations, as shown in Table 4-56 below and Table 4-57 in the following page (in which we disaggregated the data into six different timeframes within the 1983-2018 period). We have excluded no-assignee patents and patent applications with missing variable values from our calculation.

Table 4-56 List of top-10 patenting assignees in Seoul (all-time)[177]

Name	Patent filings (105,427)
Samsung	44,250
LG Corp	23,532
Hyundai Motor	3,657
SK Group	2,039
ETRI	1,523
KIST	1,449
Kia Motor	1,263
SK Hynix	1,261
Seoul National University (SNU)	1,148
Daewoo (out of business)	*1,013*
Yonsei University	756
Share of top 10	77.0%
No. of organizations	3,834

In total, Seoul-based organizations (businesses, universities, research institutes, and government agencies alike) were responsible for a total of over 105,000 patents, a figure that was close to 40% of South Korea's aggregate USPTO patent filings. Quite interestingly, almost two-thirds of patenting output in Seoul were dominated by only two major business groups (*chaebol*) alone: Samsung and LG Corp. Samsung-affiliated enterprises, in aggregate, accounted for over 42% (N = 44,250) of patent applications, whereas LG Corp was on a distant second, controlling approximately 21% (N = 23,532) of patent applications. Other major innovation actors include two business groups: Hyundai Motor (which also includes their 'sister' company, Kia Motors) and SK Group (of which SK Hynix constitutes an affiliate

firm).[178] The remaining actors in the top-10 list in Table 4-46 above are occupied by universities – notably SNU and Yonsei – and public research organizations, as represented by Electronics and Telecommunication Research Institute (ETRI) and Korea Institute of Science and Technology (KIST).[179]

When we further break down the results across 6 different six-year periods, as displayed from Table 4-57 below, we found that both Samsung and LG consistently occupy the highest two positions in the top-10 lists. The results remained robust, especially after accounting for the degree of influence exerted by Samsung and LG in terms of betweenness centrality and degree centrality (see Table 4-57 and Table 4-58 in the following pages). Daewoo, at one point, was a rising contender; in the 1989-1994 and 1995-2000 periods, the industry conglomerate was the third most active patenter after Samsung and LG. However, the 1997-1998 Asian financial crisis severely affected the performance of most chaebol, and Daewoo, indeed, became the largest business group that went bust in the aftermath of the crisis (**Joh, 2014; Witt, 2014**).[180] Hyundai Electronics, which would subsequently be transformed into SK Hynix as a result of Hyundai Group break-up post-1997 crisis, was also a significant innovation actor given their emphasis on electronic products and components. Regardless of the changes in the composition of the chaebol, one fact remains evident: since the 1980s to the present, large business groups continue to hold a considerable sway over South Korea's economy, as well as innovation landscape (**Joh, 2014; Park, 2014; Witt, 2014**).

The roles of universities and research institutes, at the same period of time, have also evolved significantly. Throughout the 1980s and 1990s, the most actively patenting organizations from these sector were KAIST, ETRI, and KIST. One thing worth noting was that prior to 1990, an overwhelming majority of South Korea's universities and research institutes were based in Seoul (**Castells, 1994; Kim and Leslie, 1998**).[181] Moreover, KAIST and KIST had been – under the government's top-down orders – frequently involved in research collaboration, as well as with chaebol enterprises in joint development of imported technologies.[182] While a large proportion of these research-performing organizations (including KAIST and ETRI) were subsequently relocated to Daejeon, a city of 1.5 million people 140 km southward from Seoul, some of these institutes – including KIST – were retained in Seoul. These dynamics were reflected in the composition of the top-10 innovator lists in the first three 6-year periods (1983-1988, 1989-1994, 1995-2000), with KAIST, ETRI, and KIST being the primary research-performing entities included in the lists. From 2000 onward, KAIST and ETRI were no longer in Seoul's top-10 patenter lists.

Before we elaborated about the subsequent roles of other universities (notably SNU and other Seoul-based universities), we shall highlight KIST's contribution to South Korea's economic development and innovation activities. While the institute's patenting boom only occurred from early 1990s onward, their roles in facilitating advanced R&D and industrialization had commenced as early as 1970. Based on in-depth studies of archived records, **Kim and Leslie (1998)** demonstrated that KIST's contribution was primarily on conducting applied R&D for technologies that were strategically suited for South Korea's export priorities, often in collaboration with their industry counterparts.[183] Two particular examples stood out: one of KIST's shipbuilding research laboratories would end up transforming Hyundai into one of the

world's largest shipbuilders, and another laboratory on steel processing methods would also be utilized to transform POSCO into one of the world's leading steel manufacturers.

Beginning from the 2001-2006 period of analysis, an increasing number of Seoul-based universities started to see their influence (as proxied by both betweenness centrality and degree centrality) increase considerably. Indeed, Seoul National University (SNU) was the first university to enter not only the top-10 list in terms of both centrality properties, but also in the top-10 position for patenting innovators. Over time, other universities followed suit, with Yonsei University also trailing behind SNU in terms of betweenness centrality, degree centrality, and top-10 innovator lists in 2007-2012 period. Korea University, while not included in the 10 most active patenter list, also played a significant role in knowledge spillover and dissemination, as shown by their entry into the top-10 lists in both types of centrality properties.[184] In the more recent period (2013-2018), other Seoul-based universities – notably Hanyang, Sungkyunkwan, Sogang, and Chung-Ang, have been competing with their three highly-ranked counterparts in the centrality positions.

These findings, overall, provide support to **Sohn and Kenney (2007)** and **Hawkins (2015)** regarding the impacts of South Korean government's ambitious efforts in transforming the roles of universities over the last 2-3 decades. Historically, most universities in the country have been positioned as primarily teaching-oriented institutions, with these institutions largely expected to closely adhere to the regulations under the Ministry of Education; one major consequence has been the centralized uniformity among these universities in terms of university policy-setting (**Sohn and Kenney, 2007**). Moreover, incentives to innovate among faculty members – until the end of 1990s – have been limited; inventions belonging to faculty members were largely owned by university inventors, institutionalized structure for KT/TT activities was primarily absent, and U-I collaboration was limited to professors serving in consultancy roles (**Sohn and Kenney, 2007**). The 1997-1998 Asian financial crisis has indirectly served as a 'wake-up call' for the government, as well as universities, over South Korea's vulnerability of relying on chaebol firms to drive economic development, and also the urgent need to transform the economic model into a knowledge-led one. In this regard, the government began to pass a series of regulations (**Sohn and Kenney, 2007; Hawkins, 2015**) as shown from the bullet points below:

- The Special Entrepreneurship Act of 1998, which was known as South Korea's version of Bayh-Dole Act (allowing universities to retain more control of university-based inventions and provide patent protection)
- A series of complementary laws in 1999 to encourage Korean universities to build their own technology transfer offices (TTOs) and structure them as companies
- Brain Korea 21, which is a government-funded strategic policy program to dramatically boost South Korean universities' research performance by transforming a large proportion of them into research universities[185]

Nevertheless, the outcomes from such policy incentives have been mixed. On one hand, there have been more efforts at university-industry collaboration, although the collaboration rate has

been stagnant over time (**Park and Leydesdorff, 2010**). On the other hand, such linkages have not pushed forward the commercialization of scientific research through start-up and/or spin-off formation, with the exception of biotechnology/life science industries (which we will elaborate in the next subsection). In order to understand the reasons why, we link our discourses with Table 4-57 below and Table 4-58 in the following pages (by which we list out organizations with the highest degree centrality scores). As an illustration, SNU has seen its degree centrality scores grow considerably, from having direct ties to 88 organizations in 2001-2006 to 220 as of 2013-2018. Nevertheless, once we refer to figures from Table 4-57 below, we can observe that a disproportionately high share of linkages, especially among top-5 organizations, are primarily with firms affiliated with South Korea's four largest chaebol business groups (namely Samsung, LG, Hyundai, and SK). And this finding is not unique to SNU alone; when we further expand our investigation into other major Seoul-based higher-education institutions – such as Yonsei, Korea U, Sungkyunkwan, Hanyang, Chung-Ang, Sogang, as well as KIST, we found such recurrent patterns as well. To a limited extent, the inter-organizational linkages took place among the universities and government-funded public research institutes (e.g. KIST, ETRI, KIIT, KRICT, etc).

Table 4-57 Most frequent direct inter-organizational linkages involving Seoul-based HEIs and government research institutes (number of recurrent linkages in brackets)

	2001-2006	2007-2012	2013-2018
SNU	Samsung (1467) KIST (95) LG Group (53) KAIST (50) Philips (32)	Samsung (4757) LG Group (826) SK Group (249) KIST (144) Hyundai Motor (143)	LG Group (8208) Samsung (4273) SK Group (1473) Hyundai Motor (482) KIST (303)
Yonsei Univ	Samsung (607) SK Group (47) KAIST (38) ETRI (31) SNU (27)	Samsung (3762) LG Group (1621) Qualcomm (290) ETRI (173) SNU (89)	LG Group (7545) Samsung (5429) Qualcomm (780) SK Group (341) Hyundai Motor (266)
Korea Univ	Samsung (11) KIST (2) NewheartBio (2) SNU (2) Biotrion (1)	Samsung (2291) LG Group (904) SNU (104) ETRI (73) SK Group (45)	Samsung (1794) LG Group (1580) Hyundai Motor (171) SK Group (113) Kia Motor (89)
Sungkyunkwan	Samsung (15) LG Group (11) Oriol Inc (9) KIIT (2) Piezonics (2)	Samsung (848) LG Group (347) KIST (80) ETRI (24) Hyundai Motor (23)	LG Group (3876) Samsung (3737) KAIST (143) SNU (106) Hyundai Motor (85)
Hanyang Univ	Samsung (399) LG Group (34) KIST (19)	Samsung (1512) LG Group (305) Hyundai Motor (96)	Samsung (1956) LG Group (709) SK Group (489)

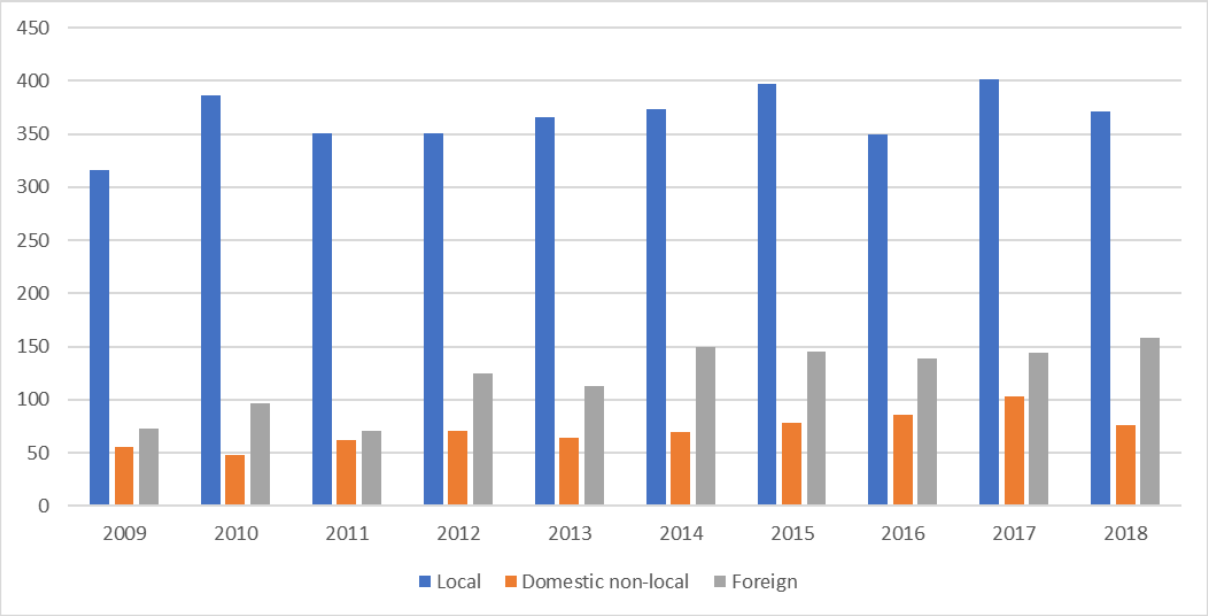
	KC Tech (15) Humax Ltd (14)	ETRI (86) SK Group (68)	Hyundai Motor (426) Kia Motor (211)
Chung-Ang Univ	LG Group (32) ETRI (30) Philips-LG Co (29) Samsung (12) KIRMS (4)	Samsung (203) SNU (41) LG Group (27) Hanyang Univ 910) Yonsei Univ (9)	Samsung (158) LG Group (68) SK Group (66) Hyundai Motor (16) Anapass (14)
Sogang Univ	Samsung (59) KIST (16) Hyundai Motor (6) LG Group (5) Kia Motor (3)	Samsung (1036) LG Group (299) ETRI (45) Hyundai Motor (32) Dongjin Ltd (29)	LG Group (1910) Samsung (382) Korea Univ (48) SK Group (32) KIST (25)
KIST	Samsung (304) LG Group (282) Hyundai Motor (125) SNU (95) KRICT (50)	Samsung (838) LG Group (835) SNU (144) Hyundai Motor (142) KRICT (95)	Samsung (2142) LG Group (1547) Hyundai Motor (500) Amkor (363) SNU (303)

Interpreting the figures from Table 4-57 above, we highlighted two possible scenarios. First, a significant proportion of university members (e.g. graduate students, researchers, faculty members, etc) may have ended up working for R&D units of these enterprises. Secondly, these organizations engaged in collaboration in technology development, with the firms sourcing their technical knowledge from university researchers. Regardless of which scenario has more explanatory salience, one obvious pattern has been deduced: in terms of inventive activities, U-I collaboration activities have remained persistently dominated by both South Korea's top universities (majority of which are located in Seoul metropolitan region) and the largest chaebol companies. Relatedly, when readers observe the degree centrality scores in Table 4-58 in the following pages, it appears that these business groups (especially Samsung, LG, Hyundai, and SK) possess larger innovation networks in comparison to those of universities (**Sohn et al., 2009**).[186]

In other words, there is a tendency for a significant proportion of university scientists to commercialize their research outputs more towards incumbent firms, rather than establish their own technology start-ups, despite intensive efforts by South Korean and Seoul municipal governments in promoting more technology-based entrepreneurship (**Sohn and Kenney, 2007**), such as encouraging universities within Seoul to establish start-up incubators and build linkages with VC associations and incubator managers. Much of this could be attributed to the persistent cultural tendencies, especially among a large proportion of university graduates, to view having stable jobs in large chaebol firms as a social aspiration to be achieved (**Sohn and Kenney, 2007; Witt, 2014**). Whether such path dependence will persist in the long run remains to be seen in the future.

UNIVERSITY-INDUSTRY COLLABORATION IN SCIENCE: EVIDENCE FROM ANALYSIS OF JOINT PUBLICATIONS

Afterwards, we focus on the second analysis, in which we further explore the landscape of scientific collaboration by the city's most vital research university, Seoul National University (SNU). Specifically, we are interested in investigating the nature of relationship between SNU and major innovation actors in Seoul, particularly on knowledge exchange with corporate researchers. Peer-reviewed journal articles, and specifically university-industry (U-I) co-publications, are proxied as the primary unit of analysis in studying the degree of such knowledge exchange. Publication data were obtained from Lens.org, covering a period of 10 years (from early 2009 to end-2018), and U-I co-publications were identified through close investigation of the co-authors' institutional affiliation. Using these approaches, we were able to collect 66,785 journal articles involving SNU researchers, of which 5,604 of them (close to 8.4% of all observations) were labeled as U-I co-publications. This figure was substantially higher than the global average of 6-7% estimated by **Tijssen et al. (2009)** for this indicator.



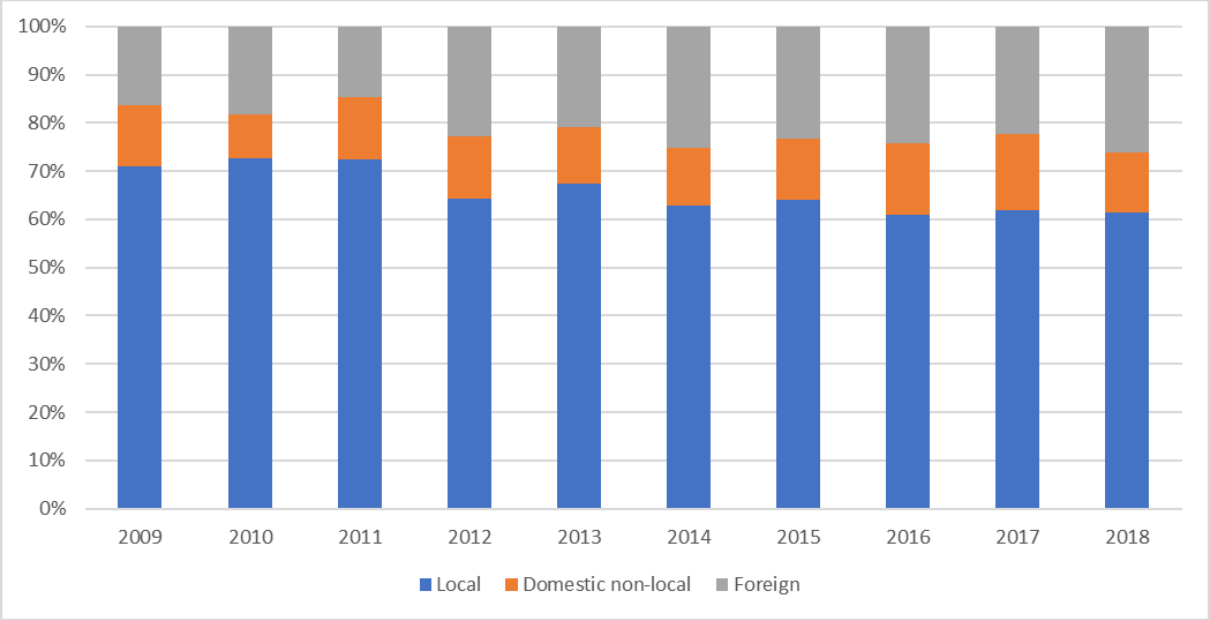


Figure 4-20 Types of U-I co-publications involving SNU (2009-2018) based on the geographical origins of collaborating firms

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Local	316	386	351	351	366	373	397	350	401	371
Domestic non-local	56	48	62	71	64	70	78	86	103	76
Foreign	73	97	71	125	113	150	145	139	144	158

Figure 4-20 above provides a further breakdown of the types of U-I co-publications based on the geographical locations of these enterprises: 1) local; 2) domestic non-local, and; 3) foreign. We proxy a collaborating firm as being 'local' when it is located either in Seoul or the capital's surrounding satellite cities (Incheon, Suwon, Seongnam, Goyang, Yongin, Uijeongbu, Namyangju, Yangju, and Paju), which comprise the broader Seoul metropolitan area. Our decision to also incorporate these cities is driven by the increasing tendencies for governments and businesses to relocate their business and operation units out of Seoul, but within a reasonable distance from the capital (**Lee et al., 2017; Sohn et al., 2009**). Domestic non-local collaborating firms refer to those located outside the metro area, but within South Korea (e.g. the company in question is located in Daejeon). The remaining collaborating enterprises not headquartered in South Korea would be classified as 'foreign enterprises'.

Interpreting from Figure 4-20, we can observe that a disproportionate majority of SNU's U-I co-publications were primarily with firms located within Seoul metropolitan area. Moreover, this pattern happened to be consistent, with the annual output of their joint academic works fluctuating between 350 and 400. In terms of proportion, however, the share dominated by local enterprises has been steadily decreasing over time (from 70% of all U-I co-publications in 2009 to slightly above 60% as of 2018), although their proportion remains the largest. Academic publications with South Korean firms outside the Seoul metropolitan area, nonetheless, have only increased more slowly, with their proportion rising from 13% in 2009

to about 15% in 2018. By contrast, SNU's scientific ventures with foreign firms grew more rapidly, both in absolute numbers and proportion. Regarding the former, SNU's U-I co-publications with these enterprises slightly more than doubled from 73 in 2009 to 158 in 2018; with respect to the latter, the share has also risen from about 17% in 2009 to around 25% in 2018. In summary, SNU scientists happen to collaborate more frequently with Seoul-based enterprises, and increasingly with foreign multinationals.

This pattern, on one hand, reflects a persistent trend of regional inequality within South Korea (**Lee, 2009; Lee et al., 2017**), particularly in U-I collaboration in scientific knowledge, and in spite of efforts by successive administrations to ameliorate this phenomenon. On the other hand, this is also attributed to the comparatively larger innovation networks nurtured by Seoul-based enterprises (for which majority of South Korea's largest businesses are headquartered), which enable them to collaborate more frequently – and also intensively – with researchers in co-located universities (**Sohn et al., 2009**). Whether such trend also holds true for other Seoul-based universities, e.g. Yonsei, Korea U, Sungkyunkwan, Hanyang, etc., is subject to further studies in the future.

Table 4-58 below provides further information about the top-10 collaborator lists for SNU researchers based on the three geographical categories. With regard to local enterprises, more than 40% of SNU's U-I co-publications were concentrated in these enterprises, majority of which are affiliated to the 'Big Four' chaebol groups (Samsung, Hyundai, LG, SK). Indeed, Samsung Electronics alone accounts for about 30% (N = 1,101) of SNU's entire U-I co-publications with Seoul-based firms. This finding demonstrates Samsung's high degree of linkages with South Korea's most prestigious university not only in technical expertise, as we have illustrated in the previous sub-section, but also in exchange of scientific knowledge that may be of strategic importance for the company's foray into emerging technologies. SNU researchers also closely work together with their corporate counterparts at Hyundai Motor, SK Group's subsidiaries (e.g. SK Telecom), as well as LG Group affiliates (notably LG Electronics and LG Chemical).

With regard to SNU's scientific collaboration with industry actors from the rest of the country, the landscape is considerably distinctive. 6 of the top-10 industry collaborators under this category happened to be South Korean government's state-owned enterprises (SOEs), and these examples include: POSCO (Pohang Iron and Steel Corporation), Korea Electric Power – better known as KEPCO, Korea Gas Corporation, K-Water (abbreviation of Korea Water Resources Corporation), Korea Rural Community Corporation (KRCC), and Korea Aerospace Industries. Many of these SOEs are located outside of Seoul capital region, partly as a government policy to minimize regional inequalities between the region and the rest of the country (**Lee, 2009**).[187] Moreover, only 1 enterprise in the top-10 list was linked to the 'Big Four' groups, namely Hyundai Heavy Industries. The remainder were occupied by firms linked to smaller-sized chaebol groups: Daewoo Shipbuilding and Doosan Heavy Industries. A significant proportion of their co-publications were concentrated on topics related to heavy industries, shipbuilding, engineering, and infrastructure development.

Last but not least, we also take into consideration SNU's research collaboration with foreign firms. In terms of the composition of the top-10 collaborator list (shown in the third column of

Table 4-58), majority (N = 7) of them are multinational pharmaceutical firms, as notably shown by Pfizer, Merck, Novartis, Roche, AstraZeneca, Genentech, and GlaxoSmithKline (GSK). The significant position of these pharmaceutical giants in the list could be attributed to the university's School of Medicine, which has been considered as among the leading research-intensive medical schools in South Korea, and the world.

Table 4-58 Top 10 collaborating firms with Seoul National University (SNU) in U-I co-publications (2009-2018 period, number of co-publications indicated in brackets)

Local firms (N = 3,662)	Domestic non-local firms (N = 714)	Foreign firms (N = 1,215)
Samsung Electronics (1,101)	POSCO (99)	Pfizer (79)
Hyundai Motor Co. (83)	Korea Electric Power (60)	Merck & Co. (42)
Amorepacific (76)	Hyundai Heavy Ind. (47)	Novartis (37)
NAVER (42)	Daewoo Shipbuilding (39)	Hoffmann-La Roche (31)
SK Group (40)	Korea Gas Corp (16)	AstraZeneca (29)
Kia Motors (37)	K-Water (10)	Siemens (29)
LG Electronics (31)	Biogenics (9)	Hewlett-Packard (23)
LG Chemical (30)	Doosan Heavy Ind. (7)	Genentech (22)
Samsung SDS (30)	Korea Rural Comm (7)	GlaxoSmithKline (22)
SK Telecom (30)	Korea Aerospace Ind. (4)	Subaru (22)

SNU's recurrent collaboration with Samsung, Hyundai, LG, and SK has been particularly interesting, with which we will elaborate in the bullet points below:

- Samsung Electronics: the very intensive linkages between the two organizations were unparalleled in comparison to other instances of academia-industry collaboration across the world. From our further analysis in Lens.org database, we found that their co-publications have been centered on a wide range of fields, e.g. electrical and electronic engineering, optical and magnetic materials, semiconductor, mechanical engineering, chemistry, solid-state physics, software, etc. In recent years, formal two-way knowledge exchanges have further intensified. Notable illustrations include plans to establish a research consortium comprised of SNU's 20 top professors with the company's Samsung Advanced Institute of Technology (SAIT) in 2018[188], a KRW100 billion (US$88 million) investment into semiconductor research at Korea's top local universities [189], and a joint graduate-degree program with the country's major universities in semiconductor-related development.[190]

- Hyundai Motor: the automotive company's scientific research collaboration with their SNU counterparts has also spanned a wide range of disciplinary fields, notably in automotive engineering, mechanical engineering, manufacturing engineering, pollution control, electronic engineering, systems engineering, etc. In recent years, the company is further intensifying their collaboration with SNU in the development of lithium-ion batteries for the company's electric vehicles (EV). Relatedly, the two organizations seek to further collaborate in developing better battery management systems (BMS),

solid-state batteries (SSB), battery processing technologies, as well as reducing charging hours for EV.[191]

- LG Group: the business conglomerate – through some of its affiliate firms, as listed in Table 4-58 above – has engaged in two-way knowledge exchange with SNU researchers on multiple disciplines, notably material science, computer science, optoelectronics, chemical engineering, artificial intelligence, composite material, etc. Some major milestones in LG-SNU collaboration, from a chronological order, include: 1) joint development of next-generation display technology in 2012[192]; 2) development of biomaterials to support the transition of agriculture industry into a more high-tech driven, e.g. crop protection materials[193]; 3) formation of a consortium between LG Science Park and Artificial Intelligence Institute of SNU (AIIS) in June 2020[194], and; 4) the launching of a 'digital transformation center' by SNU and LG Chem, with the aim of supporting the application of AI into the company's R&D, production, and overall business operation.[195]

- SK Group: similar to the cases demonstrated by Samsung, Hyundai, and LG, the business conglomerate has frequently engaged SNU researchers in various aspects of their operations. Through our desktop research, we identified at least three instances of in-depth collaboration between the two parties, such as: 1) the launching of smart hospital solutions in SNU Bundang Hospital in 2012 by SK Telecom, an ICT arm of the chaebol group[196]; 2) AI-enabled dementia prevention support services for elderly care facilities in Seoul, also through SNU-SK Telecom joint development[197], and; 3) a new consortium on COVID-19 vaccine R&D and clinical trials involving SK Bioscience, SNU, and GSK, with SNU providing support in clinical trials.[198]

Nevertheless, despite the high degree of concentration in U-I scientific collaboration on the 'big four' chaebol groups, many of the faculty members and reserchers in SNU continue to retain close ties with companies spun off from research units within the campus. Replicating our approach in other innovation hubs covered in the Task 3 report, we further subset the U-I co-publications involving firms based within Seoul metropolitan region to identify which of these industry collaborators happen to be university-based spin-offs. We adopted the approach by **Powell et al. (2016)** through comprehensive 'site visits' of company websites, with our particular interest in identifying their founders. We label such publications as 'spin-offs' when the founders had past education and/or research and/or work backgrounds in SNU at any time of their lives, whether as students, alumni, PhD candidates, postdoctoral fellows, professors, practicing doctors, etc. Spin-off categorization also encompasses firms that, while having no SNU-related background, have explicitly stated in their websites that they license follow-on technologies based on research in the university. In total, we identified 80 such companies, and an aggregate of 500 U-I co-publications, equivalent to almost 14% of SNU's joint academic works with Seoul region-based firms.

Table 4-59 Specialization of SNU spin-offs identified from U-I co-publications (2009-2018)

Sector	Number (N = 80)
Biotechnology/pharmaceuticals	51
Software	5
Nanotechnology	4
Bioinformatics	2
Consulting	2
Contract research organization (CRO)	2
Material sciences	2
Mobile gaming	2
Semiconductor	2
Social media	2
Cybersecurity	1
Fuel cells	1
Green technologies	1
Medical devices	1
Scientific instruments	1
Sensors	1

Table 4-59 above highlights the sectoral specialization of these 80 spin-offs. Interestingly, more than half of these enterprises are concentrated in life science-related industries, namely: biotechnology/pharmaceuticals (N = 51), bioinformatics (N = 2), medical devices (N = 1), and contract research organizations (CRO) (N = 2). One of these enterprises, Macrogen (see Table 4-60 below), is among the first-generation biotechnology firms in South Korea, reflecting SNU's role as a major early pioneer of life science research in the country. In aggregate, they accounted for 70% of the identified spin-offs originating from SNU. The remaining enterprises, meanwhile, are engaged in a wide variety of industries, such as software, nanotechnology, material sciences, mobile gaming, semiconductor, cybersecurity, fuel cells, green technologies, sensors, etc. The following Table 4-60 briefly summarizes the profiles of some notable spin-offs from this list.

Table 4-60 Notable SNU spin-offs identified from U-I co-publication analysis (2009-2018)

Name	University	Profile
BeadTech	SNU	BeadTech is a company specialized in producing solid-support for the synthesis of peptides and various biomolecules. Having been designated as an exclusive manufacturer of solid support in South Korea since early 2000s, the company focuses on developing Merrifield resin, Wang resin, and 2-chlorotrityl resin. BeadTech was established in 1999, initially as a biotechnology start-up venture at SNU.
BioAlpha	SNU	BioAlpha is a Korean company that specializes in promoting the

		development and regeneration of musculoskeletal system with biomaterials. They develop innovations in medical devices (especially those in restoring musculoskeletal systems) based on their innovations in artificial bone research. The company was established in 1995 in order to commercialize artificial bone research at SNU by the university's orthopedic and material engineering research team.
BioINFRA	SNU	BioINFRA is a biotechnology company focused on developing precision medicine for cancer-related treatments. Since its establishment in 2001, the company has sought to utilize their advances in biomarkers and bioinformatics to develop gene-based cancer therapeutics, as well as technologies that can systematically monitor the possibility of metastasis and cancer recurrence in blood for patients and cancer survivors. Here, the company seeks to go beyond diagnostic devices, reagent development, and molecular diagnosis. The company was established in 2001 at Seoul National University (SNU) Cancer Research Institute under the leadership of Kim Chul-woo, professor and expert on cancer research.
Celemics	SNU	Celemics is a biotechnology company whose core innovation lies on their DNA-based biomaterials and revolutionary sequencing technologies that will be useful for medical, drug identification and development, microbiome, synthetic biology, etc. Celemics aspires that these new biomaterials, when applied to these fields, would contribute to better collective health and safety. Celemics was founded in 2012, and is currently led, by Kim Hyo-ki, based on his PhD research at Seoul National University (SNU). He obtained his PhD there in 2013.
Curiosis	SNU Hanyang University KAIST Kyungpook Nat Univ	Curiosis is a Korean biotechnology company that focuses on cellular-based application. It develops Celloger Mini, an automatic, live cell-imaging system based on brightfield microscopy technique that can withstand high temperature and humidity. It also develops FASCOPE B, a fully automatic stand-alone cell-counting technology based on brightfield microscopy as well. Curiosis was established in 2015 as a merger of two start-ups (Curiosis and Cytoneers). Curiosis is led by Yun Hoyoung (PhD graduate of Seoul National University / SNU, now the company's president and CEO), Um Changyong (PhD graduate from SNU), Hur Daesung (formerly CEO of Curiosis and graduate of Kyungpook National University), and Song Seungjung (PhD graduate of KAIST). The company's scientific advisors are Noo Li Jeon (professor at SNU) and Sung Young Choi (assistant professor at Hanyang University).
FunctionBay	SNU	FunctionBay is a company that develops computer-aided engineering (CAE) simulation software for flexible and rigid body dynamics. The

		products have been applied in a wide range of technologies, e.g. automotive, shipbuilding, railway, office equipment, robots, heavy industry, military vehicles and equipment, etc. Their core innovations are RecurDyn and Multi-Flexible Body Dynamics (MFBD). FunctionBay was established in 1999, and is currently led, by Jang Kyung-cheon, based on his PhD research at SNU, where he graduated in 2001.
Macrogen	SNU	Macrogen is a leading biotechnology company and an early pioneer of precision medicine. It is also the first biotechnology company in South Korea to be publicly listed in KOSDAQ, Korea's version of NASDAQ. Macrogen's core innovations are in: 1) personalized genomics; 2) sequencing analysis; 3) biochip analysis through microarrays; 4) genetically-engineered mice (GEM), as well as; 5) bioinformatics for clinical research. The company's key areas, at present, are in precision medicine and clinical diagnostics. iD4U™ genetic testing services for kinship and personal identification, and myPETGENE™, a genetic testing service for pets. Macrogen was founded in 1997, and is currently led, by Jeong-sun Seo, a former professor at Seoul National University (SNU) College of Medicine and Bundang Hospital.
NIBEC	SNU	NIBEC (also known as Nano Intelligent Biomedical Engineering Corporation) is a biotech company that innovates in regenerative drugs and peptide technology. Their core innovations are linked to these following areas: dental bone grafts, tissue-regenerating collagen, as well as bio-collagen scaffold. NIBEC aspires to apply bioactive peptide technology to improve existing biomaterials, in order to reduce the risks of inflammation. NIBEC was established in 2000 to commercialize research on dental technologies at Seoul National University (SNU). It was founded, and is currently led, by Chong-Pyoung Chung, an entrepreneur and also a chair professor and dean of school of dentistry at SNU. He received his PhD at SNU as well.
Nanobrick	SNU	Nanobrick is a company with specialization in nanomaterial-related technologies. Its core innovation lies in developing the world's first magnetically tunable photonic crystal material technology since its establishment, which may enhance the production process of nanomaterials. In addition to developing new nanomaterials, Nanobrick has a broad portfolio of technology development projects (mainly in security-related technologies), e.g. genuine authentication solution of M-TAG, authentication packaging solution by M-PAC, magnetic writing board under M-PAPER, magnetic flexible skin with M-SKIN brand, etc. Nanobrick was established in 2007, and is currently led, by James Joo Jae-Hyun. He is a serial entrepreneur, former research scientist at Samsung

		Electronics and LG Semiconductor, and a former postdoctoral fellow at UC Berkeley in the United States. He received his PhD from Seoul National University (SNU) in 1996.
NanoEnTek	SNU MIT	NanoEnTek is a company pioneering point-of-care testing (POCT) technology. The company develops their expertise in POCT based on their in-depth R&D of microfluidic chips. A major core innovation in their microfluidic chip research relates to seamless integration between biotech and micro-electro mechanical systems (MEMS), also known as Bio-MEMS technology. The company aims to strengthen their capabilities and expertise in lab-on-a-chip platform technologies, which enhance laboratory-like processes on a fingernail-sized chip, and thus improve research in life sciences and bioengineering significantly. To this stage, the company has had a total of 100 patents in NT-IT-BT (nanotechnology-IT-biotech) convergence technology, both in Korean and overseas patent offices. Beyond lab-on-a-chip products, the company is awaiting approval from US FDA for the world's first micro blood-analyzer (ADAM-rWBC) technology. NanoEnTek was established in 2000, and is currently led, by Chan-il Chung, a serial entrepreneur and former scientist with PhD from Seoul National University (SNU) in 1997. He was a former postdoctoral fellow at Massachusetts Institute of Technology (MIT) in the United States.
PDXen Biosystem	SNU Korea Univ	PDXen Biosystem is a biotechnology company specialized in patient-derived xenografts (PDX). PDX refer to models of cancer in which existing tissues and/or cells from a patient's tumor are implanted into an immunodeficient oncomouse for medical analysis. Beyond PDX, they also focus on circulating tumor cell analysis, primarily by live imaging and single-cell tracking. The company also combines deep-learning methods from R&D in artificial intelligence (AI) in surveying, as well as classifying, biological data, especially in identifying potential oncogenes. PDXen Biosystem was established, and is currently led, by Ahn Kwang-Sung, a scientist and entrepreneur. He was a former PhD and postdoctoral researcher at the University of Houston and UCLA in the United States, and is currently a research professor at both Korea University and Seoul National University (SNU).
ToolGen	SNU	ToolGen is a biotechnology company dedicated to pioneering the commercialization of genome-editing technologies. They have contributed in developing several generations of genome-editing tools, e.g. ZFN (Zinc Finger Nuclease), TALEN (TAL effector nuclease), and most recently, CRISPR/Cas9. At present, the company's core focus lies in further refining their expertise in CRISPR/Cas9. On the basis of these platform technologies, ToolGen seeks to apply them in developing key therapeutic

		treatments, molecular breeding of plants and animals, and various treatments, as well as openly sharing these platform technologies with both academic and industry partners in South Korea and globally. ToolGen was founded in 1999 by Kim Jin-su when he was a professor at Seoul National University (SNU). He is currently a chief scientist at the Korea Institute of Basic Science (KIBS).

To conclude from our second analysis, SNU's scientific collaboration with industries (as reflected from U-I co-publications) by and large resemble the findings we have obtained from analyzing inter-organizational linkages based on USPTO patent data. In this regard, a large proportion of these published journal articles involved large corporations from South Korea's largest chaebol business groups, mainly Samsung, Hyundai, LG, and SK. To a limited extent, the university also collaborates with firms based outside Seoul metropolitan region, but a high proportion of them are state-owned enterprises (SOEs), many of which have been relocated by the Korean government over the last few decades to address the ongoing problem of regional inequalities dividing the region and the rest of the country. Interestingly, SNU also actively collaborates with numerous companies that were spun off from research taking place at the institution; majority of these businesses happen to be related to life science and biotechnology. It is, indeed, in the life science/biotechnology industries that SNU has a controversial relationship with in the past (and which we will elaborate briefly in the mini-box below), and one with important implications on the potential 'dark sides' of knowledge / technology transfer (**Fini et al., 2018**).

4.4.6.5.Discussions and conclusions

In comparison to other hubs we included in the Task 3 report, Seoul's case is outstanding as we identified one unifying thread based on the three analyses we have performed in the previous pages: the city's innovation ecosystem – and South Korea's national innovation system by extension – has been consistently dominated by the same set of business groups (chaebol) for decades. This was firstly evident from the analysis of inter-organizational linkages proxied from USPTO PatentsView data: from 1983 (the starting period of our study) up to 2018, Seoul's innovation networks were primarily centered on Samsung, LG, and to a limited extent from other major business groups (namely Hyundai and SK). Over time, universities and public research organizations – as shown by SNU, Korea University, Yonsei, Sungkyunkwan, KIST, etc. – have stepped up their roles as innovation actors within both the networks and the ecosystem, but as we have demonstrated from further analysis of their degree centrality linkages, a significant contributor that explains the enhanced roles of these institutions was attributed to very close linkages between these organizations and South Korea's chaebol groups, whether for career mobility, formal collaboration, research internships, informal knowledge exchange, etc. To a certain extent, our findings supported the proposition

by Witt (2014) about the tendencies for chaebol firms to hire the best talents, often at the expense of SMEs and other start-ups.

Inter-organizational linkages between chaebol firms and these universities are not limited to technological developments alone. In terms of exchange of scientific knowledge, we also observed intense two-way ties among the two stakeholders, as reflected from the joint publications involving these researchers. With specific regard to SNU, the 'big four' chaebols have established a wide range of joint research centers and/or programs that provide significant real-world exposure for the university students, faculty members, and research staff. Nevertheless, U-I collaboration within this category is not solely dominated by large corporations; through U-I co-publication indicator, we managed to identify a total of 80 SNU-based spin-offs, more than half of which specialize in life science-related industries. We can interpret, from this finding, that SNU has indirectly contributed to the creation of a life science cluster within Seoul.

The third analysis focuses on examining financing deals by Seoul's leading investors and VC funds, and the extent to which these transactions are dedicated for co-located technology start-ups also based within the capital region. Our finding shows that a significant proportion of the city's top-25 investors happen to be corporate VC funds of these chaebol firms (notably Samsung), but with a below-average co-located investment rate in comparison to those of top-25 investors more broadly. In other words, these companies' attention on building ties with niche-technology start-ups is agnostic to geographical proximity/distance, so long as these businesses are aligned with their core expertise and capabilities. The below-average co-located investment rate is also observed in the case of other corporate VC funds belonging to the big four chaebol groups.

What can Hong Kong learn from the Seoul case study? From our point of view, we could only identify one major lesson, which is about strengthening institutional ties between academia and industry. Before we elaborate further about our lesson, we shall point out the differences in contextual circumstances characterizing the two cities. In the case of Seoul, the fact that the city serves as South Korea's capital meant that a significant proportion of resources – whether for government administration, industry development, education, as well as research – have been highly concentrated within the city, a strategic advantage that Hong Kong, with the exception of education and research, does not possess. Moreover, Seoul's current innovation ecosystem was intertwined with South Korea's past history of strong state intervention, which also contrasts sharply with the historically, mostly laissez-faire orientation of the authorities in Hong Kong until recent years. The country's leading chaebol groups diverge considerably from Hong Kong's big businesses as well, in the sense that the former have been among the world's leading corporate R&D spenders, whereas business expenditure in R&D for the latter remains below the global average.

4.4.7. Singapore

4.4.7.1.Introduction

Located adjacent to the Malacca Straits, Singapore is a small island nation with a land area of 728.6 square kilometers (sq km), with a total population of 5.7 million and extremely scarce natural resources. Nevertheless, in spite of their significant resource constraints, the city-state has achieved impressive economic development records since its political independence in 1965. Through their ongoing commitment to investments in human resources, as well as science, technology, and innovation (STI)-related capabilities, on top of leveraging their commitment to economic globalization and harnessing the potential from global innovation networks, Singapore has continued to enhance and refine their national innovation system, and has been embarking on a structural shift from a capital-intensive, manufacturing-led economy into a knowledge- and innovation-driven model. At present, Singapore stands as one of the most economically and technologically advanced countries in the world, with its gross domestic product (GDP) per capita risen from US$516 in 1965, to US$ 59, 798 in 2020. Moreover, according to the **Global Innovation Index (GII)** 2021 published by WIPO, Singapore ranks 8th out of 132 economies, and excels in key pillars such as "institutions," and "human capital and research." Table 4-61 provides further descriptive statistics about Singapore's international position in various indicators within the Global Innovation Index.

Table 4-61 Singapore's international position in indicators under Global Innovation Index 2021

Tier 1 indicators	Ranking	Tier 2 indicators	Score	Ranking
Innovation input	1	Institutions	95.1	1
		Human capital and research	58.7	9
		Infrastructure	57.8	15
		Market sophistication	75.9	5
		Business sophistication	62.7	3
Innovation output	13	Knowledge and technology outputs	48.1	13
		Creative outputs	42.9	17

Singapore's rapid development– especially in innovation-related activities – is inextricably linked to the country's efforts to build a well-developed innovation ecosystem. The government has encouraged the foreign multinational corporations (MNCs) to establish local R&D bases and invested heavily in human resource and higher education in the past decades, enabling the industrial growth and technology upgrading in Singapore (**Wong & Singh, 2008**). In addition, small and medium-sized enterprises (SMEs) have also been given access to public research institutes and universities to develop indigenous technologies and competitive products. Since mid-1990s, the government has put in place a series of Five-Year Plans (FYP) in science and technology aiming at the development of local capabilities. As an illustration, in 2016, the

National Research Foundation (NRF) released their Research, Innovation, and Enterprise (RIE) 2016-2020 Plan, which primarily emphasized the creation of a more dynamic, and open, innovation and entrepreneurship ecosystem as a core task for Singapore's future FYP strategies (**Ministry of Trade and Industry of Singapore, 2016**). The RIE plans included sustained investment in foundational research capabilities, technology translation, and commercialisation strategies to anchor Singapore's position as a global innovation, sustainable, and digital nation. Overall, it can be observed that Singapore's innovation ecosystem development can be described as largely government-led effort, much of which has enabled the city-state to transform into a globally leading innovation hub.

Education has been high priority since the independence of Singapore, as stated in the NRE. The number of public universities have tripled from two universities to six universities in the past 2 decades. Universities have come to occupy a prominent role in Singapore's innovation system/ Singapore has six public universities, two of which are two highly ranked comprehensive universities and four more focused universities. Collectively, these six universities help to achieve a cohort participation rate of close to 40 percent. The Singapore government has assigned to the NUS and NTU a role that resembles that of Georgia Tech in the transformation of Atlanta into an innovation-driven economy**(Youtie & Shapira, 2008**).

4.4.7.2.Historical trends (of innovation and economic growth, regional industry structure)

Before we elaborate further about Singapore's innovation policy framework, we shall briefly review the city-state's post-1965 historical contexts. After the city-state declared its independence from Malaysia in 1965, the People's Action Party (PAP) solidified their political rule in the newly-established country, and has continued to remain in power to this day (**Lee, 2013**).[199] PAP's decades-old rule would also pave way for the swift, and consistent, adoption and enforcement of business-friendly policies that were aimed to promote Singapore as a strategic hub open for foreign direct investment (FDI), manufacturing, capital-intensive industries, as well as international trade. Simultaneously, the government's key strategy to develop its industries – and more recently, an innovation- and knowledge-led economy – is to rely on strong intervention and substantial resource allocation to achieve these aims. To further integrate with the global economy, the PAP-led government formulated a series of FDI-led industrialization plans (**Clark and Kim, 1995; Perry et al., 1997**). By the end of the 1980s, however, Singaporean government has decided to remodel their economic development strategies, part of which have shaped the substance of their national, FDI-led comparative and competitive advantages, particularly in the aftermath of 1985-1986 global recession – of which the city-state was adversely impacted – as well as the 1997-1998 Asian financial crisis, all of which rendered the city-state vulnerable to external shocks (**Clark and Kim, 1995; Ho, 1993; Ho, 2003**).

Singapore's innovation system has been defined by a substantial emphasis on attracting foreign direct investment (FDI) and using technology generated by multinational corporations (MNCs) to disseminate innovations to local enterprises throughout its history (**Wong and Singh, 2008**). The national innovation ecosystem (NIE) was started by the Singaporean government to

facilitate technological spillovers and learning from multinational corporations (MNCs) to local businesses. Aside from an initial 5-year plan (1960–1964), the flexibility and responsiveness of government institutions in developing a technology strategy aligned with wider economic growth objectives, which has incentivized firms to invest in technological upgrading, has characterized the development of the NIE in Singapore **(Ritchie, 2001)**. In the last four decades, Singapore's NIE has developed across the following four main phases:

Table 4-62 The four phases of NIE development in Singapore

Phase	Characteristics
Industry takeoff (1965 to mid-1970s)	Dependence on technology transfer from MNC to establish Singapore as a labor-intensive manufacturing hub
Technological Deepening (mid-1970s to late 1980s)	Rapid growth of local process innovations and the development of a critical local manufacturing base to MNCs
Applied R&D expansion (Late 1980s to late 1990s)	Expansion of applied R&D activities by foreign multinationals and the establishment of new public R&D institutions to support those activities
Shift toward high technology entrepreneurship and basic R&D (Late 1990s onward)	Rise of indigenous innovation capabilities, formation of local high-tech start-ups

Source: adoption from Singapore's four phases, **Wong & Singh (2008)**

Singapore has always aspired to achieve a higher level of economic prosperity and has developed many industrial policies to sustain and stimulate its economic development to eventually reach the status of a developed country. Singapore's industrial development can also be divided into 4 stages **(Andrew, 2006)**, which is similar to the development of NIE. In the 1960s, Singapore began industrialization only after it became an independent country. The government's industrial policy supported labor-intensive industrialization to create more jobs, due to the excessive economic dependence on entrepôt trade. In the 1970s, Singapore embarked on export-oriented industrialization driven by foreign direct investment (FDI), which boosted domestic productivity by attracting FDI inflows. These investments provided the additional potential for capacity development of Singapore industries, technology acquisition, and renewal of international business practices. The process also expanded Singapore's industrial structure to include new technology-based industries with higher value-added output. During these two phases, Singapore's R&D spending levels were low, with industrial policy emphasis placed on developing productive capacity **(Ho & Wong, 2017)**. In the 1980s, although Singapore went through a period of economic recession in 1985, its industrialization was firmly established in several sectors of industry and commerce. As global competition intensified, the Singapore government adopted cost-competitive industrial policy preferences to promote cost-competitive industrialization to further improve its overall competitiveness relative to regional economies. Singapore upgraded its economic value chain to move away from low-cost

competition in traditional manufacturing and service industries and develop new high-tech clusters and activities. R&D expenditures rose, stimulating an atmosphere of entrepreneurial and innovative pursuits.

Since the early 1990s, there has been an emerging shift in industrial policy toward developing innovative capabilities, accelerated by the strategy of developing a knowledge-based economy. The government intensified the R&D investments in the public sector, including the universities, polytechnics, research institutions, and government-linked companies, while promoting research expenditures in the private sector through incentives. Initially aimed at developing the indigenous capacity to conduct applied R&D, it later promoted the creation and commercialization of intellectual capital to support knowledge-based economic growth. Such revelation also led to further realization about the fact that in spite of Singapore's remarkable economic growth over the last 2-3 decades, the city-state has historically lacked behind in terms of commitment to research and development (R&D) activities; indeed, the country only began to attach strategic importance, and devote significant resources, to support R&D from 1995 onwards, which witnessed a marked increase in the levels of R&D expenditure (**Ho et al., 2009**). Historically, throughout the 1980s and 1990s, Singapore's R&D expenditure (proxied by its ratio to GDP) was negligible, accounting for less than 0.5% of GDP annually; nevertheless, the city-state's R&D-to-GDP ratio exceeded 2% for the first time in 2001, and has stayed at approximately 2% since the early 2000s. The number of research scientists and engineers (abbreviated by Statistics Singapore as 'RSE') also rose in tandem with R&D spending, from 8.5 RSEs per a labor force of 10,000 in 1978 to 87.6 by 2001.

Nowadays, Singapore has a highly developed free-market economy and belongs to the league of the developed nations. According to Singapore's nominal GDP by sector in 2021, around 70% of nominal value added was generated by services industries, while about 25% was generated by goods-producing industries. Moreover, high-tech sectors contribute significantly to the Singapore economy, generating 29.5% of total Value Added, with the high-tech services sector being the most dynamic sector in Singapore **(Kam et al., 2017)**. And the number of startups in Singapore has more than doubled in the last decade, growing from 22,800 in 2004 to 55,000 in 2014 **(Poh, 2016)**. Overall, the economic development base and industrial structure in Singapore have created a favorable environment for its technology innovation, knowledge and technology transfer. Singapore's research and innovation system has been developed differently from many other successful research-intensive countries around the world. R&D push in Singapore is primarily a government-led, targeted effort to upgrade and strengthen the domestic economy, which is rooted in the need for economic competitiveness and growth **(Poh, 2016)**. And the need to move to an innovation-driven economy was recognized much earlier than in neighboring countries. Today, Singapore's policies continue to heavily emphasize economic outcomes and impact, and promote technology transfer and commercialization.

Overview of R&D in Singapore

Singapore's strong performance in innovation input was backed up by data showing a steady growth in R&D expenditure across all types of performing actors in the city-state over the last

two decade. Moreover, the city has witnessed a considerable increase in the number of R&D-performing personnel and organizations over time, the details by which are visualized in Figure 4-21 (A)(B)(C)below.

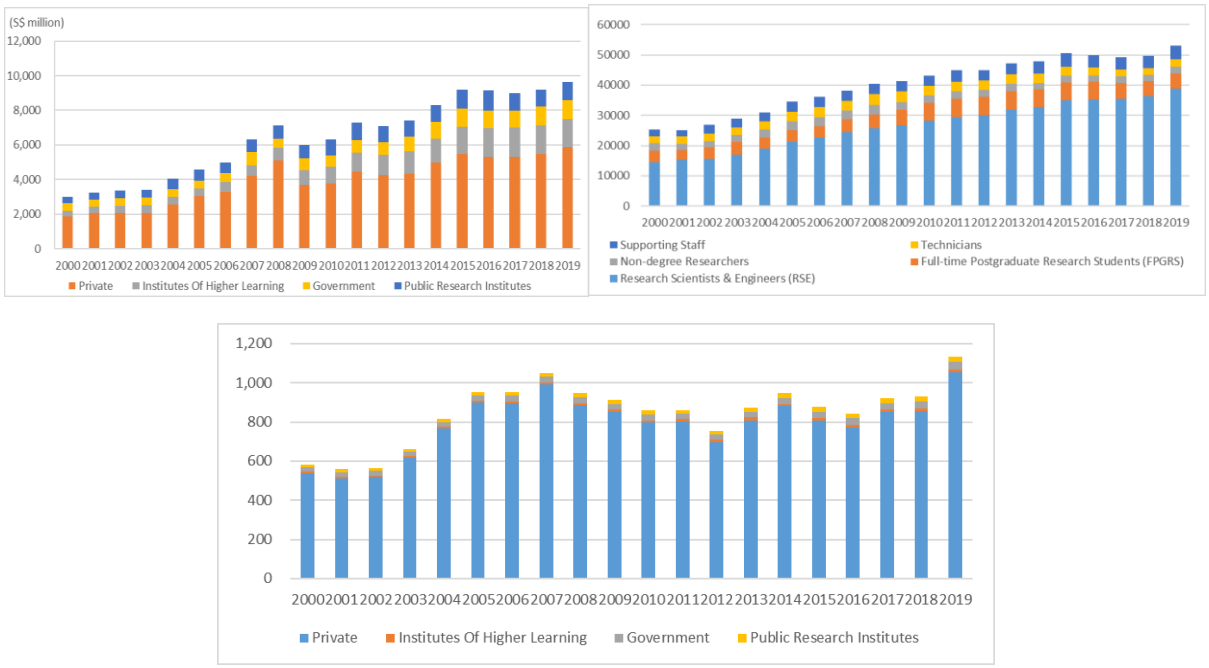
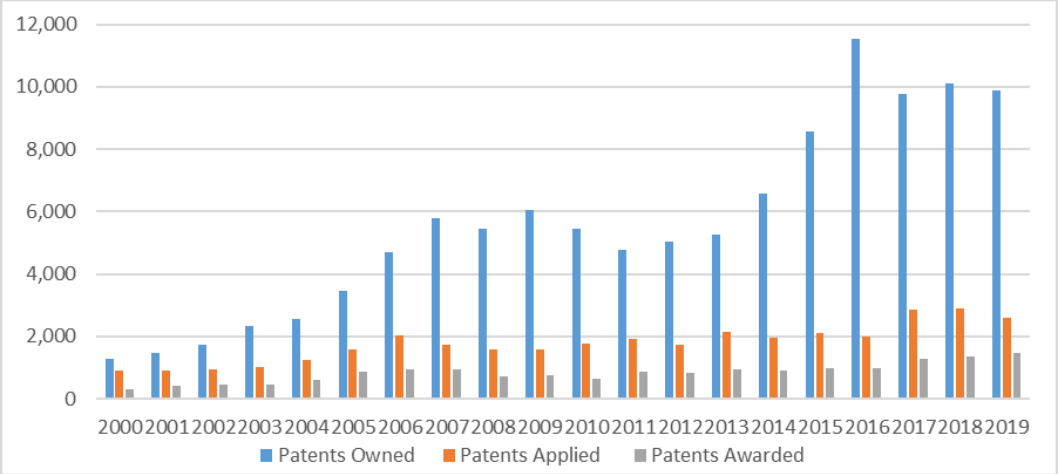


Figure 4-21 Descriptive statistics on R&D activities in Singapore, 2000-2019. (A) – Amount of R&D expenditure by different types of performing actors. (B) – Number of R&D personnel by different types of performing actors. (C) – Number of R&D-performing organizations across different years. Source: Department of Statistics – Singapore (2022)

Nevertheless, although Singapore ranked very highly globally in terms of innovation inputs, the city-state slightly lags behind with respect to innovation output indicators, in which it was positioned on the 13th rank. This aligns with the finding by **Sharif et al. (2021)** and **Wong et al. (2017)** that while Singapore's total factor productivity (TFP) corresponds positively with both public and private R&D investments, its elasticity still lags behind other more advanced, developed economies, especially those in Europe, Israel, and the United States. In other words, this suggests that the efficiency in Singapore's innovation output can be further improved, particularly in enhancing knowledge diffusion and the development of intangible assets, e.g. building a thriving creative industry. In spite of such limitation, Singapore's innovation output (which we proxy with patents, as shown in Figure 4-23 below) has been no less impressive.



Source: Department of Statistics – Singapore (2022)

Figure 4-22 Innovation output in Singapore, proxied by patent filings and grants

Multiplication of innovation policies in Singapore

One of the biggest impetus in Singapore's evolution of innovation policy framework was the establishment of National Research Foundation (NRF) in January 2006. As a government department directly under the Prime Minister's Office (PMO), NRF sets the national direction for research and development (R&D) in the city by developing policies, plans, and long-term strategies under the Research, Innovation, and Enterprise (RIE) umbrella, as well as providing funding to support strategic initiatives and the hiring of relevant research talents (**NRF, 2022a**). The NRF, through RIE, also actively promotes joint R&D projects as one of the technology transfer mechanisms to ensure the transferability of knowledge from universities and research institutes for addressing industry needs. Figure 4-23 below demonstrates the RIE policy ecosystem, which also comprises various ministries, R&D funding bodies, and R&D-performing actors. Table 4-63 further elaborates about the specific roles performed by select entities with regard to the city-state's innovation policy structure.

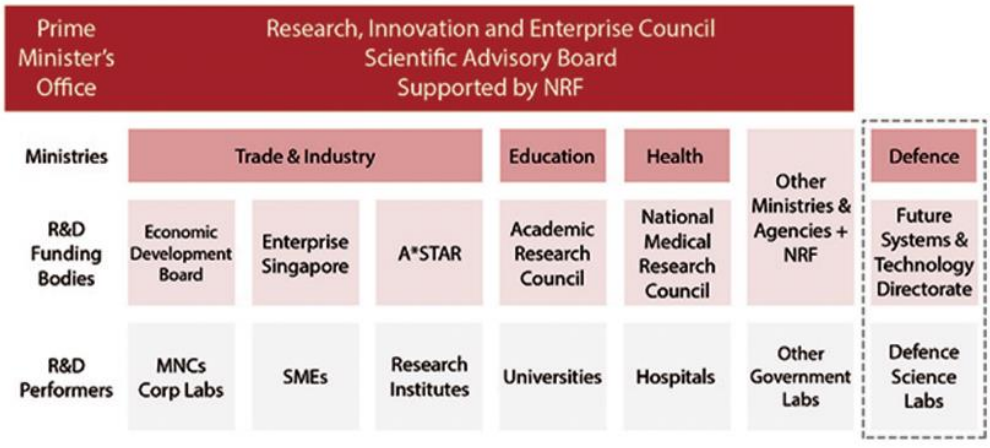


Figure 4-23 The institutional innovation policy framework of NRF; Source: **NRF (2022b)**

Table 4-63 Key government agencies under the RIE ecosystem landscape

Name	Main role (on innovation policy framework)
Ministry of Trade and Industry (MTI)	Formulating and implementing policies to promote industry R&D with strategic economic value
Economic Development Board (EDB)	Providing funding support for companies to conduct R&D, and other forms of financing for research-intensive firms and technology start-ups
Enterprise Singapore	Building a vibrant, entrepreneurial start-up ecosystem in Singapore by supporting start-ups & building networks
Agency for Science, Technology, and Research (A*STAR)	Performing applied R&D in areas of the government's strategic interest, whether with universities or in collaboration with other major enterprises in Singapore
Ministry of Education (MOE)	Overseeing policies related to higher education institutions (HEIs) and providing funding support for HEIs in carrying out research activities
Ministry of Health (MOH)	Overseeing policies and providing funding support to academic medical centers and hospitals; the ministry also operates an ongoing 'grand challenge' program on population aging, titled "National Innovation Challenge on Active and Confident Aging"
Ministry of National Development (MND)	Running an ongoing 'grand challenge' program relating to land and urban planning, titled "National Innovation Challenge on Land and Livability"
Infocomm-Media Development Authority	Jointly operating as a co-secretariat for Singapore's smart-city development program under the "Smart Systems Strategic Research Program" umbrella
Smart Nation Program Office	Jointly operating as a co-secretariat for Singapore's smart-city development program (together with Infocomm-MDA) under the "Smart Systems Strategic Research Program" umbrella
National Water Agency (OPUB)	Running an ongoing 'grand challenge' program relating to provision of water under the "Clean Water Strategic Research Program"

Energy Market Authority	Running an ongoing 'grand challenge' program relating to clean and renewable energy under the "Clean Energy Straetgic Research Program"

Further complementing the NRF's functions is the Research, Innovation, and Enterprise Council (RIEC). Chaired directly by the Prime Minister of Singapore and on an administrative level on par with NRF, RIEC is responsible for formulating the city-state's five-year plans in strengthening their collective capabilities in performing scientific research, technological development, and innovation activities. Since the first five-year plan in 1991 (National Technology Plan 1995), over time the size – and scope – of these strategic plans have expanded considerably.

Moreover, the government's RIE plans also became increasingly more targeted and sector-specific. As an illustration, in the RIE2020 plan (2016-2020), Singapore leveraged their public-sector R&D investments to grow industry research capabilities, nurture innovative enterprises, and meet the national needs in four strategic technology areas, namely: 1) advanced manufacturing; 2) health and biomedical science; 3) urban solutions and sustainable development, and; 4) services and digital economy. Prioritization of research in these areas would be implemented through government's additional funding support on three 'horizontal support areas', mainly: 1) academic research; 2) hiring of scientific research talents and commercialization of research outputs through entrepreneurship, and; 3) various types of support and R&D guarantees in the aforementioned strategic technology fields. In the most recent RIE2025 (2021-2025) plan, the government plans to invest up to S$25 billion (equivalent to 1% of Singapore's GDP annually) in further strengthening the city-state's R&D activities and STI capabilities. A significant proportion of the funding (approx. S$3.75 billion) will be allocated towards research on future, emerging technologies; moreover, another S$6.5 billion will be dedicated for mission-oriented research on addressing grand challenges.

One of the major commitments by RIE is sustained investments in fundamental, basic research. Their consistent focus in this area has allowed Singapore to develop an in-depth base of scientific knowledge, and apply its insights for real-world applications and creation of intellectual property/IP (**Heng, 2020**). The impact has been particularly positive for the National University of Singapore (NUS), which we have profiled extensively in the Task 2 report (and will further elaborate in the coming sections); in full alignment with RIE objectives, NUS has been establishing several research centers on technologies/areas prioritized by the five-year plans, such as:

- Center for Quantum Technologies (CQT): operated by NUS, it is one of the world's first institutes conducting research on quantum computing and its future applications. It has engaged in strategic partnerships with major enterprises (notably with ST Engineering, a Singaporean state-owned enterprise/SOE) in developing next-generation network encryption solutions, as well as generated research spin-offs that

seek to commercialize research outputs from CQT, which is best exemplified by the founding of SpeQTral, a company specialized in designing space-based quantum communication systems.

- Sustainable Tropical Data Center Testbed (STDCT): recently announced in June 2021, this will be a joint institute by researchers from both NUS and NTU (Nanyang Technological University) that seeks to pioneer one of the world's first sustainable data-center practices. By leveraging on the country's tropical weather and their latest cooling technologies, STDCT will set a benchmark on operating energy-efficient data centers globally (**NUS News, 2021**).

In addition, we also identified additional funding schemes, sponsored programs, as well as infrastructure in support of Singapore's innovation policy framework, whether inclusive of NRF or not. While we are unable to cover the entire innovation policy toolkits offered by the government and its agencies, we will focus on selected examples in the bullet points below:

- NRF Fellowship: this refers to a scheme by NRF to attract and/or retain top scientists, support competitive research funding, establish world-class research centers, and to engage with eminent leaders in science and technology research, both from Singapore and the rest of the world. It offers a five-year funding package for early-career scientists to perform independent research in the city-state, and is open to all S&T areas, as well as young scientists/researchers of all nationalities. Each successful applicant will be allocated a grant to implement projects with a high likelihood of a research breakthrough. Moreover, appointees will be offered tenure-track faculty positions at these following institutions: A*STAR, NUS, NTU, Duke-NUS Medical School, SMU (Singapore Management University), SUTD (Singapore University of Technology and Design), Temasek Life Sciences Laboratory (TLL), and five NRF-designated Research Centers of Excellence (RCE), which we will elaborate below

- Research Centers of Excellence (RCE): a joint initiative by NRF and MOE launched in 2007, RCEs aim to spur research excellence in Singapore's local universities. As of its establishment, a total of five such centers have been established within NUS and NTU campuses. These RCE perform basic research in areas that are aligned with the city-state's long-term strategic interests. Each RCE enjoys significant institutional autonomy in pursuing its own research missions and objectives, and is overseen by a Governing Board that provides strategic direction and tutelage. Each center is led by a distinguished scientist as a Director, who in turn receives suggestions and feedback by a Scientific Advisory Board (SAB). Principal investigators (PIs) for RCE-supported projects may hold joint-faculty appointments at the RCE's host university and/or the other university they are fully employed with.

- SMART Innovation Center Ignition and Innovation Grants: these seed grants are offered by SMART, also known as Singapore-MIT Alliance in Research and Technology. Modeled after the Deshpande Center at MIT, this facility aims to create a fertile, and conducive, environment for faculty members and researchers in further accelerating their innovation from scientific laboratory to the marketplace. This facility

also offers seamless networking opportunities for innovating faculty members, investors, aspiring entrepreneurs, as well as the broader business community within the country. Open to SMART-based researchers as well as talents based in NUS, NTU, SIM (Singapore Institute of Management), SMU, SUTD, and Singapore Polytechnic (**SMART, 2021**).[200] At least three types of grants are offered: 1) Innovation Grant (with a maximum award of S$250,000, it is aimed to support innovators in developing further prototypes and/or developing proof-of-concept for their proposed technologies); 2) Ignition Grant (with a maximum award of S$50,000, it is targeted for projects deemed too early by SMART Innovation Center for commercialization), and; 3) Execution Grant (with a maximum award of S$50,000, it is intended to further develop a successful, working proof-of-concept).

- Singapore Science Park (SSP): at present consisting of SSP1 and SSP2, this area was initially developed to provide and upgrade the infrastructure for foreign multinational corporations (MNCs) and local industries, and in turn to establish a focal point for carrying out industry, manufacturing-oriented R&D (**Koh et al., 2005**). SSP is strategically located within a close proximity to Singapore's major research and higher-education institutions, national agencies, PROs, and start-up communities, e.g. NUS, National University Hospital (NUH), Defense Science and Technology Agency (DSTA), Defense Science Organization National Laboratories, etc. Nevertheless, as we will further discuss in the coming pages, SSP's success – proxied by the degree to which it has successfully fostered inter-organizational linkages – remains limited

- National Research Infrastructure (NRI): introduced by NRF in April 2015, this framework aims to provide guidelines on the development of selected research facilities that will be operated as 'national resources' that are open and accessible to all researchers across Singapore. The NRI framework aims to promote ongoing investments in upgrading the infrastructure of NRI-selected facilities, and to ensure that research communities within the city-state have ready access to critical research infrastructure in conducting their cutting-edge works.

- NRF Technology Consortia: this is an additional program by NRF, in collaboration with HEIs, that build on individual research projects and integrate the resulting outcomes on a specific technology area. Each consortium is created with the aim of enhancing knowledge-sharing and technology transfer through close collaboration with research counterparts from the academia and industries. In turn, enterprises can build on knowledge bases from such consortia in enhancing their absorptive capacities, whether through attending technology seminars by consortia-affiliated researchers, and/or hiring personnel for their in-house R&D efforts. Moreover, industry actors may also participate in joint research projects with academics within the umbrella of these consortia.

- Singapore Fin-Tech Bay: as a platform and launchpad dedicated for developing the burgeoning financial technology (fintech) industry in Singapore, SG Fintech Bay provides a combination of co-working spaces, with state-of-the-art meeting rooms,

innovation laboratories, acceleration programs for fintech start-ups, as well as curated activities and other educational opportunities. At present, SG Fintech Bay offers two programs: 1) Venture Acceleration Program, a tailor-made acceleration program for early-stage fintech start-ups that includes partnership opportunities with established banking and financial institutions, and; 2) Fintech Talent Program, which provides internship and mentoring opportunities for students and aspiring entrepreneurs.

Overall, the multiplication of innovation policies – and the structural changes of Singapore's innovation policy framework – have inevitably reshaped the institutional configuration of numerous innovation actors within the city-state, and universities (as we have highlighted in the previous pages) have undoubtedly been impacted. Over time, HEIs within the city-state are increasingly prioritizing economic growth driven by industrially-relevant research, commercialization of university-developed technologies, establishment of high-technology spin-offs, attraction of foreign talents, and an infusion of entrepreneurial mindset for students, faculty members, and university researchers (**Wong et al., 2007**).

Universities in Singapore

Nevertheless, specific to the education sector, despite its global connectivity and diversity, Singaporean government still makes efforts to balance strategic autonomy for universities with managing a planned, regulated pathway (**Chan and Ng, 2008**). Indeed, several studies have pointed out the paradoxical situation faced by numerous HEIs within the city-state on simultaneous centralization and decentralization (**Ng, 2007; Tan and Ng, 2007**). On one hand, universities have been empowered to utilize their autonomy in reforming their institutional practice to better compete with their peers across the world. On the other hand, however, the government does not wish to relinquish its monitoring and/or control over how these universities are operated (**Chan and Ng, 2008; Ng, 2007; Tan and Ng, 2007**).

Such delicate balance in managing an autonomy-accountability nexus is highly evident in the instances of collaboration between Singapore's innovation actors (especially the government and HEIs) and foreign universities (**Chan and Ng, 2008; Olds, 2007**), itself an indirect – but vital – component of the country's innovation policy framework. Instead of adopting a free-market mechanism in preponderating the higher education sector, the government followed a more controlled pathway in attracting education providers to Singapore; in this regard, only world-renowned, top-notch universities that have been invited by the government were able to enter and participate in the city-state's higher-education sector (**Lee and Gopinathan, 2007**). In this regard, under the 'Thinking Schools, Learning Nation' (TSLN) and 'World Class Universities' (WCU) programs, the government provided very generous support and financial assistance in establishing branch campuses for these foreign universities. Nevertheless, in return, these campuses would be expected to perform well, and whenever necessary, to exceed metrics set by the authorities (**Olds, 2007; Sidhu et al., 2011**).

Consequently, a large number of foreign universities – since early 2000s – have expressed interest in establishing branch campuses and/or research institutes in Singapore, in part due to government incentives, and partly attributed to Singapore's strategic position as a core node in

the global production and R&D networks (**Coe et al., 2004; Olds, 2007; UNCTAD, 2005**). Moreover, given the high density of foreign MNCs within the city-state, the presence of these foreign universities represents a dual purpose: on one hand, they serve as a 'gateway' to emerging economies in the broader Asia-Pacific region. On the other hand, and in alignment with the views by Singaporean government, these institutions may end up 'supplying' better-quality graduates to the country's existing labor market, and in turn, enhance the quality of overall education sector (**Olds, 2007**). To date, some of these branch campuses and/or institutes have continued to remain in the city-state, with notable examples highlighted in the following bullet points below:

- INSEAD, one of the world's best business schools from Paris (France), operates a branch campus in Singapore; similar to its parent campus in France, it offers both MBA and PhD programs, as well as other executive education courses
- University of Pennsylvania – Wharton School of Business: in a joint partnership with the government, they established Singapore Management University (SMU), which is modeled on Wharton. The university has remained in operation to this day
- Massachusetts Institute of Technology (MIT): in addition to establishing and running SMART – which we have mentioned in the previous pages, MIT and the Singaporean government also engaged in joint partnership in establishing the Singapore University of Technology and Design (SUTD), which partly adopts MIT-style curriculum
- Duke University: its Duke-NUS Medical School, in collaboration with NUS, continues to exist and remains one of the world's most selective graduate schools for medical studies-related programs
- Technical University of Munich (TUM): the university continues to operate a graduate-level branch campus in Singapore, as well as a multidisciplinary research facility (titled "TUM Create") in Singapore Science Park
- ETH Zurich: the Swiss-based university also establishes a research center (Singapore-ETH Center) that focuses on urban planning, urban analytics, and environmental sustainability
- Campus for Research Excellence and Technological Enterprise (CREATE): set up in 2012 by NRF, it is a consortium involving 9 laboratories jointly operated by Singaporean universities, as well as foreign university counterparts

Nevertheless, aside from successful cases (which we have demonstrated in the above bullet points), there have also been less-than-successful instances of foreign universities' ventures in Singapore. One major example was the case of the Australian-based University of New South Wales (UNSW). With its main campus in Sydney, the university established its first Asia campus in Singapore, and began its first recruitment in 2007. However, less than a year later, UNSW abruptly announced its closure, and subsequently complete pullout, from the city-state. Much of this could be attributed to its low enrolment and unsustainable financial position; in other words, UNSW's struggle in achieving the terms and conditions

set by the government might have partly explained the reason for its pullout (**Davie, 2007**). The most recent example was in 2021 with the announced closure of Yale-NUS College by NUS administration, with the last graduation batch set in 2025 (for those admitted in 2021), and significant reorganization already taking place since early 2022 (**The Yale Globalist, 2021**).[201]

Throughout this section, we have elaborated – in details – about Singapore's history, the evolution in its innovation policy framework, some of its major policy toolkits, as well as its performance, as proxied by the Global Innovation Index ranking. In the upcoming sections, we will further investigate the dynamics of the city-state's innovation ecosystem by conducting three separate analyses, with a particular attention on inter-organizational linkages. The first analysis seeks to identify the shifts in Singapore's innovation networks across different time periods by proxy of patent data. The second analysis further complements the previous study by focusing on academia-industry collaboration in the context of scientific knowledge exchange (proxied by U-I co-publications), with a special interest in the case of NUS. Finally, the third analysis further examines the investment ecosystem in Singapore and identifies the extent to which these investors have dedicated their financing deals to support co-located technology enterprises and early-stage start-ups.

4.4.7.3. Three analysis

INTER-ORGANIZATIONAL NETWORKS: EVIDENCE FROM USPTO PATENT DATA

Our first analysis in the case study of Singapore entails the identification – and observation – of changes in the inter-organizational innovation networks in the city-state over time. Similar to other hubs in the Task 3 report, we utilized data from USPTO to collect patent applications from the city-state. An inter-organizational network is deemed to exist when two, or more, patenting organizations involved the same inventor (proxied by his/her inventor ID), an indication of career mobility, informal knowledge exchange, formal technology transfer, and/or university-industry collaboration (**Graf and Henning, 2010; Laforgia and Lissoni, 2009**). Based on the resulting networks, we made use of the relevant network properties to calculate the degree of influence (in terms of knowledge ciruclation) of these organizations, using betweenness centrality as our category of interest (**Freeman, 1977**).

Table 4-64 List of top-10 patenting assignees in Singapore (all-time)

Name	Patent filings (17,719)
A*STAR	1,261
STATS-ChipPac	1,003
Chartered Semiconductor	971
GlobalFoundries	712
STMicroelectronics	529
NUS	519
Seagate	498

Micron Technology	485
Panasonic (Matsushita)	440
Hewlett-Packard (tied)	405
NTU (tied)	405
Share of top 10	40.8%
No. of organizations	1,560

We first provided description on the top-10 organizations in Singapore based on their cumulative number of patent filings. An interesting finding we obtained was that with the exception of A*STAR (Agency for Science, Technology, and Research), NUS, and NTU, the remaining entities in the list basically represent major industry players in ICT and semiconductors, two closely linked industries. The major ICT innovators included Panasonic and Hewlett-Packard, whereas semiconductor industry actors included four foreign multinationals (GlobalFoundries, STMicroelectronics, Seagate, Micron Technology) and two locally-bred, government-operated enterprises (STATS-ChipPAC and Chartered Semiconductor). This finding closely aligns with **Mathews (1999)** regarding Singapore's aspiration to be a world-class hub for semiconductor-related innovations. Relatedly, the finding also supports the observation by **Ortmann (2012)** regarding Singapore's high degree of reliance on government-linked corporations (another terminology, by the Singaporean government, in reference to state-owned enterprises) and foreign firms in running the country's economy.

We further divided our inter-organizational network analysis into 6 different six-year periods. Historically, Singapore's innovative activities were primarily driven by industry actors in the manufacturing, ICT, semiconductor, chemical, and oil & gas-related sectors (**Lim, 2015**). These were evident from the composition of the top-10 innovator lists in 1983-1988 and 1989-1994 period, with the presence of (mostly foreign) firms such as Thomson, Texas Instruments, Chartered Semiconductor and National Semiconductor in the titled industry, Panasonic, Motorola and Hewlett-Packard in ICT-related product development[202], as well as ExxonMobil and Eastern Oil Tools in oil and gas-related sectors.[203]

As we have explained in the beginning of the write-up, economic challenges – as demonstrated by the 1985-1986 global recession and 1997-1998 Asian financial crisis – have significantly impacted Singaporean policymakers' perception regarding the vulnerability of the city-state's economy on FDI, foreign enterprises, and international trade (**Mok, 2015**). The need to rely on locally-based knowledge production as a strategy to diversify their economic development pathways has necessitated the Singaporean government to transform the roles of universities and research institutes through better integration of research outputs with their existing industrial policies. Our observation of the top-10 innovator lists displays results that support Mok's observation: with the launching of their first five-year National Science and Technology Plan (1991-1995), this period coincided with the inclusion of NUS into the list, for the first time, in 1989-1994 period. While the number of filings was initially low (N = 9), NUS' role in driving Singapore's innovation landscape would gradually intensify over time.

NUS was not the only university to be transformed by the government's subsequent five-year plans; Singapore's embrace of knowledge-led economy development strategies also entailed reshaping other research-performing institutions, notably NTU and A*STAR, into more proactive participants in knowledge production, dissemination, and commercialization.[204] A*STAR, formerly known as National Science and Technology Board (NSTB), has been particularly responsible for performing advanced R&D in support of the country's five-year S&T development plans. A major outcome of such policy action has been the meteoric rise of A*STAR as one of Singapore's leading patenters from 1995-2000 period onward. While the agency's affiliated institutes barely achieved the first rank in the top-10 lists in different time periods, in terms of aggregate patent filings, the agency is Singapore's leading innovator. NTU's position and influence was also no less vital; over time, the engineering-oriented university has also rapidly caught up with NUS in terms of patenting output; indeed, in both 2007-2012 and 2013-2018 periods, NTU has surpassed NUS with regard to this indicator. While NUS, in absolute terms, has more patent records than NTU (given the former's older establishment year), we can expect the latter to eventually replace NUS as Singapore's most patenting-intensive university.

Between 1995 and 2012, Chartered Semiconductor and STATS-ChipPAC were consistently placed on the top-10 innovator lists (as well as being the two sole Singaporean firms); such results were a testament of the Singaporean government's intensive efforts to nurture a thriving, locally-bred semiconductor industry (**Mathews, 1999**). Nonetheless, their success appeared to be fleeting, as their dominance also began to significantly shrink in 2007-2012 (for Chartered) and 2013-2018 (for STATS) in the face of intense competition from other large-scale foundries globally. Regarding the former, we observed increasing linkages between Chartered Semiconductor – which was no longer in the top-10 list – and GlobalFoundries, their Silicon Valley-based counterpart/competitor.[205] As of 2013-2018 period, Chartered Semiconductor has 'disappeared', given its acquisition by GlobalFoundries, whose centrality position substantially expanded in the innovation networks. Similarly, STATS-ChipPAC encountered the same fate like their sister company (Chartered); their patenting output declined substantially in 2013-2018 period, and it ended up acquired by Jiangsu Changyin (JCET), a Chinese semiconductor manufacturer.[206]

Overall, from patent-based analysis of inter-organizational networks, we found that in the case of Singapore, foreign firms, universities, and research institutes – with the exception of a small number of local firms as shown by Chartered and STATS – played a strategic role in driving the development of the city-state's innovation ecosystem. However, in terms of knowledge spillover and dissemination, as proxied by betweenness centrality, foreign firms' influence has been historically low, an indication of limited inter-firm networks within Singapore. Instead, publicly-funded research-performing organizations, as represented by A*STAR, NUS, and NTU, have consistently topped the lists based on this centrality measure. The finding closely resembles the observation by **Owen-Smith and Powell (2004)** regarding their study of biotechnology cluster in Boston, showing that universities and research institutes significantly contribute to their surrounding innovation system through knowledge spillover and open knowledge-sharing with industry actors.

Table 4-65 List of top-10 patenting assignees in Singapore throughout different time periods (patent filings indicated in brackets)

1983-1988 (45)	1989-1994 (305)	1995-2000 (1,805)	2001-2006 (4,197)	2007-2012 (5,587)	2013-2018 (5,737)
Chartered Semicond (4)	Hewlett-Packard (36)	Chartered Semicond (446)	Chartered Semicond (440)	STATS-ChipPac (689)	GlobalFoundries (450)
Eastern Oil Tools (3)	Molex (27)	Hewlett-Packard (87)	A*STAR (387)	A*STAR (412)	A*STAR (375)
Micropore Int'l (3)	Texas Instruments (21)	A*STAR (85)	Micron (240)	GlobalFoundries (240)	STMicroelectronics (197)
Motorola (3)	Motorola (20)	Seagate (78)	Seagate (219)	STMicroelectronics (225)	STATS-ChipPac (192)
General Electric (2)	Chartered Semicond (17)	NUS (75)	NUS (166)	Marvell (184)	NTU (172)
Nat'l Semiconductor (2)	Thomson (17)	Texas Instruments (71)	Panasonic (135)	Panasonic (165)	UMC (164)
Sun Indus Coatings (2)	Panasonic (10)	Tritech (50)	STATS-ChipPac (122)	NTU (151)	Sun Patent Trust (139)
Texas Instruments (2)	NUS (9)	AMD (44)	Hewlett-Packard (121)	NUS (131)	Seagate (138)
Lamipak Industries (1)	SGS-Thomson (8)	Panasonic (35)	Infineon (99)	Micron (125)	NUS (137)
Andrews MacLaren (1)	ExxonMobil (6)	STMicroelectronics (32)	Broadcom (86)	Broadcom (109)	IBM (135)
Share of top 10: 51.1%	Share of top 10: 56.1%	Share of top 10: 55.6%	Share of top 10: 48.0%	Share of top 10: 43.5%	Share of top 10: 36.6%
No. of organizations: 32	No. of organizations: 102	No. of organizations: 290	No. of organizations: 564	No. of organizations: 682	No. of organizations: 669

Table 4-66 List of top-10 patenting assignees in Singapore in terms of betweenness centrality scores (scores indicated in brackets)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
-	-	A*STAR (488)	A*STAR (6001)	NTU (7098)	A*STAR (7913)
-	-	NUS (331)	NUS (3260)	A*STAR (6589)	NTU (4739)
-	-	Chartered Semicond (219)	NTU (1756)	NUS (3602)	NUS (3592)

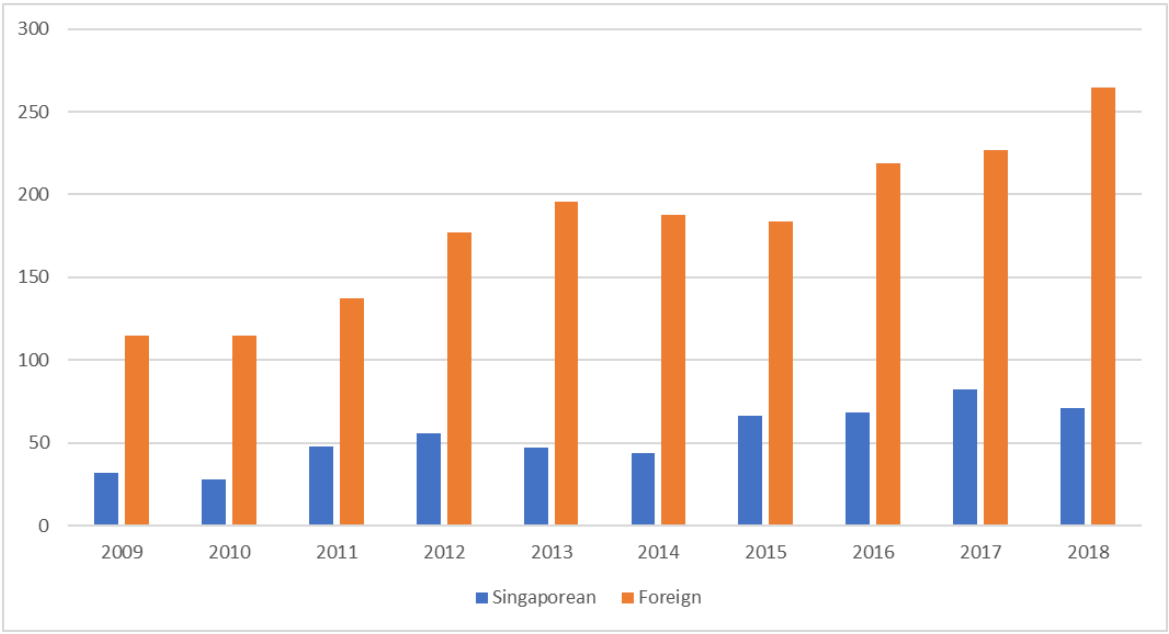
-	-	Texas Instruments (165)	Chartered Semicon (1232)	Codexis (3042)	GlobalFoundries (2162)
-	-	NTU (149)	Hewlett-Packard (1019)	GlobalFoundries (1467)	STMicroelectronics (1332)
-	-	ST Engineering (130)	Infineon (822)	MIT (1059)	MIT (791)
-	-	Kent Ridge Dig Labs (87)	Philips (643)	Panasonic (902)	UMC (696)
-	-	Alcatel-Lucent (45)	Panasonic (586)	CTI Biopharma (708)	Micron (681)
-	-	Hitachi (43)	Johns Hopkins Univ (440)	IBM (703)	BASF (664)
-	-	Apple (43)	ST Engineering (434)	STATS-ChipPac (595)	Marvell (630)

UNIVERSITY-INDUSTRY COLLABORATION IN SCIENCE: EVIDENCE FROM ANALYSIS OF JOINT PUBLICATIONS

Afterwards, our second analysis of the Singapore case study focused on academia's scientific collaboration with their industry counterparts, whether within or outside the city-state. Our approach, similar to what we have covered on other innovation hubs, is through proxying the existence of scientific collaboration with U-I co-publications, following **Tijssen et al. (2009)**. Given our coverage of the National University of Singapore (NUS) in the Task 2 report, we continue to provide further analysis of the university, particularly in terms of its scientific collaboration landscape with various business actors. We extracted peer-reviewed journal article data from Lens.org, for which our period of analysis spans from January 1, 2009 to December 31, 2018, covering a total of 10 years. After removing incomplete entries, as well as journal articles with broken records over the co-authors' institutional affiliation, we ended up with 56,196 journal articles.

In order to identify the presence of co-publications, we further sifted through the co-authors' affiliation, and assigned those employed by companies – using a combination of manual reviews and text mining on companies' incorporation titles – as joint academic works. Through these efforts, we were able to identify a total of 2,380 journal articles involving NUS scientists as U-I co-publications. This figure was equivalent to about 4.24% of the university's entire publication corpus. While considerably below the 6-7% annual average estimated by **Tijssen et al. (2009)**, the university's proportion of U-I co-publications was slightly above the average percentage for all five Hong Kong universities, which we estimated to be about 3.9%.

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Singaporean	32	28	48	56	47	44	66	68	82	71
Foreign	115	115	137	177	196	188	184	219	227	265



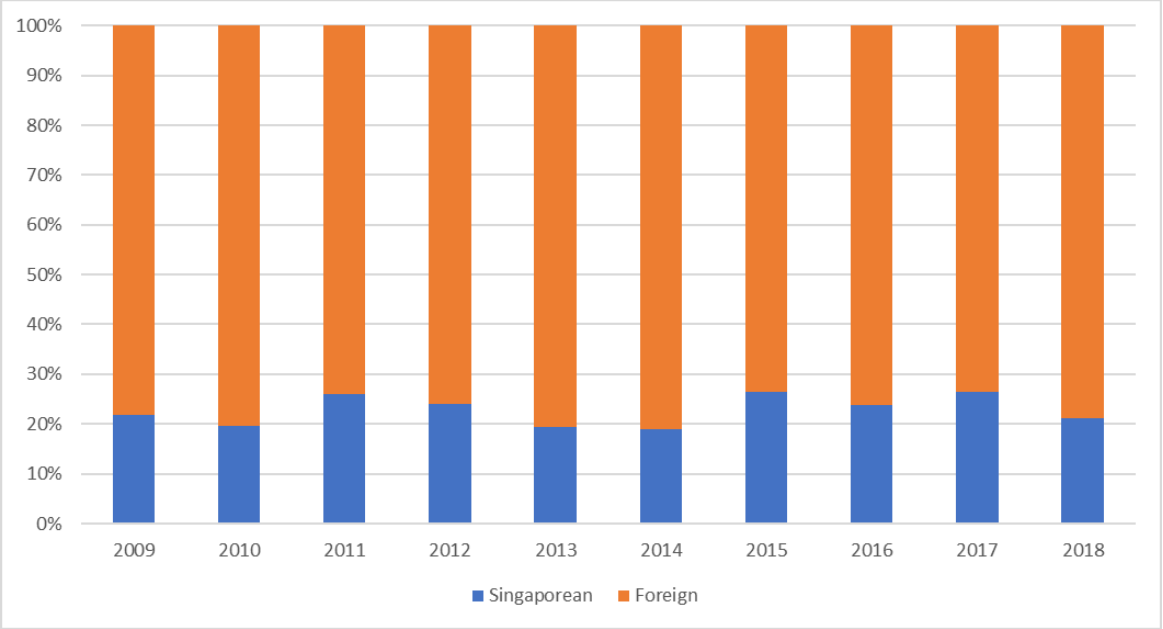


Figure 4-24 Types of U-I co-publications involving NUS (2009-2018) based on the geographical origins of collaborating firms

We further break down our analysis on U-I co-publications by dividing them into two sub-types: 1) Singaporean-based firms, and; 2) foreign enterprises and multinationals. Given its status as a city-state, we did not divide Singaporean firm sample into 'local' and 'domestic non-local' subsets that we have conducted in the cases of other innovation hubs. Overall, one persistent pattern we found was the university's tendency to more actively collaborate with foreign firms than with their Singaporean-based industry counterparts, despite an increase in the absolute number of U-I co-publications involving both types of firms. Proportion-wise, approximately 80% of such joint academic works were conducted in collaboration with non-Singaporean firms annually. This observation aligns with the finding by **Breznitz et al. (2018)** and **Breznitz (2021)** about the tendency for Singapore's top universities and research institutes to more actively disseminate knowledge with foreign actors than nurture linkages with indigenous high-technology firms.

Table 4-67 Top 10 collaborating firms with NUS in U-I co-publications (2009-2018 period, number of co-publications indicated in brackets)

Singaporean firms (N = 542)	Foreign firms (N = 1,823)
Firmenich Asia (40)	Microsoft (69)
ST Kinetics (34)	IBM (60)
SG Inst Manuf Tech (17)	Novartis (41)
Clearbridge BioMedics (11)	GlaxoSmithKline (40)
MOH Holdings (9)	GlobalFoundries (39)
Sembcorp (9)	Merck (39)
Abbott Laboratories SG (9)	AstraZeneca (30)
Bruker Singapore (8)	Eli Lilly (24)

3M Singapore (6)	Nestle (24)
Davos Life Science (6)	Pfizer (24)

For each of the two subtypes of U-I co-publications, we listed out the top-10 collaborators with NUS scientists and researchers. In the case of Singaporean-based firms, we identified two interesting insights. The first relates to the tendency by NUS researchers to closely collaborate with government-linked companies – Singapore's reference to state-owned enterprises. This is demonstrated by joint publications involving researchers from ST Kinetics (a subsidiary of Singapore Technology Engineering / ST Engineering), Singapore Institute of Manufacturing Technology (a research company under A*STAR), Ministry of Health (MOH) Holdings, and Sembcorp, all of which are owned by government agencies.

The second relates to another tendency by NUS scientific communities in working closely with their counterparts from foreign-firm subsidiaries in the city-state. Our observation of U-I co-publications with Singaporean firms demonstrates that slightly over 40% (N = 224) of such academic works were in direct collaboration with subsidiaries from a total of 94 foreign MNCs, the highest proportion that we found in comparison to other universities and hubs covered for Task 2 and Task 3 reports. Some of these enterprises also happen to be within the top-10 local-collaborator lists, such as Firmenich (a Swiss chemicals and fragrance company), Abbott Laboratories (an American food and health science behemoth), Bruker (an American scientific instrument manufacturer), 3M (a US-based chemicals and new-materials company), and Davos Life Sciences (an affiliate company of Kepong Berhad, a Malaysian palm-oil plantation and processing company). Beyond these five companies, NUS scientists have also at times engaged in research collaboration with R&D personnel of these following companies with substantial business operations in Singapore:

- BASF (a German chemical industry giant)
- Danone (a French food and beverage multinational company)
- Eli Lilly (an American global pharmaceutical firm)
- HiSilicon (a semiconductor affiliate of Huawei, a Chinese technology giant)
- Kyowa Hakko Kirin (a Japanese drug-development and chemical MNC)
- Novartis (a Swiss international pharmaceutical enterprise)[207]
- NXP Semiconductor (a Dutch semiconductor business), etc.

Regarding joint research with overseas enterprises, as we have stated in the beginning of the sub-section, most of NUS scientists' U-I co-publications were conducted with these firms (N = 1,823). A significant proportion of these collaborative activities appear to be related to medicine, life sciences, and chemicals linked to pharmaceutical development, with 7 of the top-10 foreign firm list dominated by companies such as Novartis, GlaxoSmithKline (GSK), Merck, AstraZeneca, Eli Lilly, Nestle, and Pfizer. Beyond these fields, NUS researchers have also exchanged their expertise in ICT-related areas (particularly in both software and

semiconductor) with their counterparts from Microsoft, IBM, and GlobalFoundries. Further instances of their collaboration are highlighted in the bullet points below:

- Microsoft: both NUS and the American software giant have been engaged in numerous research collaboration activities, particularly since mid-2010s. One of their first instances of large-scale collaboration was in 2016, when NUS established Data Science Institute and listed Microsoft as their first global industry partner. This institute offers courses, workshops, and seminars in big-data development by adopting Microsoft's data science resources and education curriculum (**Tegos, 2016**). A follow-up initiative ensued in 2018, when NUS, Microsoft, and AI Singapore – a Singaporean government agency specifically dedicated to promote the application of artificial intelligence in public services and daily life – launch a new program in which NUS researchers will be able to access and harness the potential from Microsoft Academic Graph, a large-scale dataset of over 200 million publications globally (**NUS News, 2018**). More recently, in early 2022, NUS School of Medicine worked together with Microsoft in introducing 3D holographic education for medical students to enable a more interactive learning environment, particularly on exploring anatomical structures during surgery simulations (**Ang, 2022**).

- IBM: the American ICT multinational has also been closely collaborating with NUS researchers on two major areas. The first relates to their 2017 partnerships – between NUS School of Computing and IBM Center for Blockchain Innovation – in joint research on financial technologies (fintech) and blockchain, with an eye towards a roadmap of pilot projects integrating both technologies by the Monetary Authority of Singapore (MAS), the city-state's central bank (**IBM, 2017**). More recently, in 2020, the company signed an agreement with NUS to conduct joint research on quantum computing, under the Quantum Engineering Program (QEP), a quantum-related flagship program of the Singaporean government to accelerate the application of quantum computing research outputs into commercialization. In this regard, NUS researchers will be able to access IBM Quantum Computation Center and experiment with the latest research in the latter (**Business Insider, 2020**).

- Eli Lilly: the US, Indianapolis-based pharmaceutical multinational has established a strong presence in the city-state over the last two decades. As an illustration, in 2001, Eli Lilly established Systems Biology R&D Center after receiving generous incentives by the Economic Development Board (EDB). This center was further expanded with the company's new Singapore Center for Drug Discovery, which performed the work of drug discovery-related R&D for the company. However, in 2010, the company eventually shut down this center (**Manufacturing Chemist, 2010**).[208] Nevertheless, the company continues to maintain their remaining clinical-trial center, also known as Lilly Center for Clinical Pharmacology Trials, which is located within the NUS campus. In collaboration with their counterparts at the university, the center performs research and clinical trials on potential treatments relating to diabetes, neuroscience, oncology, as well as auto-immune diseases (**Eli Lilly, 2022**).

Beyond large foreign multinationals or Singaporean state-owned enterprises, we also identified instances of U-I co-publications involving spin-offs originating from research performed at the university. Similar to our approach in other hubs for Task 3 report, we relied on company websites in investigating the founders' backgrounds, particularly on questions whether they were current and/or former professors, research staff, and/or students affiliated with NUS. However, our attention was primarily on Singaporean-based local firms, and we did not rule out the possibility of NUS spin-offs that are no longer headquartered in the city-state. Overall, we identified a total of 42 U-I co-publications involving 29 such enterprises, over half of which are concentrated in biotechnology/pharmaceutical/life science-related sectors (N = 13) or the development of medical devices (N = 2). The remaining spin-offs, meanwhile, are specialized in a wide variety of sectors (see Table 4-68 below), ranging from artificial intelligence, to civil engineering services, energy efficiency-related technologies, material sciences, semiconductor, etc.

Table 4-68 Specialization of NUS spin-offs identified from U-I co-publications (2009-2018)

Sector	Number (N = 29)
Biotechnology/pharmaceuticals	13
Medical devices	2
Scientific instruments	2
Artificial intelligence/machine learning	1
Chemicals	1
Civil engineering	1
Energy efficiency	1
Healthcare-related services	1
Material sciences	1
Mobile platform	1
Nanotechnology	1
Semiconductor	1
Software	1
Supply chain and logistics	1
Video gaming	1

Another limitation from our approach is that we may have also overlooked other technology start-ups/spin-offs that originated from NUS, but did not necessarily co-author scientific works with the university scientists. Nevertheless, from Table 4-69 above, the finding provides us with some definitive insights on the nature of science-driven companies emerging from NUS research. Table 4-69 below provides some examples of such spin-offs.

Table 4-69 Notable NUS spin-offs identified from U-I co-publication analysis (2009-2018)

Name	University	Profile
Ayoxxa	NUS	Ayoxxa Biosystems is a life sciences company that promotes

Biosystems		innovation in translational proteomics, with the aim of improving diagnostics and therapeutics-related technologies. The company's core technology – a groundbreaking platform technology for better protein analysis known as LUNARIS – was based on an IP license from NUS in 2010. LUNARIS is intended to offer fully scalable quantitative validation of biomarkers for disease detection. Ayoxxa Biosystems is a biotechnology company founded in 2010 in Singapore, and headquartered in Germany. Ayoxxa was founded by Andreas Schmidt (a PhD graduate from University of Cologne and UC Berkeley) and Dieter Trau (PhD graduate from HKUST, and formerly associate professor of chemical and biomolecular engineering at NUS; he is now a professor at Asia Institute of Technology - Thailand).
CellResearch	NUS	CellResearch is a biotechnology company that provides artificial skin and scar cells to laboratories across the globe, as well as engage in contract research on the development of artificial skin. One of their core innovations was their success in isolating epithelial and mesenchymal stem cells from umbilical cord lining membrane, which is potentially useful for their work in cell biology, especially in tissue regeneration. CellResearch was founded in 2002 by Gavin Tan and Phan Toan Thang. Gavin Tan is a venture capitalist and serial business executive. Phan Toan Thang, originally from Vietnam, is a medical doctor and professor at NUS. He received his PhD from Military Medical University (Hanoi), and was a postdoctoral researcher at Oxford and Stanford. Before he joined the university, he was a doctor at Singapore General Hospital.
Cosmiqo	NUS SUSS	Cosmiqo International Pte Ltd is a supply-chain and operational analytics company with a primary concentration in tourism, infrastructure, logistics, manufacturing and smart cities. In combination with artificial intelligence, the company innovates and develops sensor-based platforms to collect and analyze large-scale datasets in order to simplify company operations, as well as build intelligent and predictive engines that simplify the decision making process. Cosmiqo was founded by Koh Niak Wu, a scientist and industrial researcher. He obtained his PhD from National University of Singapore (NUS) in 2007, and worked as a research scientist at A*STAR and Dell (Singapore) before working as a professor at Singapore Management University (SMU) and Singapore University of Social Sciences (SUSS). He founded the company in 2013 while working as a professor. He is currently the company's CEO and CTO. Board of advisers include professors from SUSS and

		NUS.
Lion TCR	NUS A*STAR SYSU	Lion TCR is a clinical-stage biotechnology company whose core innovation relates to the development of T cell receptor (TCR)-T cell therapy to address life-threatening viral infections and viral-related cancers pertinent in Asia. The company's particular segment of interest is hepatocellular carcinomas, most of which are caused by chronic infection with the hepatitis B virus (HBV) which is endemic in Asia. The company aims to build precision cancer immunotherapy solutions to save patients with such underlying conditions. Lion TCR was founded in 2015 by Antonio Bertoletti and Li Lietao. Antonio was previously a director at Singapore Institute of Clinical Sciences (A*STAR) until 2013. He is currently a professor at Duke-NUS Medical School. Lietao is a serial entrepreneur based in Guangzhou with PhD from Sun Yat-sen University (SYSU). The company's chief scientist and leader is Anthony Tan, a PhD graduate from NUS.
Microfine Material Technologies	NUS	Microfine Materials Technologies is a piezoelectrics-focused technology company that develops and produces PZN-PT single crystals. Beyond PZN-PT, the company also pays attention to other high-end single crystal devices, ranging from underwater transducers to land-based piezoelectric sensors and actuators. The company's products are primarily used for the defense industry sector in Singapore. Microfine Materials was founded in the mid-2000s as a research spin-off of the National University of Singapore (NUS) to commercialize research on high-end single crystal devices.
Newrocare	NUS Huazhong Univ S&T	Newrocare is a biotechnology company whose core innovation relates to pioneering latest breakthroughs in neuroengineering, specifically in non-invasive brain-machine interface. The company focuses on research, conceptual design, product development testing, and application mentoring. Newrocare was founded in 2012 by Li Xiaoping, when he was a professor at National University of Singapore (NUS). He was a professor there from 1992 to 2016. He is now currently a full-time professor at Huazhong University of Science and Technology (HUST) in Wuhan, China, and continues to manage the company's subsidiary in Japan.
Paracrine Therapeutics	NUS A*STAR	Paracrine Therapeutics (PT) is a biopharmaceutical company whose core innovation is linked to stem exosome for regenerative medicine. PT licenses patents surrounding the production,

		composition, and use of exosomes from the Institute of Medical Biology of A*STAR. An interesting property about exosomes is that while they resemble stem cells (in properties and functions), they are not living and cannot evolve into unwanted tissues, let alone tumors. Through their innovation, the company aspires to develop exosomes as an alternative to the existing stem-cell treatment, which may better address patients' needs. Paracrine Therapeutics (PT) was founded, and is currently led, by Lee Chuen Neng and Lim Sai Kiang. Lee is currently the company's chairperson and also professor of surgery at National University of Singapore (NUS). Lim, also an NUS PhD graduate, is currently the director of Institute of Medical Biology of A*STAR.
SKINetrate	NUS	SKINetrate is a biotechnology company specialized in the R&D and manufacturing of novel skin-testing devices, as well as integrated systems, for researchers studying drug delivery and membrane transportation. Their products have been applied in a wide range of settings, e.g. drug discovery, drug delivery, drug screening, skin toxicology, performance testing, etc. SKINetrate was established in 2015 as a spin-off to commercialize research at National University of Singapore (NUS).

Summarizing the second analysis, we demonstrated that while NUS has established solid scientific linkages with various industry partners, the knowledge exchange happens to be primarily concentrated with foreign enterprises, mirroring the observation by **Breznitz et al. (2018)** and **Breznitz (2021)**. In other words, the phenomenon described by the authors is not limited to A*STAR alone; even the city-state's best universities also follow such trend. The proportion of U-I co-publications with multinationals based outside Singapore, on average, continues to remain at approximately 80% per annum. Even with regard to joint academic works with Singaporean-based enterprises, slightly above 40% of them were in collaboration with the subsidiaries of these foreign firms. By contrast, scientific knowledge exchanges with indigenous Singaporean firms beyond the SOEs – with the exception of university spin-offs – has remained limited.

FINANCING SUPPORT FOR LOCAL TECHNOLOGY COMPANIES: EVIDENCE FROM CRUNCHBASE DATA

In the third analysis, we further investigate the extent to which Singaporean-based investors have provided their financial capital support for co-located technology companies, replicating the approach we have conducted for other hubs in the Task 3 report. The rate of investment co-location has long been utilized as a proxy for resource 'regeneration' within an innovation ecosystem, in which well-resourced financiers (many of whom may have prior experiences as successful, serial entrepreneurs) dedicate their support for the next generation of emerging-technology start-ups (**Sorenson and Stuart, 2001; Stam and Spigel, 2016**).

We primarily relied on Crunchbase in obtaining our investment data for the city-state. In aggregate, we extracted a total of 1,988 investors with Singapore as their primarily domicile address. All these investors have accumulated 8,525 investment deals that were spread over a combined portfolio of 7,166 technology firms worldwide. Once we limited our search into the top 1,000 investors, we found that these financiers – organizational and individual alike – were responsible for 8,433 financing activities in 6,950 such companies. One main reason accounting for the very high degree of concentration of investment activities within the top 1,000 investors could be ascribed to the high proportion of investors with no known information (N = 783, or equivalent to 40% of all listed investors) about their existing investment records, let alone portfolio.

In comparison to Hong Kong, Singapore's investment ecosystem is considerably (about 50%) larger than in the former, for which we collected a total of 1,352 such investors. The latter also possesses, in absolute terms, a somewhat bigger number of large-scale investors (by which we set the threshold for those with at least 50+ cumulative financing deals). In other dimensions, however, the two cities are relatively similar in terms of the composition of these investors based on the size of their cumulative financing activities: approximately 40% of VCs, angels, and other institutional/individual investors in both cities had no prior known information regarding their financing deals, and another 30% were only one-off investors. This finding – to some degree – reflects **Klinger-Vidra (2018)** in her comparative analysis of VC policies in the two cities, by which Singapore's policies were shown to bring more successful outcomes than in Hong Kong.

Table 4-70 Information about investors in Singapore (source: Crunchbase)

Size of investment activities	Number of investors
No information about investments	783
1 investment only	588
2-9 cumulative investments	448
10-25 cumulative investments	106
26-50 cumulative investments	32
51-99 cumulative investments	19
100-999 cumulative investments	12
1,000 or more cumulative investments	0
TOTAL	1,988

Afterwards, we further limited our analysis to the city-state's top 25 investors based on their cumulative number of financing deals, the full list by which was displayed in Table 4-71 in the following page. In aggregate, these financiers accounted for 3,466 investment activities committed towards 2,655 technology firms in Singapore and overseas, figures that were nearly equivalent to 40% of the deals and existing portfolio accumulated by all Singaporean-based investors. Among these top investors, over 20% of their activities (N = 748) and investment portfolio (N = 549) were dedicated towards co-located technology firms, a rate that was twice as high as the proportion observed in Hong Kong. While these figures pale in comparison with those seen in other hubs, e.g. Beijing (close to 40%), Tokyo (60%), or Silicon Valley (45%), Singapore's degree of 'resource regeneration' is somewhat better than our observation in the Hong Kong case.

Moreover, through a preliminary glimpse of these top investors alone, we can observe a significant proportion of them (N = 8) are either government-operated or government-supported, but privately-run, funds. Directly government-run entities include: Temasek, GIC (Government of Singapore Investment Corporation), EDBI (operated by Economic Development Board), Singtel Innov8 (under Singtel), and Seeds Capital (VC arm of Enterprise Singapore). In the case of privately-run but government-supported funders, we identified three such examples, namely: SGInnovate (a start-up-incubator-cum-VC-fund), as well as Vertex Ventures and Openspace Ventures, both of which received considerable financial resources and other support directly from Temasek Holdings. We will further investigate the roles played by these organizations in stimulating Singapore's start-up ecosystem and link them with the analysis by **Klinger-Vidra (2018)** in another mini-box in the coming pages.

Another interesting finding is the significant presence of a number of VC funds with an explicit global outlook beyond supporting Singaporean technology start-ups. This is manifest in two subtypes of investors under this category: 1) VC funds that are subsidiaries of foreign enterprises, and; 2) investment entities with dual – and occasionally multiple – headquarters in Singapore and other parts of the world. Examples of investors in the former category include JAFCO Asia (an affiliate fund of a Japanese-based financial services multinational firm with the same name) and Surge, a special investment fund under US, Silicon Valley-based VC fund, Sequoia Capital, which invests in early-stage start-ups in India and Southeast Asia more broadly. Investors fulfilling the latter criterion include Quest Ventures (with the other headquarter in Beijing) and Spiral Ventures (with presence in both Tokyo and Singapore). A few other investors, while based in the city-state, have also set their investment objectives on a worldwide basis, such as Wavemaker Partners, Jungle Ventures, DSG Consumer Partners, Jeremy Yap, etc.

An obvious impact from the proliferation of investment funds in Singapore has been the growth of unicorn start-ups, or early-stage companies with valuation exceeding US$1 billion. Through compilation from **Failory (2021)** and **CB Insights (2021)**, we managed to identify a total of 14 existing and former unicorns from the city-state, the full list by which was shown in Table 4-71 below. These enterprises are focused on a wide variety of sectors, such as ride-hailing, e-commerce, financial technologies (fintech), cryptocurrencies, artificial intelligence (AI),

Internet infrastructure, etc. Two of these (former) unicorns – Grab and Sea – have indeed made successful exits through public listing in US-based NASDAQ stock exchange, making them Southeast Asia's most successful start-up exits thus far.[209] Quite interestingly, some of these unicorns (notably demonstrated by Trax, Moglix, and Acronis) also develop a strong global outlook, given their dual-headquarters approach with the aim of reaching consumer markets in Europe, North America, and elsewhere across the globe.

Table 4-71 List of unicorn start-up companies in Singapore

Name	Valuation (US$ billion)	Sector
Grab (exited)	40.0	Mobile app, ride hailing, fintech
Sea (exited)	5.3	E-commerce, fintech, gaming
HyalRoute	3.5	Internet infrastructure, fiber optic cable
Advance Intelligence Group	2.0	AI, fintech, lending
Trax*	1.3	Cloud, big data, retail, analytics
Carousell	1.1	E-commerce, trading, platform
PatSnap	1.0	AI, patent dataset, IP management
Moglix*	1.0	E-commerce, industrial tools
Matrixport	1.0	Fintech, cryptocurrency, trading
Carro	1.0	E-commerce, cars, trading
Bolttech	1.0	Insurtech, trading, platform
NIUM	1.0	Fintech, cryptocurrency, payment card
Ninja Van	1.0	Mobile app, logistics, delivery
Acronis*	1.0	Cloud, data storage, cybersecurity

* These following unicorn start-up companies have dual headquarters; beyond Singapore, their main offices are also based in other jurisdictions, namely Israel (Trax), India (Moglix), and Switzerland (Acronis).

Overall, Singapore's investment ecosystem is comparatively more vibrant than in Hong Kong, with a larger number of financiers and higher degree of financial support in co-located technology firms. Moreover, a significant proportion of the top investors have been either government-run entities or government-supported, privately-run VC funds, an indication of the influential role played by the city-state in building a dynamic investment community.

Table 4-72 Top 25 investment funds in Singapore and proportion of investments in Singapore technology companies

Name	Summary	No. of investments	Investments in Singapore	No. of portfolio organizations	Portfolio organizations in Singapore
Wavemaker Partners	A VC fund that offers early-stage investments in early-stage tech start-ups in Singapore and the rest of the world	465	146 (31.4%)	321	83 (25.9%)
Temasek Holdings	A US$480 billion sovereign wealth fund (SWF) by the government of Singapore that invests in various firms in Singapore and globally	394	23 (5.8%)	287	18 (6.3%)
Antler	A VC fund that offers early-stage investments in companies focused on emerging technologies with potentially radical implications	283	70 (24.7%)	238	56 (23.5%)
BEENEXT	A VC fund with a very broad geographical focus of investments, primarily in India, ASEAN, Japan, and the United States	232	21 (9.1%)	156	14 (9.0%)
GIC	A US$550 billion sovereign wealth fund (SWF) by the government of Singapore that is led directly by the Prime Minister of Singapore	216	2 (0.9%)	177	2 (1.1%)
LetsVenture	A VC fund that offers investment support to various companies, and	157	0 (0.0%)	145	0 (0.0%)

	also provides networking services to accredited investors				
JAFCO Asia	A corporate VC (CVC) fund, and subsidiary, of JAFCO, one of Japan's largest financial services and VC groups	153	9 (5.9%)	117	8 (6.8%)
EDBI	A VC fund under the Economic Development Board (EDB), a Singaporean government agency on economic development	140	34 (24.3%)	111	29 (26.1%)
Singtel Innov8	A corporate VC (CVC) unit of Singtel, a state-owned telecom and IT enterprise under the government of Singapore	122	25 (20.5%)	89	18 (20.2%)
Surge	A subsidiary of Sequoia Capital India (itself subsidiary of Silicon Valley-based Sequoia Capital) that offers rapid scale-up of technology start-ups in India and ASEAN	111	28 (25.2%)	82	21 (25.6%)
HATCHER+	A data-driven investment firm that uses insights from AI/ML research in decision-making on their VC and PE investments in tech start-ups	103	3 (2.9%)	102	3 (2.9%)
Golden Gate	A VC firm that invests specifically in technology start-ups in business services, mobile, ICT, and software-as-a-service (SaaS)	103	38 (36.9%)	68	24 (35.3%)
Jungle Ventures	A VC firm that provides investment	95	38 (40.0%)	56	23 (41.1%)

	and other types of financing for promising technology start-ups in Singapore and Asia more broadly				
NEO Global Capital (NGC)	An investment firm that provides financing support for start-ups and pre-start-up business projects centered on blockchain	93	20 (21.5%)	91	19 (20.9%)
DSG Consumer Partners	An investment company that offers VC and PE on various consumer-tech companies, specifically in India and Southeast Asia (ASEAN)	90	10 (11.1%)	46	8 (17.4%)
Insignia Ventures Partners	A VC firm that offers investments in various technology start-ups in Singapore and beyond	82	27 (32.9%)	55	18 (32.7%)
Singapore Angel Network	A VC firm that offers angel, early-stage, and seed investments in various technology start-ups, mainly in Singapore	82	8 (9.8%)	79	8 (10.1%)
Quest Ventures	A VC firm with dual headquarters in Beijing (China) and Singapore, which invests in technology start-ups mainly in Southeast Asia	78	46 (59.0%)	75	44 (58.7%)
Spiral Ventures	A VC firm with dual headquarters in Tokyo (Japan) and Singapore, with investments in technology start-ups in Japan and ASEAN	76	8 (10.5%)	63	5 (7.9%)
SGInnovate	A privately-run VC fund and start-up incubator that is wholly owned	74	61 (82.4%)	62	51 (82.3%)

	by the government of Singapore with focus on deep-tech start-ups				
Vertex Ventures (Southeast Asia & India)	A VC subsidiary fund under Temasek Holdings, Singaporean government's sovereign wealth fund (SWF), that invests in tech start-ups in ASEAN and India	71	26 (36.6%)	43	15 (34.9%)
Openspace Ventures	Another VC fund with financial support by Temasek Holdings that invests in promising technology start-ups in Southeast Asia	67	27 (40.3%)	36	15 (41.7%)
Jeremy Yap	A full-time angel investor from Singapore who mainly invests in technology start-ups in Europe, North America, and Israel	64	0 (0.0%)	54	0 (0.0%)
Seeds Capital	A VC investment arm of Enterprise Singapore, a government agency, that co-invests with other VC funds in various technology companies	60	60 (100.0%)	49	49 (100.0%)
LongHash Ventures	A start-up accelerator and VC fund that invests in blockchain- and cryptocurrency-related start-ups around the world	55	18 (32.7%)	53	18 (34.0%)
		3,466	748 (21.6%)	2,655	549 (20.7%)

4.4.7.4. Discussions and conclusions

To recap, from this chapter, we have conducted three separate analyses on Singapore's innovation ecosystem, and found interesting results. In the first analysis, we observed the evolutionary dynamics of inter-organizational linkages by proxy of USPTO PatentsView data, following the multi-applicant inventorship method by **Graf and Henning (2010)** and **Laforgia and Lissoni (2009)**. Through this method, we found an interesting shift across different time periods in the composition of most dominant nodes in Singapore's innovation networks, from one driven by foreign multinationals in the 1980s and first half of 1990s to a landscape where universities (represented by NUS and NTU) and public research organizations (notably A*STAR) play a strong role in the networks. Simultaneously, results visualized from network analysis demonstrated close triadic linkages between NUS, NTU, and A*STAR, an indication of close knowledge exchange among researchers (whether institutional or informal) from these organizations.

Nevertheless, we were aware of the limitation of relying primarily on patent data in studying inter-organizational linkages, not least due to the small amount of information disclosed on the degree of inter-organizational linkages solely from this indicator (**Ter Wal and Boschma, 2009**). This led us to the second analysis, in which we made use of publication data retrieved from Lens.org, with a particular interest in identifying U-I co-publications as a proxy for academia-industry exchange in scientific knowledge not necessarily captured in patented inventions. Given our extensive coverage of – and interest in – the role played by the National University of Singapore (NUS) in Task 2 report, we further devote this section to elaborate the relationships between NUS and the broader industrial actors in the city-state. Our results demonstrate that researchers from the university primarily collaborate with their counterparts from foreign firms, local subsidiaries of these foreign multinationals, and/or state-owned enterprises (SOEs). Few of the university's co-publications with local firms were conducted with NUS' own spin-offs, and majority of these enterprises are specialized in biotechnology and life science-related industries.

The third – and final – analysis sought to further explore the relationships between VC investment communities and technology firms in Singapore, given that not all existing science/technology-driven companies in the city-state engage in patenting and/or scientific publishing activities to signal their credibility to prospective financiers. Following **Sorenson and Stuart (2001)**, we investigated the extent to which Singaporean-based investors dedicate their financing support towards co-located technology firms. Our results show that the rate of co-located investments in Singapore (nearly 22% of all their cumulative deals) is considerably higher than those we identified in the case of Hong Kong (about 10%) and Shenzhen (approximately 16%), but remains lower than similar figures identified in the remaining Task 3-covered hubs, such as Silicon Valley, Beijing, Tokyo, etc.

Reflecting from our in-depth study of Singapore, we identified several insightful lessons for Hong Kong to learn, and possibly to replicate and/or adopt within their innovation policy framework. The first insight relates to the very close relationship between universities and PROs, as already demonstrated by the consistent, triadic ties between NUS, NTU, and A*STAR in inventive activities. In part this reflects the geographical proximity among these

institutions, especially given the close co-location between NUS and A*STAR-affiliated research institutes, but to some degree such ties have also been enabled by a strong, strategic role of the state. Transplanting to the Hong Kong case, this pattern implies the need for stakeholders in academia and public research institutes to more proactively engage in knowledge exchange with each other, which has historically been limited (**Fuller, 2010**). It is also worth noting that with the current resource constraints that have turned relationships among the two entities to be more competitive than collaborative, the Hong Kong government would do well to consider expanding their resource allocation to boost such ties.

Second, the government may also consider tapping deeper into their fiscal reserves to support the city's aspiring technology companies and start-ups. This has been vividly demonstrated by Singapore, in which a multitude of its government agencies – and most importantly, its sovereign wealth funds (SWF)s – have created specialized financing vehicles, entities, and/or incubation/acceleration programs to nurture the city's next-generation technology companies, often in collaboration with private-sector stakeholders. It is not that the Hong Kong government lacks efforts in such investments; indeed, in the last 4-5 years, the government has allocated more than HK$50 billion to develop the city's STI ecosystem. Rather, the city's whole-of-government approach in innovation policymaking processes has yet to be further enhanced. While the implementation of a new, HK$2 billion Innovation and Technology Venture Fund (ITVF) is a good start, the government can further expand their financing opportunities by making use of, say, the Hong Kong Monetary Authority (HKMA) Exchange Fund, which at present – similar to Temasek and GIC – is one of the world's largest sovereign wealth funds (SWF).[210] Nevertheless, we shall also be aware of the caveats about potential red tape and overly stringent rule constraints among agencies (**Fuller, 2010**) that may pose hindrances for the government in further enhancing existing resources.

Third, and last but not least, Singapore's innovation policy strategies and instruments (e.g. five-year RIE plans and A*STAR) may be emulated – and, to a certain degree, adapted – into the Hong Kong context, while taking into consideration the city's existing circumstances. In the past, the city has announced plans to prioritize the development of certain emerging industries and/or technologies, but details and implementation have remained prevaricated (**Fuller, 2010**). The government may consider consulting with various stakeholders more broadly about sectors and/or technologies constituting Hong Kong's competitive advantages to be prioritized. The authorities can also conduct more public outreach efforts to leading universities and/or PROs globally to establish either branch campuses or research institutes, in partnership with Hong Kong's leading universities, as an avenue to strengthen cross-country collaboration in knowledge production.

4.4.8. Tel Aviv

Introduction

The affluent entrepreneurial ecosystem, strong R&D capabilities, and highly educated workforce of Israel have earned it the reputation as a "Startup Nation" despite its limited natural resources and market size (**Startup Genome, 2021**). As one of the most research-intensive economies, Israel tops the R&D intensity in the world, with about 5.4 % of the country's GDP (**OECD, 2022**), twice the OECD average of 2.7 %. Israel's phenomenal performance has also been reflected in various international rankings. As an example, according to the Global Competitiveness Index by the World Economic Forum, as of 2019 alone, Israel has consistently been ranked among the top 20 countries worldwide for a decade (**World Economic Forum, 2019**). Furthermore, "Israel is one of the most educated societies in the world with the highest percentage of scientists and engineers (135 scientists and engineers per 10,000 population, more than any other developed country), and one of the highest ratios of university degrees per capita and academic publications per capita."

Tel Aviv, also colloquially known as the "Nonstop City", is Israel's second most populous municipality (after Jerusalem), with a total population of nearly 500,000 people living within the city's land area of about 52 square kilometers (sq km). The city is mainly composed by Jews, with more than 90% of the population are Jews (City in Numbers, 2018). The city has historically played a role not only as Israel's hub for cultural heritage – as attested by the designation of White City area as a UNESCO World Heritage Site in 2003; it has also played a major role as one of Israel's leading hubs in science, technology, and innovation (STI) activities. It is often considered as the commercial and financial center of Israel, bursting with a significant majority of the country's tech venture activities concentrated within its greater metropolitan area, and home to dozens of unicorn companies (**Garbi & Garzik, 2022**).

Tel Aviv has also been constantly positioned as among the leading start-up ecosystems by the annual Global Startup Ecosystem Ranking (**Startup Genome, 2021**). Such innovative milieu is deeply rooted in the city's pluralistic culture, 'can-do' attitude, as well as the strong 'play-it-forward' culture (**De Fontenay and Carmel, 2004**), all of which incentivize individuals within the city to engage in risk-taking ventures. Their entrepreneurial zeal, in turn, contributes to the dynamic formation of Tel Aviv's innovation ecosystem. Relatedly, Tel Aviv also performs relatively well in almost all dimensions being evaluated; a recent report by **OECD (2018)** on Israeli cities shows that the city ranks highly in many dimensions, such as market research (a full 10/10 score), funding (9/10), as well as performance, connectedness, and talent availability (8/10 scores). Nevertheless, and quite ironically, the only dimension where Tel Aviv appears to lag behind is the 'knowledge' dimension, in which the municipality only scores 4 out of 10. In the later pages, we will elaborate briefly about reasons behind such performance disparity. Overall, Tel Aviv ranks among the top 20% of OECD-assessed regions with regard to jobs and self-assessed life satisfaction (**OECD, 2018**).

Israel's innovation system emerged in the course of deliberate government policies employed in a response to objective circumstances and opportunities, as well as the internal needs and strengths of the country.

Beyond universities alone, public education-related policies have played a major part as well; since 1949, public education has been made compulsory, but free of charge, for all children until Grade 10, and which has since been extended to Grade 12 (**Nuffic, 2017**). In addition, Israel's emphasis on developing the students' English-language proficiency has, to some degree, helped them further their academic pathways not only within the country, but also globally (in terms of pursuing higher education). At present, with 49.9% of Israelis aged 25-64 having completed some forms of tertiary education (inclusive of two-year degree, four-year degree, and vocational programs), Israel ranked as the third most educated country among all OECD member-states.

Either Tel Aviv or Israel represents a complex ecosystem involving sets of institutions and processes entrenched in the context of geopolitical conditions, human capital, culture, and legal regulations. Tel Aviv's, and Israel's achievements, more broadly, cannot be solely attributed to the presence of highly-ranked research universities and strong public education policies. Two additional factors uniquely suited to Israel's circumstances further contributed, albeit indirectly, to the development of a vibrant innovation ecosystem: universal compulsory military service and waves of mass Jewish immigration. We shall elaborate about these factors in more details in the following pages, as well as in the analytical sections.

4.4.8.1.The role of Israeli Defense Forces and immigration culture

Given its fraught geopolitical status, less than a year since its establishment in 1948, Israeli government has been implementing a universal military conscription program, in which most Israelis (both men and women) will be drafted annually into the Israeli Defense Forces (IDF) by the age of 18, before they attend university education. The length of military service varies across gender: for male conscripts, the service period lasts for 2.5 years (a reduction from 3 years before 2020), and in the case of female conscripts, military service lasts for 2 years.[211] What is unique about IDF is that the armed forces, together with its affiliated research institutions, serve as another 'educational anchor' that provide training and guidance for highly capable and skilled teenagers, especially in the fields of computer science and engineering. Oftentimes, during their time in service, the selected best and brightest high-school graduates are assigned into key units and programs that deal with technology development and engineering projects for IDF; one instance was in 2013, when a special IDF program targeted Israeli high-school students to prepare them as soldiers in the Teleprocessing Corps (**Israel Defense Forces, 2013**). Moreover, under such programs, IDF commanders often act directly as advisors to the trainees, providing them with personal support and mentorship. Conscripts graduating from such units/programs would join the ranks of IDF's most talented innovators, computer programmers, and technology experts.

IDF's strong emphasis on maintaining military superiority is of paramount importance to Israel, and much of this has to do with Israel's historical vulnerabilities (**Breznitz, 2007; Taylor, 2016**). From Israel's founding in 1948 up to the collapse of Soviet Union in 1991, the country has long been faced with constant military threats from the surrounding Arab states, many of which were historically supported by the Soviet government. With a significantly smaller population than their counterparts in the neighboring Arab countries, in addition to enforcing a mandatory military conscription, Israel desperately needed to rely on advanced weaponry and equipment to address its demographic, and socio-economic, disadvantage; majority of the Jewish immigrants arriving in Israel in the country's first 2-3 decades were refugees, often with limited possession of wealth and/or income. While the country initially relied on France for ensuring a constant supply of arms and other weapons, Israel's 'creative insecurity' was further exacerbated by a French-imposed arms embargo in 1967, by the time when Israel was waging Six-Day War against Egypt, Syria, and Jordan (**Taylor, 2016**). Such moment became an impetus, and a 'bitter pill', for Israel in recognizing the need to master their own ability to research, and manufacture, their own armaments. From this turning point onward, Israel began to intensify their efforts in military R&D, all the while strengthening their capacities in absorbing imported technologies from overseas (**Breznitz, 2007**). As shown from Figure 4-25 below, Israel's military spending (measured as a share of GDP) rose very sharply, from 9.4% in 1966 to 15.4% in 1967, and reaching its peak of 30.5% in 1975, shortly in the aftermath of its 1973 war with neighboring Arab states.[212]

It is also worth noting that modern weapon systems are extremely complex, and highly technical, equipment; the military industry's high tolerance of failure during their R&D process may explain their substantial amount of resources dedicated into this area. One 'unintended consequence' from the country's strong focus on military research has been their unparalleled competitive advantages in the fields of communications (especially in wireless communication), networking, and data security (**De Fontenay and Carmel, 2004**). Elite military technical personnel also tended to have long mandatory tours of duty throughout their service period, which meant that cadres of highly-skilled personnel were constantly exposed to the uses of advanced technologies within the military. This may, therefore, explain a high proportion of such individuals, upon their discharge from IDF, engaging in technology-based entrepreneurship.



Source: **World Bank (2022)**

Figure 4-25 Military spending in Israel (as % of GDP)[213]

Furthermore, military service has frequently been an 'alternative' pathway for many Israeli conscripts and soldiers in seeking advanced degrees, and much of this was by policy design. One major example is the case of Israel's Armament Development Authority (RAFAEL). Since the 1970s, RAFAEL has been offering graduate academic education for thousands of its employees at the best engineering schools in Israel, the United States, and elsewhere across the world, notably to MIT, Stanford, and UC Berkeley (**Breznitz, 2007**).[214] Such experiences allow them to be exposed to the broader innovation ecosystem communities, notably networks of researchers, entrepreneurs, technology-based SMEs, and venture capital (VC) investors in the Silicon Valley, where Stanford and UC Berkeley are located. Upon graduating, many of these RAFAEL fellows return to Israel, whether to continue working in the agency, serve in academia, other government institutions, or establish their own start-ups, all the while retaining their ties with those overseas (**Engel and Del-Palacio, 2011**). Indirectly, such networks also enable major multinational corporations, especially ICT-oriented giants such as Apple, Intel, Google, Facebook, Microsoft, and among many others, to invest and establish R&D centers in Israel; we will further elaborate about the roles of foreign firms in Tel Aviv's innovation ecosystem in the coming pages.

Another explanatory variable accounting for Israel's achievements in human capital development was also related to waves of mass Jewish immigration since the country's independence, the most pivotal by which was the exodus of Jews from former Soviet Union states from 1989 onward, and which intensified in the aftermath of its collapse in 1991 (**De Fontenay and Carmel, 2004**). It was estimated that up to 1 million Jews from the region migrated to Israel throughout the 1990s, many of whom had already developed scientific and/or engineering backgrounds. While a significant proportion of this demographic initially struggled in entering the country's scientific and academic communities, many of them eventually found their way into the ICT industry, part of which was 'helped' by the boom of Internet sector, and its enabling technologies (**De Fontenay and Carmel, 2004**). Such influx

of immigrants, in turn, has given Israel not only a massive access to scientific talents, but also tapped into a reservoir of scientific knowledge based on decades of education and training received in the then-Soviet Union, particularly in physics and material sciences. Much of their knowledge would end up being applied in the measurement, testing, and scientific instrument-related industries, electro-optics sector, and ICT-related industries. More importantly, given their religious background, these immigrants coalesced and adapted fairly quickly with Israel's broader population.

When it comes to government policymaking in science, technology, and innovation, we cannot simply attribute Israel's success to the omnipresent role of military forces and their stance of allowing mass immigration of talents. In this regard, the state's economic and industrial policies have also played a no less vital role, partly as a 'spillover' from military R&D. Beginning from the early 1970s, in parallel with a massive increase in military spending-to-GDP ratio, the country's civilian STI policy was strongly, and almost exclusively, attuned towards directing the R&D capacity to creating new products. In addition, the national R&D policy viewed private firms as the primary R&D-performing actors, and strongly pushed them to diffuse technologies resulting from research undertaken from academia and the military into civilian applications, on top of two-way collaboration between the firms and the latter (**Breznitz, 2004; Breznitz, 2007**).

Universities in Tel Aviv

Tel Aviv University

The effervescence of Israel's higher-education infrastructure, particularly for research activities, has contributed to the abundance of skilled, well-trained human capital within the country. A major institution contributing to Tel Aviv's strengths in STI-related areas is the Tel Aviv University (TAU), which we have profiled in the preceding Task 2 report. As one of the key, and most prestigious, publicly-funded research universities in Israel, TAU has long enjoyed its reputation as a globally leading research-performing institution, and consistently ranks in the top 200 universities worldwide in various international rankings. TAU is also the highest-ranked university in Israel in terms of aggregate research output, citation impacts, and popularity among the students. As demonstrated by Figure 4-26 below, within the Tel Aviv municipality alone (exclusive of satellite cities constituting the broader Tel Aviv metropolitan region), TAU has consistently accounted for close to 90% of scientific publications generated from the city. In the last five years alone (2017-2021), of nearly 35,500 published journal articles originating from Tel Aviv, about 32,000 of them involved TAU scientists.

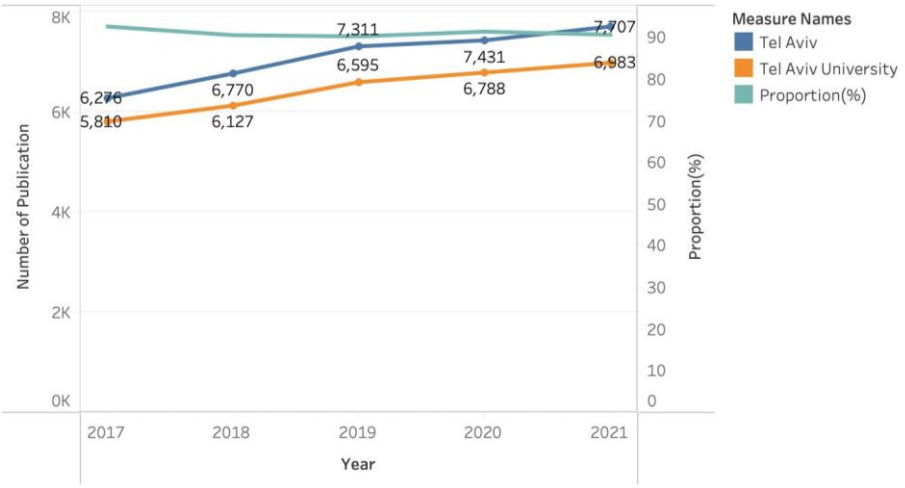


Figure 4-26 Annual publication output by Tel Aviv municipality and Tel Aviv University (TAU) for 2017-2021 period

Beyond TAU, Tel Aviv hosts other prominent universities and research institutions, many of which are strongly oriented towards teaching-related activities.

Some of the major examples are displayed in the following bullet points below:

- Reichman University (IDC College): established in 1994 as Israel's first private non-profit higher education institution, the university aimed to carry forward its founders' mission of creating a university in which personal achievements would go hand-in-hand with social responsibilities. Since its founding, the university has sought to actively promote an interdisciplinary higher education model. As of early 2021, Reichman University was authorized by the government of Israel to offer PhD programs in law, psychology, and computer science, the first such programs offered by a private university in Israel.
- College of Management – Academic Studies (COMAS): located in Rishon LeZion, one of the satellite cities comprising the Tel Aviv metropolitan region, COMAS was the first non-subsidized, non-profit academic institution in Israel that is recognized and certified by the country's Council for Higher Education. Currently with 8,500 students and 60,000 alumni in aggregate, COMAS is one of the biggest colleges in Israel in terms of enrollment.
- Open University of Israel: since its establishment in 1974, the distance-education university has been making strides in providing accessible, affordable higher education for all residents, enrolling more than 20,000 students each year regardless of their occupational, family, social, location, or age backgrounds. The university is officially accredited by the Council of Higher Education in awarding undergraduate and graduate degrees, diplomas, and/or certificates. The university also enrolls many students across the world in comparison to other academic institutions in Israel.
- Weizmann Institute of Science: located in Rehovot (another satellite city of Tel Aviv metropolitan region), the institute serves as both a public research organization (PRO) and a postgraduate research-oriented school. Since its establishment in 1934 (nearly 15

years before the establishment of Israel's modern-day state), the institute has gained its international reputation given their strong research focus in the areas of natural and physical sciences.[215] At present, 6 Nobel Prize laureates have been affiliated with Weizmann Institute. The institute also participates actively in international, cross-country knowledge exchange and collaboration (**Garbi and Garzik, 2021**).

Overall, the effervescence of Israel's higher-education infrastructure, particularly for research activities, has contributed to the abundance of skilled, well-trained human capital within the country.

4.4.8.2.Government agencies and programs

Office of the Chief Scientist (OCS)

One of the most relevant examples is the case of the Office of the Chief Scientist (OCS), renamed as Israel Innovation Authority (IIA) since 2016. Established by the government in 1965, the agency has been a major mainstay of Israel's R&D activities, especially in incentivizing two-way R&D linkages between public research institutions (in academia, government PROs, and the armed forces) and private-sector firms. The agency has also contributed, indirectly, to the creation of Israel's modern VC ecosystem (**Avnimelech and Teubal, 2006**), and the 'start-up incubation' model now proliferating across the globe. Since its restructuring in 2016, IIA has since consolidated their focus under five major areas, namely: 1) Startup Division; 2) Growth Division; 3) Technological Infrastructure; 4) International Collaboration; 5) Advanced Manufacturing, and; 6) Societal Challenges. In aggregate, over 30 grants and incentive programs are offered by IIA (**Israel Innovation Authority, 2022**), the details by which are shown in Table 4-73 below.

Table 4-73 Major programs, funds, incentives, and schemes by Israel Innovation Authority

Name of IIA division	Programs/funds/incentives/schemes
Startup Division	• Incubator Incentive Program • Innovation Labs Program – Incentive Program • Tnufa (Ideation) Incentive Program • Early-Stage Companies Incentive Program • Renewable Energy (Cleantech) Technology Center
Growth Division	• Incentive Program to Encourage the Establishment of Multinational Companies' R&D Centers in the Fields of Biotechnology and Health • Incentive Program for Innovation with Government Entities • Generic R&D Incentive Program for Large Companies • R&D Fund
Technological Infrastructure	• TELEM (The National Infrastructure Forum for R&D) • Leveraging R&D for Dual Use Technologies (MEIMAD)

	• Applied Support of Research Institutes • Promoting Applied Research in Academia (NOFAR-KAMIN) • Technology Transfer (MAGNETON) • Generic Technology R&D Consortia (MAGNET) • Users' Association R&D Infrastructure
International Collaboration	• Bilateral Programs for Parallel Support • R&D Cooperation with Multinational Corporations • EU Framework Agreement – Horizon 2020 • Program for Boosting Participation of Israeli Companies in the European Framework Program – Horizon 2020 • European Programs for Parallel Support • Incentive Program for Adapting Products for Emerging Markets • Bi-National Funds
Advanced Manufacturing	• R&D Preparatory Incentive Program for Companies in the Manufacturing Industry • MOFET – R&D in Manufacturing Industry
Societal Challenges	• GCI – Grand Challenges Israel Incentive Program • Coding Bootcamp Program • Digital Innovation for Public-Sector Challenges • Assistive Technology for the Disabled Program • Diverse Startups: Incentive Programs for Ultra-Orthodox and Minorities • Innovation Visas Program for Foreign Entrepreneurs • Back-to-Tech Program

We have extensively discussed about the roles of education, universities, military service, mass immigration, and government policies in shaping Tel Aviv's – and Israel's – innovation ecosystem. Nevertheless, beyond the abundance of talented human resources and the resulting knowledge and technological base, Israeli culture has, in large part, also accounted for the country's unique success in this area. Three cultural traits contribute to shaping Israel's success as follows: 1) a flexible, bureaucratic structure with limited red tape (**Breznitz, 2007**); 2) a collectivist culture with strong organizational loyalty (**De Fontenay and Carmel, 2004**), and; 3) a no-barrier culture that emphasizes improvisation skills and agile thinking (**Garbi and Garzik, 2021**). We shall elaborate about these characteristics in the following paragraphs below.

There is very limited red tape within not only Tel Aviv's innovation ecosystem, but also across Israel more broadly. Given that the country's national security and survival depends strongly on its innovation performance, and in order to maintain a strong domestic economy centered within this scope, regulations that hinder innovation are kept to a minimum, with an emphasis on flexibility and agility over stability (**Garbi and Garzik, 2021**). Furthermore, Israel's civil service structure is relatively 'porous', in the sense that employees working for government agencies often establish their career trajectories as 'revolving doors' between the state,

academia, and industry; in other words, many civil servants may have a combination of careers as bureaucrats, academic researchers, and/or entrepreneurs. The structure of the Israeli bureaucracy has been designed in a way that makes it more likely for civil servants to perceive the country's ICT industry as representing – and an extension – of the national interest, making it fairly easy for policymakers to formulate and implement policies (**Breznitz, 2007**). In other words, this flexible structure reflects a conscious political decision to empower leaders under such policymaking framework.

Moreover, studies have shown that Israelis have strong group attachments, and often identify themselves as members of a group, are more likely concerned with the well-being and collective interests of the group, and – largely as a product of military service culture – are generally loyal to their groups, demonstrating a strong teamwork ethic (**Shahar and Kurtz, 1995; De Fontenay and Carmel, 2004**). Israelis' collectivist group attachment arises from their shared sense of identity, common purpose of 'survival', as well as common experience with military conscription. There are two major implications on the organizational and occupational culture in Israel (**De Fontenay and Carmel, 2004**). First, Israelis prefer to work in teams, often for the sake of their teams and/or the companies. Second, the collectivist tendency implies a relatively low turnover rate, although the scholars cautioned that such assumption is increasingly questioned with increasing turnover among start-up employees, and the tendency for a growing number of Israeli companies to move overseas (**De Fontenay and Carmel, 2004; Breznitz, 2021**).

In addition, another cultural characteristic within Israel relates to their 'barrier-free communication' model, in which individuals can openly approach anyone and are encouraged to share their ideas and/or thoughts. The no-barrier culture tends to be especially beneficial for start-up founders, as this allows them to approach experts and potential clients without the need for significant prior validation or proof of merits regarding their still early-stage start-ups (**Garbi and Garzik, 2021**). Such culture increases the agility of the ecosystem, and in turn flattens the organizational structure, as well as shorten the distance between the entrepreneurs and necessary resources to brainstorm and tinker with high-value ideas and formulate effective execution plans.

Last but not least, Israeli culture heavily emphasizes improvisational skills and agile thinking (**Garbi and Garzik, 2021**). Since their early age, Israelis have been trained to improvise and think abstractly, and mandatory military service serves as a further 'push' for them in this direction given the rigorous challenges of military life. Due to the challenging conditions throughout their service period, Israelis must learn to quickly adapt, as well as to overcome differences, in low-resource environments, such as the need for survival or shelter during field training. Moreover, given the relatively flat organizational structure within IDF units, conscripts are often expected to assume full responsibility in their units, undertake long working hours, respond quickly to existing challenges, improvise, and take into consideration strategic objectives rather than job-related specifics (**De Fontenay and Carmel, 2004**).

Undoubtedly, Israel's unique cultural traits have, more often than not, caused significant misunderstanding when Israelis venture outside the country, particularly to the US. **Shahar**

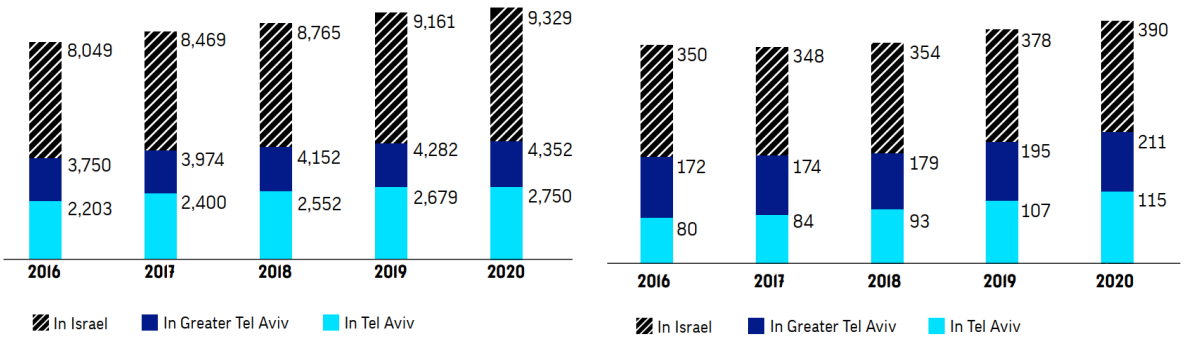
and Kurtz (1995) summarized the 'culture clash' between Israelis and Americans perfectly, as shown in Table 4-74 below.

Table 4-74 Differences in cultural perception between Israelis and Americans

While Israelis see themselves as:	**Many North Americans see Israelis as:**		**While North Americans see themselves as:**	**Many Israelis see North Americans as:**
informal	rude		polite	insincere / artificial
direct / honest	rude		friendly	naive / sexually provocative
spontaneous	out of control		respectful for privacy	unfriendly / shy
hospitable	smothering		sharing personal concerns	tastelessly exposing private matters
assertive	aggressive / arrogant		organized	inflexible / going by the book
casual about rules	inefficient / sloppy		respectful of authority	conformist / excessively formal
creative	undisciplined		professional	arbitrarily differentiating between work and social things
taking the initiative	insubordinate		efficient	arbitrarily differentiating between work and social things
self-confident	arrogant		self-confident	arrogant
willing to take risks	overconfident		trusting	naive
realistic / wary	cynical		trustworthy	naive

Source: http://ion.uwinnipeg.ca/~aappel1/iscultur.html

Overall, the combination of factors we have elaborated above enables Israel – and Tel Aviv, in particular – to be the innovation hub as it is today. According to a 2020 report by the Tel Aviv municipal government, more than half of Israel's leading technology companies and MNC R&D centers are based within the Tel Aviv metropolitan region (**Tel Aviv Government, 2021**), the details by which are visualized in Figure 4-27 below.[216]



Source: **Tel Aviv Government (2021)**

Figure 4-27 Number of identified Israeli technology companies (left-side), and R&D centers by foreign multinational corporations (right-side)

Nevertheless, several scholars have pointed out that, in recent years, and as a consequence of years of government-mandated budget cuts on education and research since the 2000s, Israel's

education system has been deteriorating, with its ability in producing highly-qualified talents declining considerably (**Breznitz, 2021**). This was further demonstrated by the students' average PISA test results in recent years, which have shown either stagnation or a steady decline, especially in reading, mathematics, and science, and overall results that were below the averages of OECD member-states (**OECD, 2019**). To make matters worse, according to the **Shoresh Institution for Socioeconomic Research (2021)**, nearly half of Israeli children – most of whom from low-income and/or minority backgrounds – were shown to receive a 'third-world' education.[217] If such trends persist in the future, it is feared that Israel's long-term competitive advantage will be increasingly under threats.

Despite its current challenges, Tel Aviv's evolution as an innovation hub is worth studying. In the coming sections, we will conduct a series of in-depth studies on inter-organizational linkages that shape the city's innovation system. Near the end of this chapter, we will discuss what Hong Kong can learn (and possibly to emulate) from the Tel Aviv case.

4.4.8.3.Three analysis

INTER-ORGANIZATIONAL NETWORKS: EVIDENCE FROM USPTO PATENT DATA

First, we utilized USPTO patent data to observe the evolutionary shifts in the Tel Aviv innovation ecosystem. Having removed no-assignee patent filings, design patents, as well as those with missing values in most of their variables, we managed to collect over 11,000 patent applications for inventions based in the municipality. Table 4-75 below displays the ten most actively patenting organizations within the city. One interesting finding is that most of the top-10 assignees (with the exception of Tel Aviv University / TAU and Weizmann Institute of Science, both of which are research universities) are foreign multinational enterprises, all of which are based in the United States. Four of them (Intel, Apple, Google, Marvell) happen to be Silicon Valley-based technology companies; this fnding highlights the strong linkages between Tel Aviv and Silicon Valley, largely due to 'bridging' efforts by Israeli and the broader Jewish diaspora in both innovation hubs (**Breznitz, 2007; De Fontenay and Carmel, 2004; Schafer and Henn, 2018**). Moreover, most of these major patenting firms are engaged in high-technology, ICT-related industries, for which Israel has long enjoyed a competitive advantage since the early 1990s (**Breznitz, 2007**).

Table 4-75 List of top-10 patenting assignees in Tel Aviv (all-time)

Name	Patent filings (11,145)
IBM	709
EMC Corporation	613
TAU	414
Intel	355
Microsoft	209
Apple	205
Google	168

Motorola	151
Marvell	138
Weizmann Inst of Science	133
Share of top 10	27.8%
No. of organizations	1,852

One thing worth noting about Israel was its initial status as a developing, middle-income country up to the early 1990s. Even until the end of 1980s, the country was barely considered as a high technology-powered innovation hub; moreover, they had only recently recovered from economic malaise that has been affecting the country's economy since the mid-1970s (**Breznitz, 2007**). This was evident from the patenting landscape in Tel Aviv in 1983-1988 period; throughout the 6-year period, we could only identify 131 USPTO patent filings originating from the municipality. Back then, Motorola was the most actively patenting assignee organization, given their presence of R&D centers throughout Israel. Tel Aviv University (TAU) was the second most frequent patenter. Of the top-10 list in this period, one notable local technology enterprise was Elscint, a local nuclear-technology company and subsidiary of Elbit Systems, one of the largest military weapons manufacturers in Israel.[218]

Nevertheless, seeds laying the grounds for the city's – and more broadly, the country's – eventual dominance in technological innovation have been set in place from 1967, when France (then Israel's largest arms supplier) announced an embargo, which hit Israeli military particularly hard. Long dependent on foreign technology imports, the embargo served as a bitter pill, and eventually a huge impetus, for Israel to build their R&D and technological capabilities. It was in this period that the government established RAFAEL (Armament Development Authority), which fast-tracked the deployment of technological innovation – especially in ICT-related areas – from universities and research institutes to government agencies and the armed forces (**Breznitz, 2004**). Moreover, RAFAEL provided generous funding for thousands of Israelis, whether for civilian engineers or talented military conscripts, to study in some of the best universities in Israel and the United States.

One major impact from Israel's decades-old investment in their R&D capabilities was the subsequent 'explosion' in their patent filings from early 1990s onward. Starting from the 1989-1994 period, Tel Aviv's patenting output (N = 306) was already more than double the figure for the preceding period (N = 131). An interesting pattern we observed was the entry of more foreign (and especially American) firms, notably from National Semiconductor and IBM. TAU has also further expanded their dominance in the university technology-transfer landscape in Israel with their tremendous increase in the number of patent filings. Indeed, from the mid-1990s up to mid-2000s, TAU was the most actively patenting organization in Tel Aviv. To a limited extent, universities and research institutes in the surrounding Tel Aviv metropolitan region, namely Bar-Ilan University (located in Ramat Gan, a satellite city of Tel Aviv) and Weizmann Institute of Science (located in Rehovot, 38 km from Tel Aviv), have also been quite influential in the region's innovative activity landscape.

Since early 21st century (as shown in the 2001-2006 period), the composition of organizations in the top-10 patenting assignee lists has been increasingly dominated by multinational, and primarily US-based, enterprises. As we have stated in the previous paragraphs, many of these large corporations are headquartered in Silicon Valley, with notable examples including Intel, Cisco, Hewlett-Packard, Marvell, SanDisk, Apple, Google, etc. Furthermore, Tel Aviv has witnessed the proliferation of numerous high-technology start-ups, oftentimes founded by professionals with work experience in some of these companies. Much of this was enabled by what **Schafer and Henn (2018)** described as 'return migration' of a significant proportion of overseas Israelis; of over 67,000 Israelis immigrating to the US for study and/or work throughout the 1950-1990 period, over 1/3 of them returned, but a high proportion of these returning talents would either 'invite' their employers to establish R&D centers in Israel or to establish high-technology companies given Israel's economic boom (**Kenney et al., 2013**).[219]

Table 4-75 in the next page described the influence of Tel Aviv-based organizations on account of betweenness centrality, a network property describing the degree to which a node in a network facilitates knowledge flows between any possible nodal pairs within the network of interest (**Freeman, 1977**). One interesting observation we found was TAU's consistent position as the organization with the highest betweenness centrality score throughout all six periods of analysis. Interpreting this finding, we argue that TAU's inclusion as one of the world's most innovative universities may have been enabled by the university's role as a pivotal 'bridge' in facilitating inter-organizational knowledge flows within Tel Aviv innovation ecosystem, whether through technology transfer, spin-off formation, career mobility of university scientists, etc. To a certain extent, foreign, Silicon Valley-based firms also score relatively high in betweenness centrality scores, as shown by Intel, SanDisk, Marvell, and Apple.

Box 1. Military service as an 'unlikely incubator' for entrepreneurship in Israel

In the previous pages, we have mentioned several factors that contribute to the rise of Tel Aviv – and Israel more broadly – as one of the world's leading innovation hubs: strong commitment to scientific research and technological development, the rapid deployment of R&D results into products and/or services (especially by the military and government agencies), close ties between the Israeli state and the Jewish diaspora (especially in the United States) that facilitated the entries of US multinational firms into the country, as well as the influx of Jewish immigration from ex-Soviet states – most of whom had background as well-educated scientists, engineers, and doctorate holders – throughout the 1990s. Once again, mandatory military conscription is a major explanatory factor (**Breznitz, 2004; De Fontenay and Carmel, 2004**). Since its independence in 1948, Israel's existence has been, by and large, contentious: the country fought multiple wars against their neighboring Middle Eastern states in 1948, 1967, and 1973. Israel's perilous geographical and political position

necessitated the state to impose mandatory military conscription for virtually every adult reaching the eligible age of 18 in the country, with 3 years of service for males, and 2 years for females.

Nevertheless, Israel's organizational military culture is highly distinctive from those of other countries, particularly those with similar conscription policies (e.g. South Korea and Singapore). The conscripts, since their inception into the armed forces, have been taught to learn computing and other engineering skills, and those considered highly talented would often be assigned tasks and/or projects considered very challenging or near-impossible. Moreover, the *chutzpah* ('positive rudeness') spirit is highly evident in the military's largely non-hierarchical organizational culture, with conscripts and junior military officers frequently challenging their seniors when the latter are perceived by their former subordinates of committing any errors or other mistakes. One major breakthrough enabled by this driving factor is Israel's strengths in electro-optics, fiber-optics, as well as robotic manufacturing industries, the skills by which have been obtained through conscripts' engineering training in the armed forces. Furthermore, the country's cyber-security industry – considered one of the best in the world – was 'born' from research conducted at military units, which received further boost with the global-scale personal computer (PC) and laptop 'revolution' from the 1980s onward (**Breznitz, 2005**). Overall, organizational skills in the military can be described as befitting better those of emerging start-ups rather than of large, incumbent, hierarchical organizations (**De Fontenay and Carmel, 2004**).

Table 4-76 List of top-10 patenting assignees in Tel Aviv throughout different time periods (patent filings indicated in brackets)

1983-1988 (131)	1989-1994 (306)	1995-2000 (1,070)	2001-2006 (1,674)	2007-2012 (3,459)	2013-2018 (4,347)
Motorola (13)	Motorola (18)	TAU (62)	TAU (57)	IBM (313)	EMC Corporation (359)
TAU (11)	Scitex (17)	Motorola (58)	IBM (56)	EMC Corporation (221)	IBM (318)
Aligena Ag (5)	TAU (16)	3Com (42)	Intel (54)	TAU (140)	Intel (201)
Elscint Ltd (5)	Nat'l Semicond (15)	Weizmann Inst Sci (32)	Cisco (44)	Intel (91)	Apple (139)
Spectronix (5)	Spectronix (12)	Teva Pharmaceutical (25)	Teva Pharmaceutical (41)	Google (85)	Microsoft (134)
Stanford Univ (5)	Symbol Tech (10)	Medinol (18)	Weizmann Inst Sci (34)	Microsoft (69)	TAU (115)
Amcor (4)	IBM (9)	ZAG Industries (16)	IXI Mobile (26)	Red Hat (68)	Google (83)
Salgad Int'l (4)	DSP (8)	Technion (15)	SAP (25)	SanDisk (67)	Mellanox (69)
Harbor Branch Inst (3)	SUNY (8)	EMC Corporation (14)	Hewlett-Packard (24)	Apple (66)	General Motors (60)
Shakbar Investments (3)	US DHHS (8)	Adv Recog Tech (13)	Marvell (24)	Marvell (65)	Marvell (47)
Share of top 10: 44.3%	Share of top 10: 39.5%	Share of top 10: 27.6%	Share of top 10: 23.0%	Share of top 10: 34.3%	Share of top 10: 35.1%
No. of organizations: 66	No. of organizations: 115	No. of organizations: 379	No. of organizations: 550	No. of organizations: 720	No. of organizations: 771

Table 4-77 List of top-10 patenting assignees in Tel Aviv in terms of betweenness centrality scores (scores indicated in brackets)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
TAU (9)	TAU (18)	TAU (367)	TAU (154)	TAU (2837)	TAU (3747)
-	Teva Pharmaceutical (6)	Hebrew Univ Jer (167)	Weizmann Inst Sci (58)	Mor Research (1065)	Technion (2148)
-	-	Technion (158)	Hadasit Medical (20)	Hebrew Univ Jer (1011)	Samsung (1759)
-	-	Weizmann Inst Sci (153)	SanDisk (18)	IBM (774)	IBM (1472)
-	-	Mor Research (112)	Bar-Ilan Univ (18)	Niti Technologies (684)	Apple (1209)
-	-	Motorola (63)	Intel (17)	Hairstetics (616)	Hebrew Univ Jer (955)
-	-	Intel (62)	Univ of California (11)	Weizmann Inst Sci (497)	Microsoft (628)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
-	-	US DHHS (33)	Marvell (6)	EMC Corporation (487)	Intel (484)
-	-	DSPC Tech Ltd (32)	EMC Corporation (5)	TASMC (381)	Rosetta Genomics (408)
-	-	Alcatel-Lucent (14)	Biol Signal Process (3)	Tel Hashomer Med (285)	TASMC (391)

UNIVERSITY-INDUSTRY COLLABORATION IN SCIENCE: EVIDENCE FROM ANALYSIS OF JOINT PUBLICATIONS

Beyond inter-organizational networks in terms of technology development, we also studied the landscape of scientific collaboration in Tel Aviv, with a particular emphasis on the city's leading research university, Tel Aviv University (TAU). Based on a subset of publication data collected from Lens.org that spans early 2009 to the end of 2018 (for a total of 10-year period), we identified 30,751 published journal articles involving at least 1 scientist and/or researcher affiliated with the university. Furthermore, approximately 5% of TAU's 10-year cumulative publications (N = 1,538) are U-I co-publications; this figure is slightly below the 6-7% global annual average estimated by **Tijssen et al. (2009)**. Nevertheless, in comparison with those of Hong Kong universities, TAU's figure appears to be substantially higher.

Once we break down the types of U-I co-publications based on the geographical location of these firms (local, domestic non-local, and foreign), we identified an interesting pattern. Within Israel, a higher number (and in turn, proportion) of such joint publications involve collaborators from enterprises within the Tel Aviv region than with fellow Israeli firms from the rest of the country, although the gap between the former and the latter has consistently declined throughout the 10-year period.[220] By contrast, the largest proportion of TAU's U-I co-publications was with foreign enterprises. Over time, the share by these companies has increased from nearly 60% in 2009 to approximately 70% in 2018 (while peaking at 75% in 2016).

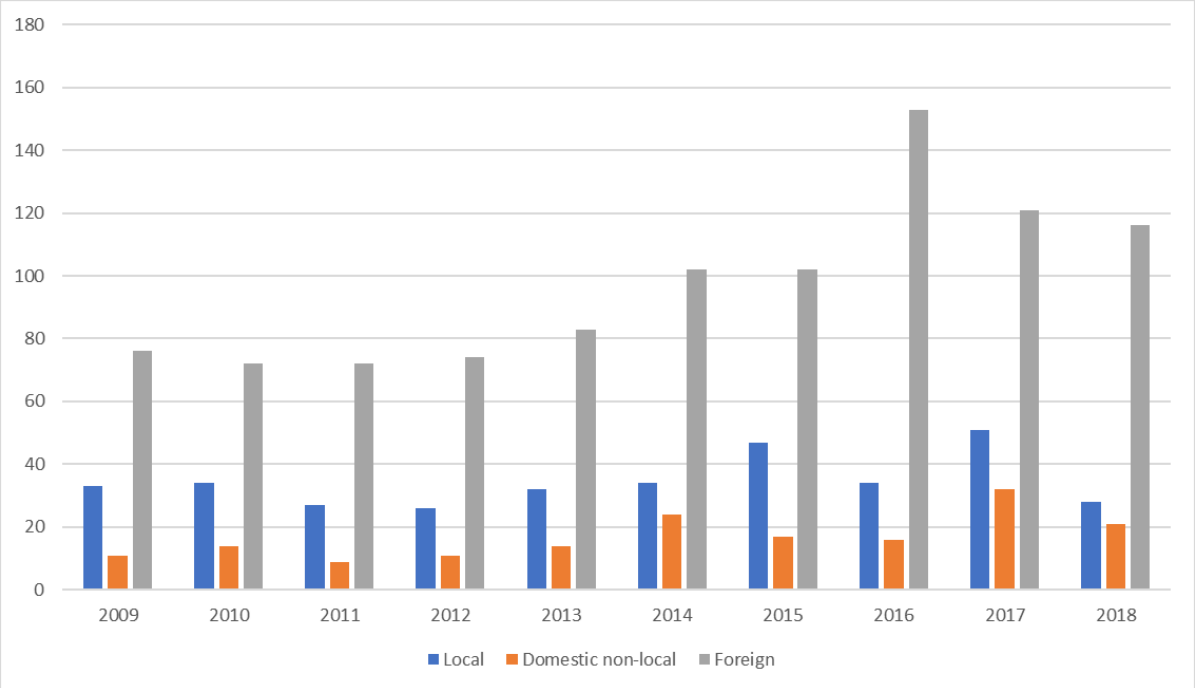
Unlike other innovation hubs such as Seattle or Silicon Valley, Tel Aviv does not host home-grown companies that are on par – in terms of revenues, market size, as well as market capitalization – with those of established giants such as Facebook, Apple, Amazon, Microsoft, Google, etc. Instead, the city has primarily hosted a large number of high-technology small-and-medium-sized enterprises (SMEs), many of which specialize in niche technologies, and had backgrounds in either university research (again, mainly in TAU) or from Israeli talents returning from study and/or work overseas (**Kenney et al., 2013**). Through a closer analysis of TAU's U-I co-publications involving local firms, we identified 100 such journal articles (nearly 30% of the entire observation) co-authored by the university researchers and their counterparts from 51 TAU

spin-offs. As shown in Table 4-78 below, more than half of these enterprises engage in either biotechnology/life sciences/pharmaceuticals (N = 23) or in the development of medical devices (N = 7).

Table 4-78 Top 10 collaborating firms with Tel Aviv University (TAU) in U-I co-publications (2009-2018 period, number of U-I co-publications indicated in brackets)

Local firms (N = 346)	Domestic non-local firms (N = 169)	Foreign firms (N = 971)
Rosetta Genomics (20)	IL Ocean Limno R&D (17)	Leidos (183)
Gertner Inst Health (19)	Israel Electric (7)	Sci Appl Intl Corp (129)
Teva Pharmaceuticals (9)	Insightec (5)	Microsoft (65)
Israel Military Industries (7)	Tower Semiconductor (4)	Merck (29)
Xceed Imaging (7)	NovellusDx (4)	IBM (22)
BSP Ltd (6)	Atlantium Technology (3)	Google (21)
Orbotech (6)	CCAM Biotherapeutic (2)	Rafael (13)
Brainstorm Cell Therap (5)	Immune System Key (2)	Silver Spring Networks (12)
Neurim Pharmaceutical (5)	Intertrust Technologies (2)	Fujitsu (11)
NeuroDerm (5)	Medgenics Medical (2)	NxGen Partners (11)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Local	33	34	27	26	32	34	47	34	51	28
Domestic non-local	11	14	9	11	14	24	17	16	32	21
Foreign	76	72	72	74	83	102	102	153	121	116
TOTAL	124	129	116	117	138	172	166	210	199	167



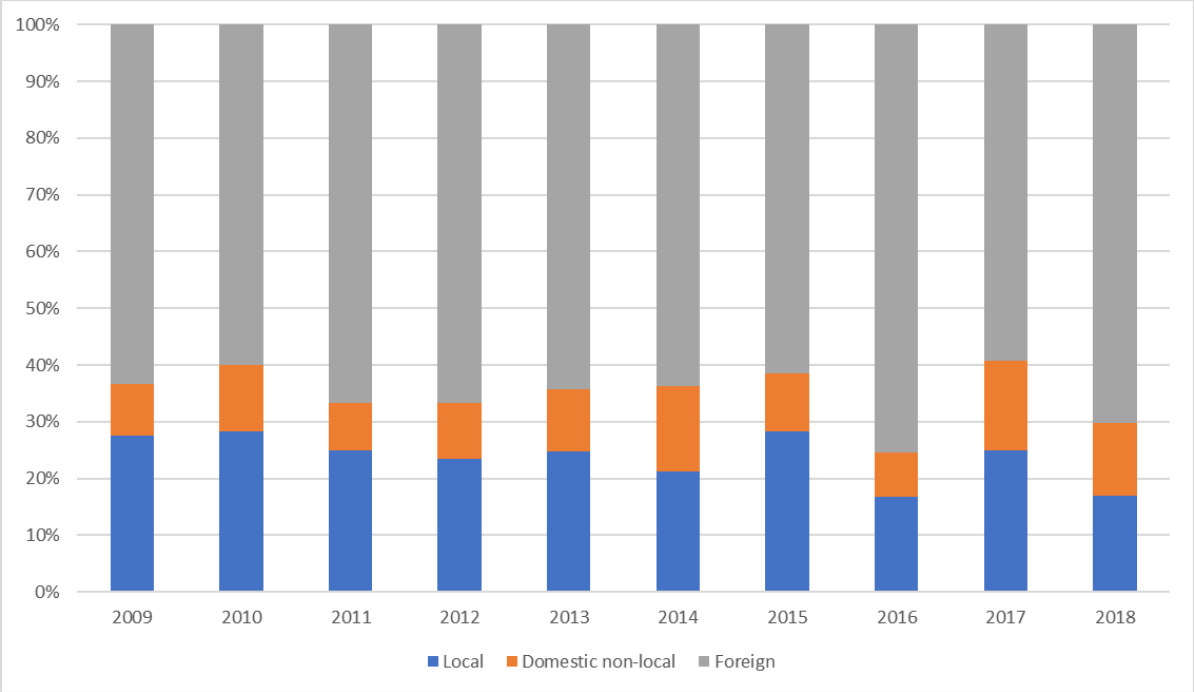


Figure 4-28 Types of U-I co-publications involving TAU (2009-2018) based on the geographical origins of collaborating firms

Table 4-79 Specialization of TAU spin-offs identified from U-I co-publications (2009-2018)

Sector	Number (N = 51)
Biotechnology/pharmaceuticals	23
Medical devices	7
Consulting	2
Energy technology (energy-tech)	2
Geophysics engineering	2
Information & communication technology (ICT)	2
Material sciences	2
Nanotechnology	2
Sensors	2
Wearables	2
Clean technology (clean-tech)	1
Environmental conservation	1
Laser	1
Satellite and related instruments	1
Scientific instruments	1

Name	University	Profile
Silenseed	TAU	Silenseed is a biopharmaceutical company which builds their core technologies based on proprietary RNA

		interference (RNAi)-based cancer drugs and delivery systems; these technologies are aimed to effectively penetrate and eventually eliminate malignant solid tumors. Silenseed combines their novel drugs with LODER (LOcal Drug EluteR), a novel delivery system to transmit cancer drugs to the intended tumors. The company's products are targeted for patients with pancreatic cancer, prostate cancer, and several types of brain cancers. It was founded in 1999, and is currently led, by Amotz Shemi, a serial entrepreneur, inventor, and scientist with PhD from TAU.
Aspect Imaging	TAU	Aspect Imaging is a company specialized in the design and development of compact magnetic resonance imaging (MRI) and nuclear magnetic resonance (NMR) systems for a wide range of applications, notably clinical, medical, and industrial. The company was founded in 2007 by Ehud Katzenelson, a PhD graduate of Tel Aviv University (TAU) with postdoctoral research experience in Germany and Italy, as well as research work in several technology companies.
Biological Signal Processing (BSP)	TAU	Biological Signal Processing (BSP) is a company currently developing new, non-invasive diagnostic and monitoring technologies for various cardiovascular diseases, notably Ischemic Heart Disease. Using proprietary signal processing technology, BSP's products perform analysis with results that are significantly more reliable and accurate than those from conventional stress testing. Recently, the company has also begun to expand their business scope into ECG testing. It was founded by Dr. Amir Beker, a scientist with PhD training from Tel Aviv University (TAU). It has since been acquired by China-Israel Biological Technology Ltd, and is jointly managed by a group of Chinese and Israeli professionals.
Biop Medical	TAU Technion	Biop Medical is a company currently building advanced medical devices that can monitor uterine cervix tissue. Their core innovation lies on the state-of-the-art, high-resolution optics for the medical device. These devices are instrumental for doctors in diagnosing potential abnormalities such as lesions, cancer, and tumor, which can be useful for potential biopsy in real time. It was

		founded, and is currently led, by Ilan Landesman (as the company's CEO) and Micha Zimmermann (as the company's CTO). Ilan is a graduate of TAU, whereas Micha is a graduate of Technion.
Cellect Biotechnology	TAU	Cellect Biotechnology is a company focused on promoting innovation in their cell therapy treatments. Their core innovation is ApoGraft technology (bone marrow transplantation-related), which enables the transformation of cell-based therapies into a simple, safe and inexpensive regenerative medicine. It was founded in 2011 by Shai Yarkoni and Kasbian Nuriel Chirich. Shai is a serial entrepreneur, having founded several biotechnology companies in the past, and is also a former professor of medicine at TAU.
Corephotonics	TAU Hebrew Univ Jerus Technion Stanford	Corephotonics is one of the first pioneers and global market leaders in multi-aperture technologies for mobile devices (notably in smartphones). Their core innovation – mainly in the field of material sciences – lies in end-to-end multi-aperture solutions, which enable optical zoom, optimal low-light performance, as well as optical image stabilization. It was acquired in 2019 by Samsung Electronics, a South Korean multinational ICT giant, for more than US$150 million. It was established in 2012 by serial entrepreneurs Professor David Mendlovic, Dr. Gal Shabtay, Mr. Eran Kali, Dr. Noy Cohen and Mr. Ephraim Goldenberg. David Mendlovic is currently a professor at Tel Aviv University (TAU). Gal Shabtay is a scientist and serial entrepreneur, having obtained his PhD from TAU. Eran Kali is also a scientist and serial entrepreneur, with PhD from Hebrew University of Jerusalem. Noy Cohen is an experienced industry scientist with BSc and MSc from TAU, and PhD from Stanford University, and has worked in Google and Nvidia in Silicon Valley. Ephraim Goldenberg was formerly a scientist based in Technion.
Emedgene	TAU Technion	Emedgene is the world's first company that builds a completely automated genetic interpretation platform. The company aspires to utilize the most advanced AI technologies in order to dramatically scale genetic interpretation and discovery. By making use of end-to-end AI, especially in natural language processing (NLP),

		Emedgene's products can help accelerate genomic-driven discovery, which can assist numerous organizations in making their research processes faster, more efficient, and more productive. Emedgene was founded in 2015 by Einat Metzer (now the company's CEO), Shay Tzur (the company's CSO), and Niv Mizrahi (the company's CTO). Einat is an Israeli software developer, business executive, and venture capitalist based in Silicon Valley. Shay is a scientist and serial entrepreneur, with PhD from Technion. Niv is a serial entrepreneur and software engineer, graduating from Tel Aviv University (TAU).
Laser Detect Systems	TAU Open Univ of IL	Laser Detect Systems (LDS) is a company that pioneers laser-based trace detection technology. The company's products, which are based on this technology, have been commercialized and applied in various areas, primarily in homeland security, law enforcement, military, and environmental safety, particularly in identifying dangerous substances (e.g. drugs, chemicals, explosives, other hazardous chemical elements, etc). It was established in 2004 to commercialize research by Lev Nagli (professor at TAU) and Michael Gaft (a former professor at Open University of Israel). Both of them concurrently serve as the company's chief scientists and scientific advisors.
Nano Retina	TAU	Nano Retina is a nanotechnology-focused company that is currently developing products (based on their core technologies) that are aimed to restore functional vision for individuals with vision impairment-related diseases. Their primary innovation lies in the advanced, artificial retina technology that can mimic the physiological functions of natural retina, and by which can effectively substitute the affected retina of these vision-impaired patients. Nano Retina was founded in 2009 by two visionary medtech experts - Yossi Gross, a serial entrepreneur, inventor and co-founder of Rainbow Medical, and Jim von Ehr, a leader in the field of nanotechnology, serial entrepreneur, and founder and CEO of Zyvex Labs. The company's R&D is currently led by Yael Hanein as the company's Vice President of Scientific Affairs (and also a full-time professor at TAU),

		and includes other TAU professors in the company's scientific advisory board (Dov Weinberger and Adiel Barak).
Notal Vision	TAU	Notal Vision is a diagnostics company that utilizes insights from artificial intelligence (AI) in advancing precision medicine treatment for eye care. The company offers an 'on-demand' treatment regimen that can be tailored for each patient's disease condition. Their two core functions are: 1) Notal Vision Diagnostic Clinic (NVDC), which serves as the hub for testing collection, analysis, and interpretation, and; 2) Optical Coherence Tomography (OCT), a technology that allows ophthalmologists to tailor their assessments following each patient's different condition, as well as to recommend personalized medicine treatments based on individualized diagnostic results. Their OCT product is targeted towards eye injections delivered primarily in the US. Notal Vision was founded in 2000 by Barak Azmon, a former researcher at Tel Aviv University (TAU) Sourasky Medical Center. Barak is currently the company's CTO. The company is led by Kester Nahen, a serial entrepreneur and scientist with PhD in physics from Medical University of Lubeck (Germany).
Pronto Diagnostics	TAU Weizmann Inst Sci	Pronto Diagnostics is a company offering molecular diagnostic products and services. Their expertise is in researching and developing SNP-detection kits that can rapidly identify polymorphisms in DNA sequences linked to genetic diseases. Furthermore, the company offers clinical diagnostics and clinical research services, including DNA purification, genetic sequencing, fragment analysis, pharmacogenomic testing, etc. The company was founded, and is currently led, by Nir Navot and Ruth Shomrat. Nir is a serial entrepreneur and scientist with PhD from Weizmann Institute of Science. Ruth is a scientist who has been based in Tel Aviv University (TAU) Sourasky Medical Center for a long time (since 1970). She had PhD from TAU as well.
SynVaccine	TAU Weizmann Inst Sci	SynVaccine is a company developing immuno-oncolytic viruses that can be used for cancer immunotherapy-related treatments, as well as the development of vaccines

		for various diseases, including cancer diseases. It also specializes in computational designing of viral genomes and physical DNA editing based on their viral vaccine genome libraries. It was co-founded in 2013 by Tuval Ben Yehezkel (based on his PhD and postdoctoral research at Weizmann Institute of Science) and Tamir Tuller (based on his PhD at TAU). Tuval was the company's chief scientist until 2015 when he left to start another biotechnology company.
Tracense	TAU	Tracense is a nanotechnology company that aims to use their innovation in this technology to build next-generation threat-detection sensors that can identify potential explosives, biological, as well as chemical warfare agents. Their sensor products have been used in a wide range of sectors for threat identification and deterrence, namely airports, seaports, border crossings, transportation terminals, large-event venues, critical infrastructure facilities, etc. Tracense Systems was founded in 2007, and is currently led, by Nir Regev and Fernando Patolsky. Nir was formerly a military commander at Israeli Defense Forces (IDF). Fernando is now an expert of nanomaterials and an associate professor at TAU.

With specific regard to spin-offs, Ramot – TAU's technology transfer office structured as a company – has been particularly dedicated in identifying, incubating, nurturing, and subsequently transforming the university's inventions into useful products and/or services. Together with the university's other entrepreneurship-related programs, namely TAU Entrepreneurship Club, TAU Annual US$100,000 Startup Competition, and TAU Ventures (the university's own venture capital/VC fund), these entities have made tremendous efforts in building a vibrant innovation and entrepreneurial ecosystem not only within TAU, but also in Tel Aviv more generally. The role played by TAU Ventures has been especially exemplary; endowed with initial capital worth US$20 million in 2018, the fund has been utilized to support dozens of university-based companies – whether student-founded start-ups or research output-commercializing spin-offs.

While Ramot did not fully disclose information about the number of start-ups originating from TAU, research by **PitchBook (2021)** shows an ongoing increase in the cumulative number of graduates-turned-entrepreneurs (as shown by Table 4-80 below) based from the university. Indeed, in terms of alumni-founded start-up category, TAU ranked within the top-10 universities worldwide, placing it on par with institutions such as Harvard, Stanford, MIT, etc.

Moreover, from our additional research at Tracxn (2021), we identified a total of 1,498 companies – whether located in Tel Aviv or beyond – with founders that are/were TAU alumni, 19 of which have become start-up unicorns, or early-stage companies with valuation of at least US$1 billion. In relation to the third analysis that we will display shortly, we list some of the major examples (both unicorn and non-unicorn companies) founded by TAU alumni in Table 4-80 below. Interestingly, from our additional desktop research in Crunchbase (the main source of data we utilized for the third analysis), we found that less than 40% of these companies still remain within Tel Aviv metropolitan region, supporting the assertion by **Schafer and Henn (2018)** about the increasing internationalization of these enterprises by relocating their headquarters overseas.

Table 4-80 TAU cumulative graduate entrepreneurship-related figures (2018-2021)

Year	Graduates-turned-entrepreneurs (cumulative)	Companies founded (cumulative)	Capital raised (US$ billion, cumulative)
2018	640	531	7.9
2019	694	577	10.6
2020	807	673	16.1
2021	912	761	26.8

Source: **PitchBook (2021)**

Table 4-81 Notable TAU alumni-founded companies, courtesy of Tracxn (2021)

Name	Short description	Year founded	Current HQ	Founders
Wix	Provider of cloud-based website development platform	2006	Tel Aviv (IL)	Nadav Abrahami Giora Kaplan Avishai Abrahami
Celsius Network	App-based cryptocurrency-backed loans solutions for SMEs and individuals	2017	London (UK)	Shlomi Leon Alexander Mashinsky
Houzz	Online listing platform for home design, décor, remodeling, etc	2009	Silicon Valley (US)	Alon Cohen Adi Tatarko
Team8	Start-up accelerator for supporting cybersecurity-themed early-stage firms	2014	New York City (US)	Liran Grinberg Nadav Zafrir Israel Grimberg Ronni Zehavi Sarit Firon
Innoviz	Pioneer of solid-state LiDAR-based sensors and software	2016	Rosh HaAyin (IL)	Oren Buskila Amit Steinberg Omer Keilaf Oren Rosenzweig

Monday.com	Cloud-based enterprise solutions for team collaboration	2012	Tel Aviv (IL)	Eran Zinman Roy Man
Curve	NFC-supported multi-account payment cards	2015	London (UK)	Anna Williams Shahar Bialick Shachar Bialick
Via	Technology-enabled software solution for transport shuttles	2012	New York City (US)	Oren Shoval Daniel Ramot
Waze	Mobile app-based navigation and carpooling services	2007	Tel Aviv (IL)	Amir Shinar Ehud Shabtai
Tripledot	Mobile game development company (Android and iOS)	2017	London (UK)	Eyal Chameides Akin Babayigit Lior Shiff

FINANCING SUPPORT FOR LOCAL TECHNOLOGY COMPANIES: EVIDENCE FROM CRUNCHBASE DATA

In the final analysis for this hub, we focused on financing activities by Tel Aviv-based investors (VCs, private-equity firms, institutional and individual investors, etc). We made use of Crunchbase in compiling the list of investors in the city. In total, we identified a total of 855 such investors. While the number, in absolute terms, is slightly more than half of Hong Kong's (the figure by which is close to 1,400), per-capita wise – considering Tel Aviv's population of 0.5 million, the density of investors and VCs in the city is among the highest in comparison to the other hubs we covered for this report, and indeed in the world. This observation appears to align with **Avnimelech and Teubal (2006)** in their discussion on how VC industry – with Yozma, a state-led fund being a main pioneer – grew in tandem with the emerging ICT industry cluster in Israel, and Tel Aviv more specifically.[221]

Collectively, we have recorded a total of 5,941 investment deals by all these 855 investors in 3,907 companies, both in Israel and worldwide. We limited our attention to the top-25 investors (in terms of their cumulative number of financial deals), as listed in Table 4-83 in the following pages. These top-25 investors, collectively, were responsible for 2,702 investment rounds (equivalent to 44% of all Tel Aviv-based investment deals) in 1,481 technology-related companies (around 38% of Tel Aviv investors' portfolio organizations). No information on investment-related experiences could be obtained in 40% of the listed investors, whereas another 21% (N = 179) of them were one-off investors (having been involved, per record, in only one financing deal). The remaining investors, or close to 40% of the total, were involved in two or more aggregate investment deals on various technology companies worldwide.

Table 4-82 Information about investors in Tel Aviv (source: Crunchbase)

Size of investment activities	Number of investors
No information about investments	344
1 investment only	179
2-9 cumulative investments	196
10-25 cumulative investments	81
26-50 cumulative investments	29
51-99 cumulative investments	16
100-999 cumulative investments	10
1,000 or more cumulative investments	0
TOTAL	855

An interesting insight from a brief glance on the profiles of these top-25 investors shows that nearly half of them (N = 12) are focused on offering angel, seed-stage, and/or early-stage investments. Some notable examples include Pitango Venture Capital (which directs their investments primarily into health technology-related start-ups) and Viola Ventures, which provides financing deals and other types of support for Israeli companies across a wide range of emerging technologies. Foreign firms and VCs have also established 'branch' funds in Israel, as exemplified by Microsoft ScaleUp Tel Aviv (an acceleration and investment program by Microsoft) and Sequoia Capital Israel (an Israeli-focused subsidiary of the Silicon Valley-based VC fund).

Table 4-83 Top 25 investment funds in Tel Aviv and proportion of investments in Tel Aviv technology companies

Name	Summary	No. of investments	Investments in Tel Aviv	No. of portfolio organizations	Portfolio organizations in Tel Aviv
Pitango Venture Capital	A VC firm that invests in early-stage and growth-stage start-ups, with a particular focus on health-tech companies	313	67 (21.4%)	152	39 (25.7%)
Viola Ventures	A VC firm that invests specifically in Israeli-related early-stage technology companies	229	43 (18.8%)	104	26 (25.0%)
Vertex Ventures Israel	A VC firm that offers investments as well as firm leadership strategies and advice to invested firms	173	48 (27.7%)	94	28 (29.8%)

Sequoia Capital Israel	A subsidiary of Silicon Valley-based Sequoia Capital that focuses on technology companies in Israel and beyond	152	12 (7.9%)	61	9 (14.8%)
Gemini Israel Ventures	A VC firm that offers investments in seed-stage and early-stage companies	138	14 (10.1%)	66	7 (10.6%)
Giza Venture Capital	A VC firm that invests in seed-stage and early-stage technology start-ups in Israel and abroad	128	23 (18.0%)	80	18 (22.5%)
Magma Venture Partner	A VC firm that specializes primarily in early-stage companies in Israel and abroad	114	50 (43.9%)	54	22 (40.7%)
Vintage Investment Partners	An investment firm that conducts investments in VC funds and start-ups worldwide through primary and secondary transactions	113	22 (19.5%)	78	18 (23.1%)
Genesis Partners	One of the earliest VC funds in Israel (established in 1996), which has co-invested in many Israeli start-ups with major VC funds such as Sequoia, Accel, etc	112	32 (28.6%)	62	17 (27.4%)
Microsoft ScaleUp Tel Aviv	An accelerator and investment fund support program by Microsoft to support cloud computing and other IT start-ups in Israel	110	39 (35.5%)	107	39 (36.4%)
Evergreen Venture Partners	A VC fund that offers investments in both early-stage as well as emerging-growth start-ups	95	12 (12.6%)	48	8 (16.7%)
iAngels	A firm that functions as a VC fund, angel investor, and also 'connector' between investors and aspiring technology entrepreneurs	90	28 (31.1%)	67	19 (28.4%)

Pontifax	A VC fund that specializes in investing in pharmaceutical, life sciences, and biotech-related firms	86	2 (2.3%)	59	1 (1.7%)
Aleph	A VC fund focused on offering early-stage investments in promising Israeli entrepreneurs in expanding their start-ups globally	83	31 (37.3%)	40	16 (40.0%)
BRM Capital	A VC fund offering early-stage investments in Israeli start-ups focused on software, Internet and related infrastructure, telecom, and other ICT-related industries	82	15 (18.3%)	39	7 (18.0%)
Viola Credit	A credit investment management firm offering financial support and lending services for technology and fintech companies	79	13 (16.5%)	50	8 (16.0%)
StageOne Ventures	An investment fund that offers early-stage deals in business-to-business (B2B) high-tech start-ups	77	34 (44.2%)	36	16 (44.4%)
Peregrine Ventures	A VC fund offering investments at high-technology start-ups at various stages (seed/early, first round, second round, advanced, etc)	76	35 (46.1%)	54	21 (38.9%)
Cedar Fund	A VC fund offering seed-stage, early-stage, and first-round deals at Israel's promising start-ups	76	6 (7.9%)	39	3 (7.7%)
Firstime Venture Capital	A venture fund concurrently serving as a club for angel investors that invests in Israel's ICT and digital-tech start-ups	73	37 (50.7%)	31	14 (45.2%)

Iool Ventures	A VC firm that offers early-stage investments in Israel's promising technology start-ups	69	30 (43.5%)	33	12 (36.4%)
TLV Partners	A VC firm offering early-stage investments at Israel's technology start-ups, with a particular focus on those based in Tel Aviv area	67	38 (56.7%)	33	19 (57.6%)
2B Angels	An angel investment and VC firm that offes financial deals at Israel's technology start-ups	59	25 (42.4%)	34	17 (50.0%)
Maniv Mobility	A specialized VC firm offering early-stage investments in Israel's start-ups focused in mobility, transportation, and logistics-related technologies	55	23 (41.8%)	31	10 (32.3%)
Glilot Capital Partners	A specialized VC firm offering early-stage investments in Israel's start-ups focused in artificial intelligence (AI), cybersecurity, and big data	53	17 (32.1%)	29	12 (41.4%)
TOTAL (for top 25 funds)		2,702	696 (25.8%)	1,481	406 (27.4%)

4.4.8.4.Discussion and conclusions

Throughout the analyses on Tel Aviv, one major lesson stands out: the city's growth as an innovation ecosystem has been – both directly and indirectly – linked to the role played by Tel Aviv University (TAU) as not only the city's, but also Israel's more broadly, leading university. Our study of historical evolution in Tel Aviv's innovation networks, which we proxied using USPTO patent data, illustrated the university's persistent position as the most influential innovation actor – from early 1980s to as recent as 2018 – in bridging inter-organizational ties (using the betweenness centrality indicator), despite their slide down the top-10 ranking in terms of the absolute number of patent applications filed. While foreign firms largely dominated the top-10 lists based on patent filings in recent periods, their betweenness centrality scores hardly surpassed that of TAU; interpreting this finding in layman's term, enterprises –

and foreign multinationals in particular – were not preferred as 'brokers' in bridging inter-organizational ties given their interests in restricting external actors in accessing their proprietary intellectual assets, the knowledge by which may spill over to other entities within the surrounding locality; instead, universities and research institutes are more likely candidates in knowledge dissemination, as well as spillover (**Owen-Smith and Powell, 2004**). To a limited extent, other research-performing entities, e.g. Weizmann Institute of Science, are also another pivotal driving force on Tel Aviv's innovation ecosystem.

TAU's strong linkages with other innovation actors in Tel Aviv are not limited in the area of technological development alone, as shown by patent analysis summarized above. Scientific publications, and U-I co-publications to be specific, have been another avenue by which the university disseminates their research impacts for the city's regional development. Within Israel, the higher proportion of such joint publications took place within Tel Aviv metropolitan area, although the gaps in collaborative works with those in non-Tel Aviv areas have been diminishing in recent years. And quite interestingly, almost one-third of TAU's co-publications with local industries involved collaborators from spin-offs with direct and/or indirect linkages to TAU, whether to research performed in the university alone or in collaboration with other institutions. Many of the spin-offs we profiled in one of the tables above signified the success of inter-organizational collaboration with TAU, especially on matters pertaining to economic development and technology applications.

In the case of investment activities, TAU has not been as actively involved (as indicated by their absence in the top-25 investor list), but the university has nevertheless played an important bridging role through building networks with the VC community in Tel Aviv. As we have explained in the Task 2 report, an indirect way the university helps contribute to the city's innovation ecosystem is through Ramot, which employs technology-transfer and IP licensing management professionals with past experiences as serial entrepreneurs, venture capitalists, commercially-active faculty members, and/or senior TTO officials in other universities. In turn, these Ramot employees are able to leverage their expertise, as well as professional networks, in linking TAU's entrepreneurship communities to the broader actors in Tel Aviv's innovation ecosystem. Moreover, beyond Ramot, some of TAU's schools and departments also establish their own technology transfer units and/or entrepreneurship clubs that build close ties with these diverse actors.

Indeed, more recently, TAU has established their own investment fund, the first such instance of university-led venture capital entity in Israel. Known as TAU Ventures, the enterprise was established in 2018 with a focus on providing seed-stage and early-stage financial support for start-ups founded by members of TAU community (students, alumni, researchers, faculty members, etc). While it was not listed in the top-25 list in the previous section – given the fund's rather recent establishment, from our observation in Crunchbase and the company's own website, TAU Ventures has been – in collaboration with other investors in Israel and beyond – involved in 27 investment activities in 18 TAU-based start-ups. Beyond offering financing deals, TAU Ventures also provides a co-working space for these supported early-stage companies, on top of mentoring support and networking access to other innovation actors in Tel Aviv.

What can Hong Kong learn from Tel Aviv's experiences? While replicating certain Israeli-specific characteristics (e.g. mandatory universal military service, Israel's cultural values and customs, relatively flat organizational culture, willingness to challenge superiors in case of mistakes, etc) either is nearly impossible to replicate or has no necessarily causal linkages to the country's innovation performance, there are some common traits that can be adapted in the context of Hong Kong. First, universities may be encouraged to establish their own VC funds to support the booming spin-offs. Thus far, university spin-offs primarily receive their early-stage funding from the Hong Kong government under Technology Start-up Support Scheme for Universities (TSSSU). We have thus far identified one instance of a university-initiated investment fund – notably HKUST Entrepreneurship Fund – that offers advanced-stage investments, but further efforts by other universities in establishing more ambitious VC-like funds remain to be seen.[222] Another alternative, beyond university VC funds, would be for existing KTOs/TTOs in Hong Kong's universities to recruit more professionals with business-relevant backgrounds, particularly those with experiences as serial entrepreneurs, venture capitalists, and/or academic entrepreneurs.

Second, Hong Kong can build stronger connection with overseas Hong Kong and Chinese diaspora, and in particular those with science, technology, and engineering-related expertise who are currently based in major innovation hubs overseas (e.g. Silicon Valley). Tel Aviv – and Israel more broadly, by extension – has been able to thrive thanks to their success in building strong ties with Israeli and Jewish communities in Silicon Valley and New York City. Oftentimes, attracting overseas returnees necessitates concerted efforts by dedicated, multi-stakeholder 'coalitions of the willing', one example by which has been demonstrated in our case study of TAU in Task 2 report regarding university-industry-government tripartite efforts to invite Israeli scholars in the United States and beyond to return to the country. Such tripartite efforts that are specifically tailored for Hong Kong's areas of innovation priorities are worth considering for replication.

Third, Hong Kong government may further expand their bilateral collaboration with more countries globally – in particular countries that are leading innovation hubs – in terms of STI-related collaboration, with a structure akin to US-Israel Bi-national Industrial Research and Development (BIRD) model. Thus far, UGC has several joint schemes in place (primarily with mainland China, European Union, Germany, and France), but these schemes are largely limited to scientific research and travel grants for visiting scientists.[223] Further expansion of such schemes to other areas (e.g. joint technology development and/or commercialization) may be one area that Hong Kong government can consider.

4.4.9. London

Introduction

In contemporary times, London is well-renowned as a global hub for financial services, commercial activities, as well as various creative industries (e.g., fashion, design, arts, etc). Historically, London was one of the first cities in the world to pioneer the first-generation industrial revolution and traditional manufacturing industries (**Del-Palacio and Chapman, 2014**), beginning from steam engine-driven textile production. The city was also a 'home' to clusters of various, once-thriving manufacturing industries, e.g., electrical cables, aerospace parts, household appliances, furniture, clothing, printing, etc. Nevertheless, London's status as a pioneer of such advances could not salvage it from new waves of technological revolution that subsequently followed; as low-cost production began to shift to emerging economies in Asia from 1950s onward, the city has been faced with a wave of severe deindustrialization that lasted for more than three decades (**Atkinson and Ezell, 2012**).

What follows from deindustrialization, afterwards, was the emergence of four separate, but inter-related, phenomena that reshape London's innovation ecosystem. First, as we will show from the next sections, the city's innovation dynamics would increasingly be dominated by the entry of foreign multinationals seeking to enter European markets by establishing main offices, as well as R&D centers, in London. Second, and in a trend quite similar to that of Hong Kong, financial services-related industries expanded their presence in London (Del-Palacio and Chapman, 2014), which, while contributed significantly to the city's – and UK's broader – GDP output, has also exposed their vulnerability to internal and external challenges, such as 2008-2012 global financial and banking crisis, Brexit, and most recently, COVID-19 pandemic. Third, the vacant spaces resulting from decades of deindustrialization would 'seed' a new generation of business-service and creative industries to occupy these spaces, and in turn, revitalize surrounding communities (Nathan and Vandore, 2014). Fourth, education sector was also a highly strategic field in London's post-industrial economy, given the high number of universities – both publicly-funded (as shown by University of London constituent schools) and privately-funded – as well as the large population of fee-paying domestic and international students. In the later pages, we will elaborate more about each of the phenomena.

4.4.9.1.London's industrial transition process and government policies

Simultaneously as London underwent through economic transformation, the government – both at the national (UK) and the municipal level – has been engaged in substantial policy efforts to manage the city's industrial transition process. One example relates to their incentives to revive manufacturing industries within London metropolitan area, especially after the 2008 global financial crisis revealed London's – and in turn the UK's – vulnerability to risks from disruption to the financial-services industry. Since the publication of a white paper by the UK Department of the Treasury (Growth Review) in November 2010 on strategies to nurture advanced manufacturing industries in the UK[224], there have been a proliferation of policy plans

to implement these strategies (**Livesey, 2015**), with some examples listed from the bullet points below:

- Funding for Catapult Centers (originally named Technology and Innovation Centers), with the first Catapult hub established to solely cover technologies surrounding high-value-added manufacturing. In aggregate, these Catapult Centers would specialize in: 1) high-value manufacturing; 2) cell therapy; 3) offshore renewable energy; 4) satellite applications; 5) connected digital economy; 6) future cities; 7) transport systems; 8) energy systems, and; 9) diagnostics for stratified medicine (**United Kingdom Government, 2010**)
- The formation of nine Centers for Innovative Manufacturing across the country to undertake research on strategic areas of importance for manufacturing
- The re-launching of Manufacturing Advisory Service to provide expert advice to industry firms on productivity improvements and process innovation
- The establishment of an international engineering prize worth £1 million (now known as Queen Elizabeth Prize for Engineering)
- Advanced Manufacturing Supply Chain Initiative, a four-round £245 million investment scheme to promote integration of advanced manufacturing and supply chain in the country

Moreover, in the November 2010 report, the Department of Business, Innovation, and Skills – then under the leadership of Sir Vince Cables – outlined priority sectors in which the UK government aspired to develop as the country's new sources of competitive advantages, and these priority sectors would encompass: 1) aerospace; 2) agricultural technologies; 3) automotive; 4) construction; 5) information economy; 6) international education; 7) life sciences; 8) nuclear; 9) offshore wind; 10) oil and gas, and; 11) professional and business services (**United Kingdom Government, 2010**).

Key Policies and programs to promote university-industry collaboration

Knowledge Transfer Partnership (KTP) Programme

The Knowledge Transfer Partnership (KTP) Programme is a tri-party collaboration mechanism established in 1975. Funded by the UK Research and Innovation (UKRI) through Innovate UK and other government co-funders, KTP supports businesses and companies to achieve technological innovation or change to a more entrepreneurial style of management (M. Wynn & Jones, 2019). It is achieved via two types of KTP projects: (a) classic KTPs, with a focus on developing new or better products and services via innovative technology, and (b) management KTPs, aiming at increasing effectiveness and productivity through better management practices. This programme is especially beneficial for SMEs as they have high priority when applying for management KTPs and they are granted with higher portion of funding (up to 67%) with regard to eligible costs compared with large companies (up to 50%) (gov.uk, 2022). KTP links the below three parties, including:

(a) Business partner, must be a UK registered business or not-for-profit organisation. To enable them to get access to the UK's academic expertise;

(b) Associate, such as graduates or Post-graduates from education institutions. To provide them with career platforms, and enable them to lead the project with full support and input from the organization and academia teams;

(c) Knowledge base, must be a UK registered higher education or further education institutions, Research Technology Organisation (RTO) or Catapult. To enable them to apply their research outcomes to real world businesses.

The mechanism of granting funding to selected KTP projects can be summarized into three steps: (a) Business partners need to partner with knowledge base, supported by a Knowledge Transfer Advisor, (b) the Knowledge base serves as lead organization to submit the application for KTP (c) upon approval, they jointly recruit suitable Associates to start working on their projects. (See Figure 4-29). Probability of being successful applications are quite high, around 80-90% (Perera, 2022).

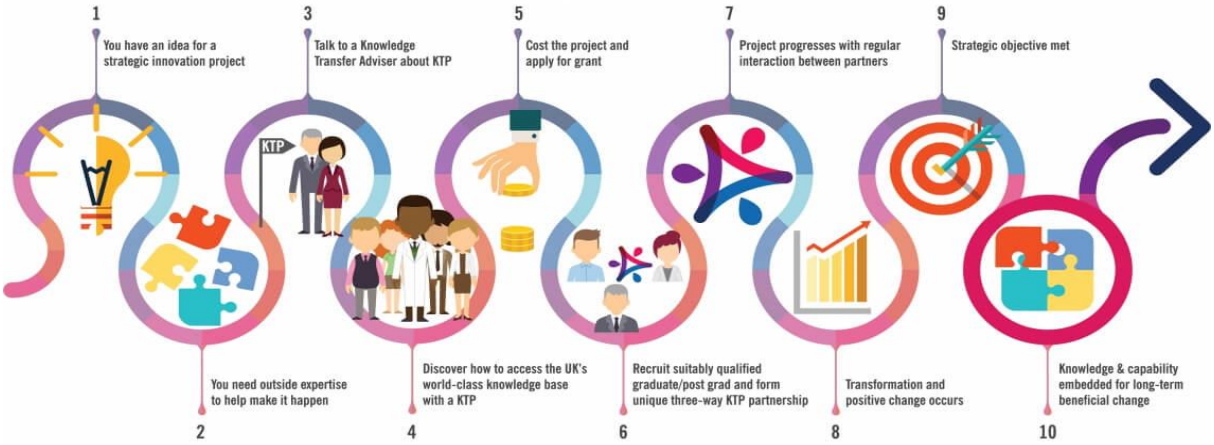


Figure 4-29 Roadmap of KTP for Business Partners. Source: Innovate UK

The impacts of KTP on business partners and knowledge base include multiple aspects according to many case studies. By providing a platform for interaction and collaboration of businesses and graduates, it promotes the university-firm collaboration (Bertoletti & Johnes, 2021). It can therefore provide benefits to all three parties. In particular, universities can gain both collective and individual benefits according to Wynn and Turner (2013), including establishment of a selling culture and ability, involvement of both academics and industry colleagues in the project design, and delivery of multiple benefits from supervising projects such as teaching based on case studies and providing work opportunities. Other benefits include using knowledge and experience to solve challenges in the real world, earning research income and publishing high-quality research papers and journals. For each KTP project, an average of three new research projects and two research papers were created (KTP-UK, n.d.). Although detailed information such as the number of projects engaging specific universities in London, universities such as Imperial College London (ICL) and University College London (UCL) publish on their website some related companies they have collaborated with in the form of case studies. Another indirect benefit is related to the Research Excellence Framework (REF),

where academics can be inspired with new research topics and thus can increase their impacts to be assessed in REF. More details of REF, which serves to assess UK higher education institutions' research excellence, will be introduced in the next section.

On the other hand, some challenges are also identified for the operation mode of KTP. As it involves knowledge sharing, mainly coming from the knowledge base side, it is highly dependent on the academic staff's enthusiasm of participation and is therefore subject to the research culture and incentives (Wynn & Jones, 2017).

Research Excellence Framework (REF): assess and evaluate research

REF is the UK's system for assessing the research excellence in UK higher education providers, which first carried out in 2014. It is managed by Research England on behalf of all 4 UK higher education funding bodies ((Research England, Scottish Funding Council, Higher Education Funding Council for Wales, Department for the Economy, Northern Ireland). Its main aims are threefold (Higher Funding Council of England, n.d.):

- To ensure that public research investment (around £2 billion per year) is held accountable and proof the benefits of this investment;
- To provide benchmarking data and reputational yardsticks;
- To assist in the selective allocation of research funding

The REF indirectly promotes UIC by including impact assessment as part of the assessment element (See Table 4-84).

Table 4-84 Elements of Assessing Universities

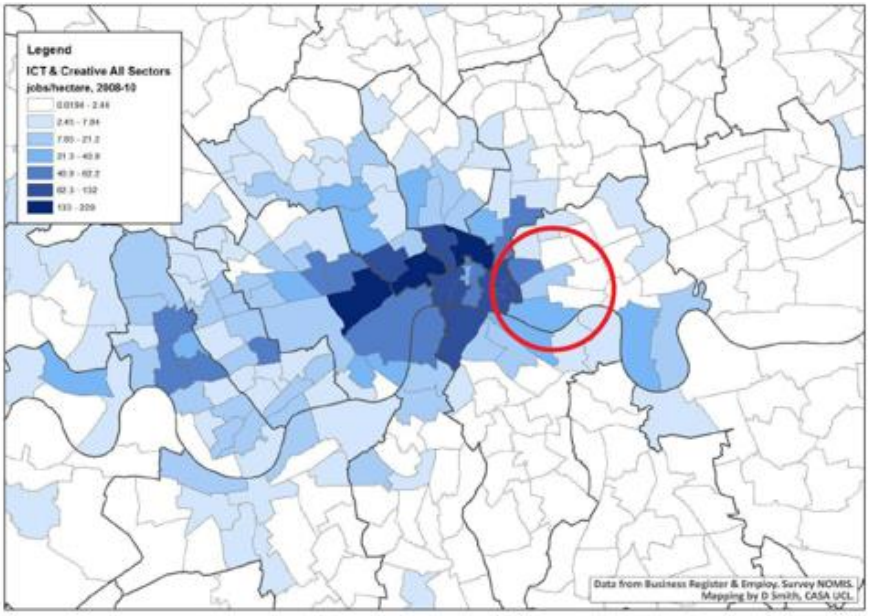
Element	Description	Proportion
Outputs	Any form of research published within the set time frame; Assessed against the criteria of 'originality, significance and rigour'	60%
Impact	An effect on, change or benefit to the aspects beyond academia (including the economy, society, culture, public policy or services, health, the environment or quality of life); Assessed in terms of 'reach and significance' via compulsory impact case studies	25%
Environment	Strategy, resources and infrastructure that support research and enable impact; Assessed based on 'vitality and sustainability'	15%

Source: REF 2021 Key Facts

A case for re-industrialisation: East London

Beyond manufacturing, the UK government and London municipal authorities also paid attention on developing technology clusters in London, with a particular focus on East London. Once an industrial hub in the previous centuries, East London has been particularly hit hard by the waves of deindustrialization from the 1950s to the 1980s. With vacant spaces resulting from abandoned factories, as well as affordable rents, this area has since been undergoing gentrification with the emergence of creative industry clusters; this began when Shoreditch, one of the areas in East London, witnessed the growth of professional communities centered on graphic design stores and web designers in the 1990s. These former factory sites and warehouses, in turn, were converted into co-working spaces for these professionals. The cluster effects soon followed with the 'attraction' East London offered to aspiring visual artists, musicians, and fashion designers, and subsequently start-up companies in digital and creative media sectors. These clusters are particularly concentrated in Clerkenwell, Shoreditch, Hoxton, and Haggerston.

It is noteworthy that the East London clusters of entrepreneurship had long emerged before the UK government – and London municipal authorities – took further policy action in transforming this region into 'Tech City', one that is also colloquially known as 'Silicon Roundabout'.[225] It was in 2010 that then-UK Prime Minister, David Cameron, unveiled his administration plans to convert the region into a thriving innovation and technology hub through a series of policy incentives, e.g. special incentives for seed-funding of early-stage technology start-ups (which we will elaborate in the sub-section on investment activities in London), tax breaks for these start-ups, special visas for entrepreneurs, etc. Much of the impetus for such policy action was attributed to the 2008 global financial crisis, in which technology entrepreneurs began to urge the British government to utilize policy tools by transforming East London as a 'base' for revitalizing London's, and UK's, economy given the severe impacts of the crisis on London's economy.



Source: Max Nathan, Emma Vandore, and Rob Whitehead, *A Tale of Tech City: The Future of East London's Digital Economy* (London: Centre for London, 2012), http://centreforlondon.org/publication/a-tale-of-tech-city/.

Figure 4-30 Location of 'Tech City' within London

The case of Tech City initiative is particularly worth elaborating. Established in November 2010 by the David Cameron administration, the initiative sought to put into practice the notion of 'Silicon Roundabout' previously already applied in colloquial terms to describe the East London region. Moreover, the initiative entailed the government to establish a series of new innovation and technology centers in the Silicon Roundabout region and beyond, as well as a site adjacent to Olympic Park (which hosted the 2012 Summer Olympics). In 2011, it was restructured and rebranded as 'Tech City UK', a quasi-NGO directly funded by the UK Department of Trade and Investment (since then renamed as Department of International Trade from 2016 onward), with Erik van der Kleij – a successful technology entrepreneur and civil servant – serving as the NGO's first CEO. The initiative also appeared to receive direct personal support from then-PM Cameron, as he was reported to frequently initiate monthly breakfast meetings by inviting technology entrepreneurs to Downing Street 10 for informal networking, two-way sharing of information about progress in the Tech City program, and listening to concerns about potential policy barriers (**Volpicelli, 2020**).[226]

Complementing the Tech City initiative is a series of related national-level policies initiated by the British government from early 2010s onward, such as:

- A new Entrepreneur Visa targeted for individuals originating from countries/regions outside the European Economic Area (EEA) with a business idea and at least £50,000 worth of committed early-stage funding
- Financing measures, such as Entrepreneurs' Relief, early-stage financial initiatives (e.g. Enterprise Investment Scheme, Seed Enterprise Investment Scheme / SEIS – which we will elaborate in our analysis on VC activities in London, Angel Co-Fund Scheme, etc.), and Launchpad competition by Technology Strategy Board

- An independent six-month review of the UK's existing intellectual property policy

Nevertheless, the UK would eventually experience another major turning point in 2016, when the referendum on UK's membership in the European Union (EU) resulted in a slight majority of British voters opting for the country to leave the EU, which would subsequently be known as 'Brexit'. David Cameron immediately resigned and was replaced by his then-Home Secretary, Theresa May, as the country's Prime Minister. The impact on Tech City initiative was reported to be fairly serious, with its then-chair, Eileen Burbidge, describing that "May's government had other massive priorities… everything was about Brexit" (**Volpicelli, 2020**). Moreover, Tech City UK was subsequently merged with Tech North (a separate initiative launched in 2014 by Cameron administration to support the development of innovative clusters in UK's Northern region) into 'Tech Nation' (**Tech Nation, 2017**).

It is worth noting that in recent years, the UK government – under the premiership of Boris Johnson – has been making efforts to redistribute a portion of their resources to implement their 'leveling up' agenda. This plan entails an increase in government intervention and support, particularly to major cities, towns, and rural areas outside London metropolitan region to address the persistent issues relating to regional disparities between the capital and the rest of the country. Specifically, the Johnson administration aims to – through increased funding – support regional rejuvenation in 101 cities and towns across the country up to 2030 (**United Kingdom Government, 2021**).

4.4.9.2.R&D landscape in London

As of 2021, according to research brief by the UK Parliament, UK's total R&D expenditure was approximately £38.5 billion (equivalent to about US$52 billion, assuming 1 GBP = 1.35 US$). In comparison to the country's GDP of about £2.2 trillion (around US$3 trillion), the country's R&D-to-GDP ratio in that year was 1.75%. While UK's figure ranked the country as among the world's most research-intensive nations, the UK has lagged other high-income economies considerably with this respect, particularly in comparison to the US (with 2.7% R&D-to-GDP ratio), France (over 2%), Germany (around 3%), or even Israel (above 4% of GDP). Referring back to the recently mentioned 'leveling up' agenda by the Johnson administration, the UK government is planning to increase their investment in R&D activities up to £20 billion by 2024-2025 fiscal year, and for the country's R&D-to-GDP ratio to surpass 2.4% by 2027, with the expectation of having R&D investments uplifted across all regions within the country. Relatedly, the Department for Business, Energy, and Industrial Strategy (BEIS) would also receive an additional allocation of £39.8 billion for 2022/2023 and 2024/2025 fiscal years to boost business R&D and academic research across the entire UK, with at least 55% of these resources prioritized for regions outside the Greater South East (where London is located) to address some of the existing disparities in STI performance (**United Kingdom Government, 2022**).

At present, in terms of geographical breakdown of the location where R&D was performed, slightly above half of the dedicated investments in 2021 were concentrated in only three regions: South East, East of England, and London, as Figure 1a below demonstrates. The high

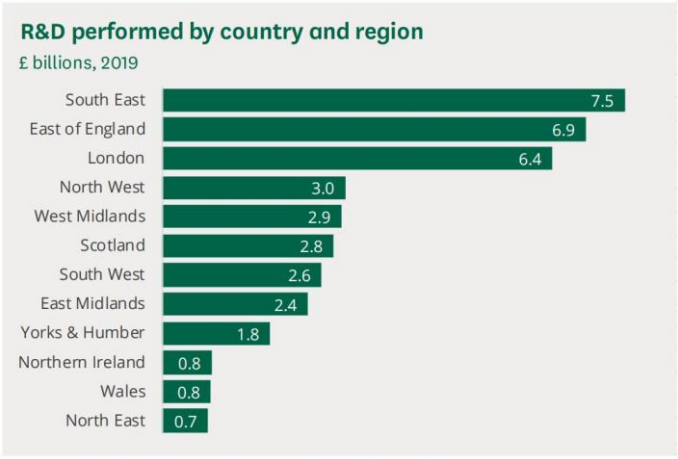
amount of research activities in the first two regions could be attributed to the presence of major universities (e.g. Oxford in South East, Cambridge in East of England), as well as large clusters of pharmaceutical, life science, and other science-driven high-technology companies (e.g. the presence of AstraZeneca, GSK, and various biotechnology SMEs). As evidently shown from Figure 4-31 below, a disproportionate majority of R&D investments in the two regions were driven by BERD (business expenditure on R&D).

Table 4-85 R&D expenditure on London, break down by sector. Million, Source: **Office of the National Statistics / ONS, 2022**

Year	GOVERD	GOVERD, % of GDP	HERD	HERD, % of GDP	BERD	BERD, % of GDP	GERD	GERD, % of GDP
2001	238	0.11	965	0.43	700	0.31	-	-
2005	329	0.12	1,297	0.47	552	0.20	-	-
2009	324	0.10	1,591	0.49	907	0.28	-	-
2010	339	0.10	1,606	0.48	877	0.26	-	-
2011	324	0.09	1,671	0.47	1,118	0.32	3,258	0.93
2012	327	0.09	1,679	0.46	1,570	0.43	3,719	1.01
2013	336	0.09	1,792	0.46	1,291	0.33	3,567	0.92
2014	335	0.08	1,842	0.45	1,724	0.42	4,015	0.97
2015	429	0.10	1,930	0.45	1,878	0.44	4,510	1.05
2016	453	0.10	1,871	0.41	2,351	0.52	4,985	1.10
2017	445	0.10	1,982	0.43	2,791	0.60	5,555	1.20
2018	588	0.12	2,058	0.43	2,973	0.62	5,970	1.24
2019	591	0.12	2,196	0.44	3,198	0.63	6,351	1.26

Notes:

- denotes nil, figures unavailable or too small to display.



Source: ONS, Gross domestic expenditure on research and development, by region, 4 August 2021

Country and regional breakdown of expenditure on R&D in the UK: by sector of performance, 2019

Current prices — Sector performing the R&D — £ million

Area Codes		Government & UKRI [1]	Higher Education [2]	Business [3]	Private Non-Profit [4]	Total
K02000001	**United Kingdom**	**2,662**	**9,067**	**25,948**	**843**	**38,520**
E12000001	North East	50	251	411	30	**742**
E12000002	North West	177	733	2,051	16	**2,977**
E12000003	Yorkshire and the Humber	130	610	1,012	5	**1,757**
E12000004	East Midlands	90	353	1,922	3	**2,368**
E12000005	West Midlands	76	470	2,357	14	**2,917**
E12000006	East of England	304	968	5,384	239	**6,895**
E12000007	London	591	2,196	3,198	366	**6,351**
E12000008	South East	740	1,361	5,326	102	**7,529**
E12000009	South West	272	474	1,835	15	**2,596**
E92000001	**England**	**2,429**	**7,416**	**23,496**	**791**	**34,132**
W92000004	Wales	23	323	442	6	**794**
S92000003	Scotland	184	1,150	1,409	46	**2,789**
N92000002	Northern Ireland	26	178	601	-	**805**

Source: Office for National Statistics

1 Government estimates include UK Research and Innovation (UKRI) and those areas of government not available from the GovERD survey, such as NHS trusts or local authorities.
2 Higher education estimates provided by the Higher Education Statistics Agency (HESA).
3 Business estimates first published in the BERD publication on 20 November 2020.
4 Prior to 2011 PNP data were estimated. From 2011 data have been collected from a biennial survey with non-survey years being estimated using data from survey years.

- denotes nil, figures unavailable or too small to display.

Please note:

Regional expenditure data by funding sector are unavailable.
Differences may occur between totals and the sum of their independently rounded components.

Figure 4-31 (a) and (b) Breakdown of R&D expenditure by selected geographical regions in the UK, as of 2019 (source: **Office of the National Statistics / ONS, 2022**)

London's R&D landscape was quite distinctive, however. Although the city occupied the biggest proportion of the UK's GDP (**Statista, 2022**), which was approximately 22.5% (close to £500 billion, or equivalent to US$675 billion), London only ranked third in terms of total R&D spending, which was shown to be £6.4 billion (US$8.5 billion). In other words, the city's R&D-to-GDP ratio, close to 1.3%, placed it below the national average with regard to the degree of research intensity in their economic activities. When we further break down London's composition of R&D spending, we found that over 1/3 of them, or about £2.2 billion (US$2.9 billion), entailed higher-education R&D (HERD). Approximately another 50% of the spending involved business R&D by London-based enterprises.

Judging from the above findings, we can interpret that of all regions in the UK, London has the highest share of R&D expenditure accounted for by higher-education institutions, and to a certain extent by public research organizations, whether government-funded or private. By contrast, the city's level of business R&D (BERD) was low, given that the sectors comprising London's economic backbone are largely finance and service-related. London's figures, particularly for higher-education R&D (HERD), also bear resemblance, to a degree, to those of Hong Kong, although the latter's R&D-to-GDP ratio (0.8% per annum, on average) remained considerably lower, in the sense that Hong Kong's R&D expenditure was largely evenly divided among higher-education and business sectors, or about 0.4% for each. This is primarily attributed to the presence of numerous universities and colleges, and particularly research-intensive ones, in the city.

4.4.9.3.University system in London

The fact that London's HERD expenditure has consistently exceeded those of the UK's remaining regions could be attributed to the presence of numerous universities, colleges, medical schools, and other higher-education institutions within the city. In 2018/2019 academic year alone, there were nearly 386,000 students – equivalent to 16% of the UK's overall student population – registered at the city's higher-education institutions, of which 34% of them (approx. 129,000) were studying in postgraduate programs (**London Higher, 2020**). Another outstanding strength of the city relates to the cosmopolitan character of its student population; close to 30% (about 115,000) of London-based university students originated from outside the country. The most commonly enrolled fields for these students are primarily in: 1) business and administrative studies; 2) creative arts and design, and; 3) healthcare-related disciplines (**London Higher, 2020**).

Moreover, some of the world's highest-ranked research universities are based in the city, with notable examples including the Imperial College London / ICL (which we have covered extensively in the Task 2 report), University College London / UCL, King's College London / KCL, and the London School of Economics and Political Science / LSE. These institutions have also been particularly active with respect to their involvement in knowledge/technology transfer (KT/TT) activities. Specific to ICL, we will further elaborate about the university's broader relationship with London's innovation ecosystem in the following sections.

We briefly recap our profile of ICL from the Task 2 report. The university, established in July 1907, primarily focuses on research and teaching in the areas of science, engineering, medicine, and more recently, business/management studies. One of its outstanding features has been the highly cosmopolitan nature of ICL's community; in 2019, nearly 60% of its students were non-British citizens. Located in the South Kensington area, ICL boasts its close proximity to some of the UK's leading art centers, such as Royal College of Music, Royal College of Art, Royal Albert Hall, etc. Moreover, the university has been widely credited for numerous world-changing scientific and technological breakthroughs since its establishment, as demonstrated by penicillin (discovered by Alexander Fleming while at the School of Medicine), fiber optics (invented by Harold Hopkins and Narinder Singh Kapany in the School of Engineering in

1953), as well as the more recent COVID-19 transmission simulation model by Robin Shattock and Neil M. Ferguson. In recent years, ICL has been actively involved in efforts to promote more efforts at knowledge and/or technology transfer, whether in the form of spin-off establishment to commercialize university research, or through increased collaborative ties between ICL researchers and their industry counterparts.

UCL, meanwhile, is the UK's second largest university in terms of total enrolment for all students (in general) and postgraduate students (**Higher Education Statistics Agency, 2022**). The university is comparatively older than ICL as it was established in 1826; interestingly, it was also the first educational institution in the UK to provide admission to female students. In an approach that is distinctive from ICL, UCL strongly prioritizes cross-disciplinary research under the outlined umbrella of four 'Grand Challenges', namely: 1) global health; 2) sustainable cities; 3) inter-cultural interaction, and; 4) human well-being. Moreover, UCL also operates disciplinary-specific research centers in partnership with academic and non-academic organizations, such as:

- UCL Center for Blockchain Technologies (UCL-Ripple Lab)
- London Center for Nanotechnology (in partnership with ICL and KCL)
- Center for the Study of the Legacies of British Slave Ownership (with Harvard)

Moreover, UCL has been highly involved in knowledge and/or technology transfer activities, in which we will elaborate in the following bullet points below:

- Knowledge Transfer Partnership: as a nation-wide program supported by UK Research and Innovation (UKRI) – a government agency – KTP focuses on implementing two types of knowledge/technology transfer practices: 1) developing new and/or better products and services, and; 2) enhancing the management capabilities of existing businesses. A KTP-funded project duration ranges from 12 months up to 36 months. Moreover, KTP encourages supported firms – whether SMEs or large businesses – to work actively with academics, in which the latter will provide relevant expertise. In terms of funding support, KTP disburses 2/3 of project expenditure from SMEs, and up to 50% for large companies.[227] UCL has been particularly active in making use of KTP grants, such as its partnership with Numbermix (an edu-tech start-up) to design a digital education platform for teachers and students, as well as the establishment of a Digital Lab with British Petroleum (BP) to build advanced chemistry simulation techniques in oil and gas production.
- Challenge-Oriented Innovation (COIN) meetings: COIN is intended to apply insights from UCL-based research and expertise to external partners (whether businesses, non-profits, government agencies, etc.) seeking to address their existing challenges. Conducted on a meeting-based format, a typical COIN meeting would run for about an hour, including informal presentations by external partners, as well as Q&A sessions and open discussions involving researchers and students from UCL. In turn, those from UCL would follow up with a series of interactive workshops, 'hacks', or evaluation sessions.[228] Notable outcomes from COIN meetings included collaborative research bids to UKRI, development of a new UCL institute, as well as ongoing policy work centered on post-COVID recovery within London.

- Global Innovation Team: this is a specially dedicated team from the university, funded by Innovate UK EDGE (another program by UKRI), to support London-based SMEs, start-ups, and/or university spin-offs.[229] On an annual basis, the team provides advice to about 150 SMEs, centered on: 1) repurposing these companies' existing technologies to address emerging demands from COVID-19 pandemic; 2) modifying existing approaches to firm innovation, and; 3) supporting existing businesses to expand their global markets through strategic advice and networking.
- East London Inclusive Enterprise Zone: abbreviated as ELIEZ, this program is intended for entrepreneurs with existing disabilities, and/or those that employ individuals with such conditions. This dedicated area is located at Here East, in the Queen Elizabeth Olympic Park within East London. UCL, and its Global Innovation Team to be specific, are some of the major partners in ELIEZ's establishment. One of ELIEZ incubatees, GiveVision, pioneers a wearable device that utilizes augmented reality (AR) technology to assist visually-impaired individuals.[230]

While details from other universities are comparatively more limited, we also mention two other illustrations from two of London's leading universities. In the case of King's College London (KCL), researchers from the university recently established a collaborative agreement with their counterparts at NVIDIA – one of the world's leading companies in developing graphics processing units (GPU) based in the United States – to build the UK's first artificial intelligence (AI) platform for hospitals. NVIDIA researchers will make use of AI platform to provide training for National Health Service (NHS) specialists in automating radiology workflows. Moreover, these technologies will be implemented in King's College Hospital (KCL's university hospital), Guy's and St. Thomas', as well as South London and Maudsley. NVIDIA's collaboration is one of KCL's proposed development of disruptive technologies to radically transform 12 existing clinical pathways in oncology, cardiology, neurology, as well as diagnostics and patient care within NHS.[231]

London School of Economics (LSE) has also been no less active in knowledge exchange relative to its science and engineering-oriented counterparts in ICL, UCL, and KCL. One major example was in 2020, when CANDRIAM – one of the world's biggest sustainability-focused investment managers – announces its multi-year partnerships with LSE Grantham Institute (a center dedicated for research in climate action and sustainability strategies) to conduct in-depth research on advancing the global investment industry in sustainability and inclusiveness as driving pillars in the post-COVID recovery era. Under the new "Sustainability, Investments, Inclusion, and Impact" (SI3) program, both entities embark on a three-year partnership to facilitate innovative research, strengthen dialogue, and promote cross-country knowledge exchange in linking sustainable investing with the social and economic impacts of climate action.[232]

Beyond partnerships with industries and/or non-profits, each of the four selected universities has also established their own start-up incubation and/or acceleration programs. Such initiatives are intended to provide support for companies that seek to commercialize research originating from these institutions. Table 4-86 below highlights some of the major examples.

Table 4-86 Notable examples of London's university-based start-up support programs

University	Program name	Summary
ICL	White City Incubator	The White City Incubator campus, in operation since 2016, supports ICL-based start-ups and research spin-offs through financing, co-working space, and other resources. Since its opening in 2016, the incubator has provided about £100 million worth of investments for these incubated early-stage companies. One of its notable programs is the Advanced Hackspace, in which local entrepreneurs and/or hardware enthusiasts can access specialized equipment, 3D printers, among many others. The campus also hosts its own acceleration program to provide fast-track support for ICL-based spin-offs that seek to further expand their businesses. It also operates Imperial College ThinkSpace (I-Hub), which specifically focuses on companies that seek to commercialize research breakthroughs that they originated from. Overall, the White City Campus provides co-working spaces, scientific labs, and various research facilities.
UCL	Hatchery Startup Incubator	Hatchery Startup Incubator provides free-of-charge support and dedicated office space for selected start-ups founded by UCL students, researchers, faculty members, and/or recent alumni (within 3 years after their graduation). Its co-working space is located in BaseKX, UCL's premiere entrepreneurship hub in King's Cross district. Designed as a one-year program, Hatchery provides co-working spaces, mentorship, legal services, networking opportunities with existing investors, as well as peer-group sessions for incubated start-ups.
KCL	King's 20 Accelerator	The startup program is launched to support, on an annual basis, 20 selected 'best and brightest', promising ventures established by students, researchers, faculty members, and/or alumni of KCL. The accelerator program offers '3-month intensive sprints', followed by '9-month follow-

		on support', which encompasses networking opportunities with investors, mentorship, access to funding, facilities, networks, etc.
LSE	Generate Accelerator Program (GAP)	Also known as GAP, it is a 12-week part-time acceleration program to support promising early-stage start-ups co-founded by students, staff, faculty members, and/or alumni of LSE. Every year, GAP seeks to identify 10 commercially viable start-ups whose entrepreneurial activities, as well as mission orientation, are relevant to addressing at least one of the UN Sustainable Development Goals (SDGs). Moreover, these start-ups will be supported by a network of selected experts, mentors, and 'Entrepreneurs in Residence' to help scale-up their businesses and showcase them during the 'Demo Day' by the end of the acceleration program.

Beyond excellent research universities, London also houses a large number of non-profit, as well as government-funded, public research organizations (PROs). Majority of such entities conduct research on life sciences and healthcare-related challenges. Three notable examples of such institutes are listed in the following bullet points below:

- Cancer Research UK London Research Institute (LRI): the institute, also one of the major facilities under Cancer Research UK (a research-performing charity), conducts research primarily in the basic biology surrounding cancer-related diseases. Some of its researchers have – given the impacts of their research – ended up winning Nobel Prizes, such as Renato Dulbecco (a Nobel Prize laureate in physiology/medicine in 1975 for discovering interaction between DNA-tumor viruses and human cells) and Paul Nurse (another laureate in 2001 for his work on cell cycle).
- Institute of Cancer Research (ICR): as a constituent member of the University of London, it is a PRO with a specialized focus in oncology. It was 'integrated' into the University of London organizational umbrella in 2003. ICR has gained reputation for their research on discovering the basic causes of cancer.
- Francis Crick Institute: established in 2010 and formally in operation since 2016, the institute is a joint partnership between Cancer Research UK, ICL, UCL, KCL, Medical Research Council (MRC) of the UK government, and Wellcome Trust (another health research-perfomring charity). Beyond its research on cancer, the institute – with over 1,500 full-time researchers and an annual budget over £100 million – also conducts extensive studies on developing new treatments to address other illnesses, such as heart disease, stroke, neurodegenerative diseases, etc.

In the next sections, we will further explore the historical and evolutionary dynamics of London's innovation ecosystem. We first begin our series of analyses by identifying – and observing – the shifts in inter-organizational innovation networks within London over time by proxy of patent data. We are specifically interested in investigating the presence of multi-applicant patents as well as those with investors having worked for 2+ organizations, an indication of exchange of technical knowledge between these entities. The second analysis, with a particular interest in ICL and its relationships with London's industries, broadens the scope of the first study by taking into account U-I co-publications, or academic works involving researchers from ICL and the industries. Finally, the third analysis seeks to explore the investment ecosystem in London, and examine the extent to which London-based investors have provided financing support for technology firms/start-ups co-located within the same metropolitan region as these investors. We conclude our analyses with discussions on lessons that Hong Kong can learn.

4.4.9.4.INTER-ORGANIZATIONAL NETWORKS: EVIDENCE FROM USPTO PATENT DATA

We made use of USPTO patent data in analyzing the evolutionary dynamics of London innovation ecosystem. After we filtered the dataset, removed both design patents and no-assignee patents, as well as other filings with missing information, we ended up generating a subset of data consisting of over 19,000 patent applications based in the city. Once we limited our period of analysis to 1983-2018, the size of the subset decreased slightly to over 18,200. The first interesting feature worth noting (as shown from Table 4-87 below) is the dominance of foreign multinational corporations in patenting activities within London. 6 out of the top 10 assignee organizations in the city are non-British firms, notably represented by Google, Microsoft, Qualcomm, and IBM (all of which originated from the United States), Sony (Japan), and Philips (Netherlands). Only 1 British enterprise – British Telecom – was included in the top-10 list in Table 4-87. The other 3 UK-based organizational assignees are either universities (represented by ICL and UCL) or a non-profit health research center (Cancer Research Ltd). In comparison to other hubs that we cover, London's innovation ecosystem is relatively fragmented, given that the top-10 innovators only occupied slightly less than 15% of the city's aggregate patent output.

Table 4-87 List of top-10 patenting assignees in London (all time)

Name	Patent filings (19,049)
Google	603
British Telecom	347
Sony	326
Imperial College London (ICL)	310
Microsoft	256
University College London (UCL)	247
Qualcomm	221
IBM	206
Cancer Research Ltd	169
Philips	165
Share of top 10	14.9%
No. of organizations	3,275

Table 4-88 in the following page provides further breakdown on changes in the top-10 patenting assignee lists across 6 different six-year periods. Throughout the 1980s, 9 of the 10 most actively inventive organizations – with the exception of Dutch-based Philips – were UK-based organizations, the overwhelming majority by which were industrial firms. NRDC (National Research and Development Corporation), a non-departmental government agency, had the highest number of patent filings in the 1983-1988 period.[233] Other major innovators – in addition to pharmaceutical giant GlaxoSmithKline and oil/gas company British Petroleum – included Lucas Industries (a manufacturer of motor and aerospace-relaed components), Molins (a producer of tobacco-processing machines), BICC / British Insulated Callender's Cables (a

construction and cable-manufacturing enterprise), Crosfield Electronics (one of the world's first pioneers of electronic imaging technologies), Thorn plc (a multi-sectoral industrial conglomerate centered on electronic engineering), and Standard Telephones and Cables (one of the pioneers of telecommunication equipment manufacturing industry).

Substantial changes began to occur in the 1989-1994 as majority of the innovators described in the previous paragraph were no longer in the top-10 assignee list by this period. NRDC was subsequently privatized and transformed into British Technology Group (BTG), a technology-licensing company and also the most active assignee throughout the early 1990s. Simultaneously, universities and research institutes began to exert their influence with both Imperial College London (ICL) and the University College London (UCL) increasing their patenting records. Indeed, at one point (1995-2000), ICL was positioned as the most frequently patenting assignee organization, with their patenting output far exceeding those of UCL. Over time, however, UCL has steadily closed the gap with their ICL-based counterparts; from 2013-2018 period onward, UCL has surpassed the latter as the most actively inventive university in the London metropolitan area.

From the early 21st century onward, the composition of major innovation actors in London began to demonstrate a considerable shift, notably with the 'entry' of large foreign, multinational firms into the city's top-10 patenting organization lists. With the exception of British Telecom, GlaxoSmithKline, and British American Tobacco (BAT), all major assignees in those lists were non-British firms. Nokia (Finland) was originally the most actively patenting organization in London throughout the 2001-2006 period, but as their influence in the global ICT industry has waned significantly, Nokia's position – as well as those of other foreign firms in other sectors, e.g. Philips – was replaced by US-based technology firms, notably Google, Microsoft, Facebook, IBM, Qualcomm, Palantir, etc.

We also analyzed changes in the composition of the most influential organizations in London innovation ecosystem through the lens of betweenness centrality (**Freeman, 1977**), the measure by which has been replicated in other case studies throughout the report. In the 1983-1988 and 1989-1994 periods, NRDC had the highest betweeness centrality score, an indication of their significance in bridging inter-organizational knowledge flows within London's innovation networks (thanks to their primary role as a then government-funded technology transfer organization). From the mid-1990s onward, universities – as displayed not only by ICL and UCL, but also King's College London (KCL) and Queen's Mary University of London (QMUL), as well as research institutes – represented by Cancer Research UK and Medical Research Council (MRC), began to dominate the city's top-10 patenting organization lists regarding this category.[234] Since the early 2000s, 5 of the most influential 10 nodes in London's constantly evolving innovation ecosystem have been universities and research institutes. By 2013-2018 period, the shift has reached another level of significance, with the remaining 5 organizations with the highest betweenness centrality scores being foreign firms (as shown by Samsung, Qualcomm, Nokia, Microsoft, and Facebook). Overall, it can be assumed that London's innovation ecosystem is increasingly shaped by the involvement of universities in research translation, as well as the city's rich linkages with non-local innovation actors, two

factors that seemingly enable London to stay relevant in the global innovation competitive landscape (**Oinas et al., 2018**).

Box 1. Where are they now? The former industrial 'giants' of UK

The transformation of London's innovation ecosystem from one initially driven by local manufacturers to one dominated by universities and foreign multinationals has raised a major question: what has happened to the former? From our additional desktop research, we found that most of these enterprises have no longer existed; they had either gone bankrupt or were acquired by other enterprises that had also 'gone bust'. London's experience provides important lessons for policymakers interested in regional development to consider (**Clark, 2018**). The bullet points below provide illustration of subsequent events that impacted the industrial innovators originally listed in the 1983-1988 period:

- Lucas Industries: founded in 1860, it was a major manufacturer of motor industry and aerospace parts and components. At its apex, the company provided full-time employment to over 90,000 people, and was one of the largest industrial giants in the United Kingdom. From the 1970s onward, however, the company has been on the verge of decline, and despite comprehensive plans to rescue the company,[235] it was eventually sold and merged with an American industrial firm, Varity, to form LucasVarity. The successor firm eventually went bankrupt in 1999 and was acquired by another American firm, TRW Inc., which by itself also subsequently went bust in the early 2000s (**Nockolds, 1976; Cheesright, 2005**)
- Molins: it is one of the world's earliest companies specialized in the design and manufacturing of tobacco-processing machines. Established in 1912, the company has been involved in a notable innovation in the early 1920s, with their patenting of the world's first cigarette-making machine. With operations spanning across the United States, Brazil, Russia, and Czech Republic, the company continues to remain in operation as of these days (link: https://www.molins.com/en/about-us)
- BICC Ltd: the company was formed in 1945 as the result of merger between Callendar's Cable and Construction (established in 1870) and British Insulated Cables (established in 1890). Both companies were early pioneers of electric cables, and were also involved in the nationwide electrification of the whole country throughout the 1930s by establishing the National Grid transmission networks (**Morgan, 1982**). From the 1980s onward, however, BICC has been struggling with stagnating businesses in the electrical-cable industry, and by 2000, BICC Ltd was dissolved, and the remaining units of the enterprise were integrated into Balfour Beatty, its former subsidiary that is engaged in construction.
- Crosfield Electronics: the company was established in 1947 by John Crosfield and Dennis Bent as a spin-off of the University of Cambridge, where Crosfield conducted his research and invented print-imaging technologies. At one point, the company was a major global pioneer of color-drum scanning technology, and was responsible for numerous process-imaging devices for the print (and especially newspaper) industry.

It was acquired by another British industrial firm, De La Rue, in 1974, and was subsequently sold to Fujifilm, a Japanese multinational chemical technology company, in 2008 (**McGarrigle, 2013**).

- Thorn plc: established in 1928, Thorn, at one time, was one of the largest electrical-engineering firms in the UK. At its heyday, the company manufactured a wide range of products, such as lamps, lighting components, television sets, cookers, food mixers, fire-protection equipment, microwave equipment, etc. Similar to the companies listed above, Thorn has been struggling since the 1970s; it was merged with another British firm, EMI (which subsequently also ended up with bankruptcy), to form Thorn EMI. Nevertheless, the company continued to struggle, and by 1998, the company was dissolved, and its remaining units were sold to various SMEs and private-equity firms (**Sandall, 2008**).
- Standard Telephone and Cable (STC): the company could trace its origin to 1883, when Western Electric, the company's predecessor, was established. It would be the world's first pioneer of the emerging telephone and telegraph industry.[236] By 1925, Western Electric was transformed into STC, and was among the world's first innovators in optic cable technologies. Nevertheless, the company faced serious struggles during the advent of ICT revolution in the 1970s, and was sold to Nortel, a Canadian ICT firm that whose fate also ended in bankruptcy (**Young, 1983**).

Overall, from a descriptive analysis of patenting activities in London from 1983 to 2018, we can observe interesting dynamics in the landscape of inventive activities in the city, with the decline, and subsequent collapse, of British industrial firms in the 1980s, followed by the increasing involvement of multinational enterprises in London's technological and innovation activities (**Atkinson and Ezell, 2012; Crafts, 1998**). The demise of manufacturing industries in London – and in the UK more broadly – was attributed to numerous reasons, some root causes by which were firms' persistent stagnation in R&D investments, resistance to the adoption of latest technologies, the lack of policies incentivizing innovative activities, and the lack of coherent government policies to upgrade industries.[237]

Nevertheless, London – being the UK's epicenter of economic activities – was able to transition from manufacturing-based industries to services (**Del-Palacio and Chapman, 2014**). The city has witnessed a significant growth in high-technology start-up communities, in addition to their diversification into financial services, fashion, media, tourism, and education. London's universities, in particular, have been major contributors to both the city's economic activities, as well as research-based spin-offs and graduate-founded start-ups (**Del-Palacio and Chapman, 2014**).[238] Before we elaborate further about London's start-up and investment activities, we will first highlight how the city's education sector has shaped London's scientific, technological, and innovation prospects, with a particular interest on the case of the Imperial College London (ICL), which we have covered in the Task 2 report.

Table 4-88 List of top-10 patenting assignees in London throughout different time periods (patent filings indicated in brackets)

1983-1988 (693)	1989-1994 (903)	1995-2000 (2,286)	2001-2006 (3,501)	2007-2012 (4,702)	2013-2018 (6,113)
NRDC (64)	British Tech Group (39)	ICL (80)	Nokia (69)	Google (221)	Google (375)
Lucas Ltd (31)	Eastman Kodak (39)	Nortel (58)	Philips (64)	Sony (126)	British Telecom (232)
Molins (25)	GlaxoSmithKline (22)	GlaxoSmithKline (42)	ICL (55)	ICL (84)	Microsoft (160)
GlaxoSmithKline (22)	NRDC (20)	Ludwig Inst Cancer (38)	MEMC (49)	Brit Amer Tobacco (78)	Palantir (159)
BICC Ltd (18)	ICL (18)	Philips (38)	Merck (43)	Qualcomm (77)	Facebook (155)
British Petroleum (14)	British Petroleum (16)	Merck (37)	Qualcomm (39)	UCL (77)	Sony (144)
Crossfield Electro (12)	Framo (16)	New Transducer (35)	IBM (36)	British Telecom (70)	Ford Motor Co. (111)
Thorn plc (12)	Lucas Ltd (16)	British Tech Group (32)	UCL (35)	Nokia (68)	Qualcomm (105)
Philips (11)	Ludwig Inst Cancer (13)	UCL (32)	Accenture (32)	Microsoft (64)	IBM (87)
Stand Telep & Cable (11)	UCL (12)	British Telecom (28)	GlaxoSmithKline (29)	Red Hat (60)	UCL (85)
Share of top 10: 31.7%	Share of top 10: 23.4%	Share of top 10: 18.4%	Share of top 10: 12.9%	Share of top 10: 19.7%	Share of top 10: 26.4%
No. of organizations: 280	No. of organizations: 351	No. of organizations: 683	No. of organizations: 992	No. of organizations: 1,054	No. of organizations: 1,056

Table 4-89 List of top-10 patenting assignees in London in terms of betweenness centrality scores (scores indicated in brackets)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
NRDC (3)	NRDC (15)	ICL (1046)	KCL (2053)	ICL (2262)	ICL (3880)
Stand Tel & Cable (3)	ICL (11)	Univ of Florida (594)	QMUL (1474)	UCL (2251)	Cancer Research (2894)
Int'l Standard Electric (1)	British Tech Group (11)	UCL (530)	ICL (1473)	Cancer Research (790)	Samsung (2811)
Thorn plc (1)	MRC UK (11)	Moorfields Eye Hosp (494)	Proteome Sciences (1102)	Univ Southampton (636)	Qualcomm (2685)
STC plc (1)	Ludwig Inst Cancer (5)	Amersham (230)	UCL (988)	Hvivo Services (557)	Nokia (2595)
-	UCL (1)	Nycomed (188)	US DHHS (832)	KCL (540)	UCL (2003)
-	-	Picker (144)	Spirogen (780)	Ark Therapeutics (485)	KCL (1642)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
-	-	NEC (144)	Cancer Research (774)	QMUL (381)	QMUL (1498)
-	-	MRC UK (143)	Oregon H S Univ (292)	Volcano (184)	Microsoft (1435)
-	-	ICO Services (98)	British Tech Group (222)	Nokia (168)	Facebook (1035)

UNIVERSITY-INDUSTRY COLLABORATION IN SCIENCE: EVIDENCE FROM ANALYSIS OF JOINT PUBLICATIONS

In the next section, we analyze the landscape of scientific research by Imperial College London (ICL), one of London's most foremost research organizations and universities. We relied on Lens.org in obtaining the publication data (the publication date by which was limited from January 1, 2009 up to December 31, 2018, both dates inclusive), and performed multiple layers of data cleaning and analysis afterwards. Within the 10-year period, we have managed to identify a total of 60,892 journal articles with at least 1 researcher from ICL as a co-author; from this subset of data, 5,112 of them (equivalent to approximately 8.40% of the university's entire publication corpus) were joint university-industry publications. This percentage placed ICL above the 6-7% annual global average estimated by **Tijssen et al. (2009)**, an indication of the university's highly active focus on exchanging scientific knowledge with industry actors.

Nevertheless, once we break down the types of collaboration based on the geographical location of these firms (local, domestic non-local, and foreign), we found that a substantial majority of ICL's U-I co-publications were primarily with foreign firms, with the percentage figures ranging from 60% to 70%. In other words, less than half of the university's joint academic research works with industry were conducted with British firms, especially with local, London-based firms. In the case of U-I co-publications with British enterprises, the most dominant collaborators were GlaxoSmithKline and Royal Dutch Shell (in the case of London-based firms), as well as AstraZeneca and Rolls-Royce (with regard to domestic non-local businesses). To a lesser extent, other notable British-based industry collaborators include Amec Foster Wheeler (a major engineering consulting firm), British Petroleum, Atomic Weapons Establishment/AWE (a state-owned enterprise dealing with the research and management of UK's nuclear weapons), and Diamond Light Source (another state-owned enterprise managing UK's synchrotron light facility). Regarding foreign-firm collaborators, majority of firms in the top-10 position are in pharmaceuticals and healthcare, as shown by Pfizer, Novartis, Roche, GE Healthcare, Merck, and Bristol-Myers Squibb.

Table 4-90 Top 10 collaborating firms with Imperial College London (ICL) in U-I co-publications (2009-2018 period, number of co-publications indicated in brackets)

Local firms (N = 655)	Domestic non-local firms (N = 1,148)	Foreign firms (N = 3,388)
GlaxoSmithKline (266)	AstraZeneca (174)	Pfizer (97)
Royal Dutch Shell (82)	Rolls-Royce (98)	Novartis (96)
Imanova (57)	Diamond Light Source (44)	Hoffmann-La Roche (62)
EDF (24)	AWE plc (26)	GE Healthcare (56)
Amec Foster Wheeler (17)	East Malling Research (18)	Merck (47)
Dr Foster Intelligence (14)	Statsconsultancy (12)	Microsoft (47)
Ixico Technologies (11)	Jaguar Land Rover (11)	IBM (46)
British Petroleum (8)	Qinetiq (8)	Syngenta (44)
QuintilesIMS (7)	BG Group (7)	Bristol-Myers Squibb (43)
CD-adapco (6)	Anglian Water (5)	Waters Corp (43)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Local	49	60	46	52	68	65	66	62	106	80
Domestic non-local	80	100	106	90	107	106	129	118	159	153
Foreign	214	238	272	288	276	366	432	428	456	418
TOTAL	346	382	412	422	445	529	609	608	709	650

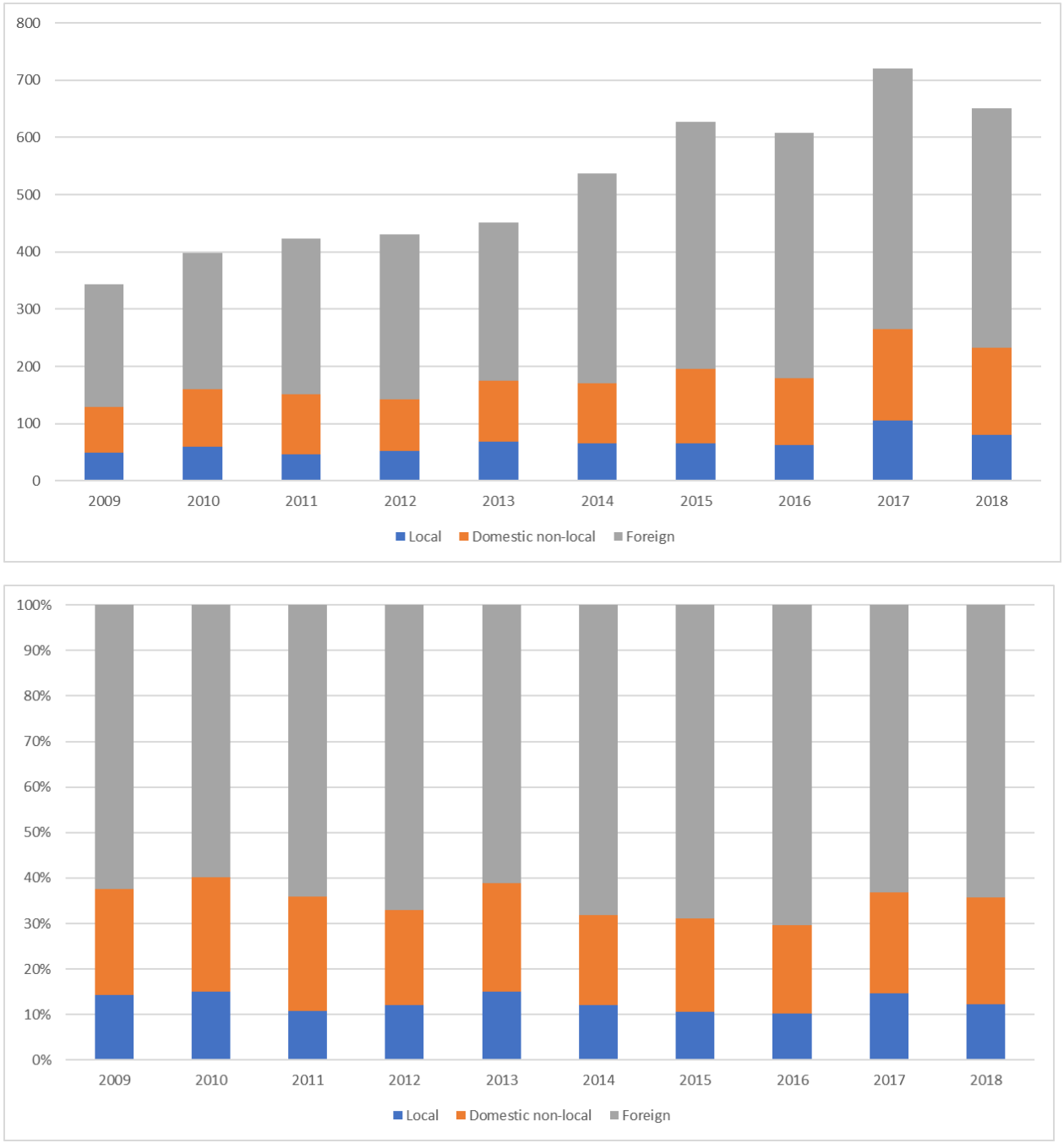


Figure 4-32 Types of U-I co-publications involving ICL (2009-2018) based on the geographical origins of collaborating firms

Furthermore, of 655 co-publications between ICL researchers and their counterparts at London's local enterprises, 148 of them (slightly above 22% of all U-I co-publications by ICL involving local firms) happened to be joint publications involving companies that were formerly spin-offs based on the university's research activities. These journal articles were contributed by a total of 33 Imperial College-related spin-offs that we identified through our 'visits' to local companies' respective websites. Similar to what we have identified from other case studies, the largest proportion of spin-offs involved in research collaboration with universities are those in biotechnology, life sciences, and pharmaceutical industries. Other sectors also notably represented by these spin-offs include consulting, scientific instruments, artificial intelligence (AI), material sciences, and energy technologies (energy-tech), the details by which are shown in Table 4-91 below. Table 4-92 below illustrates some notable spin-offs from ICL that continue to engage in scientific collaboration with the university.

Table 4-91 Specialization of ICL spin-offs identified from U-I co-publications (2009-2018)

Sector	Number (N = 33)
Biotechnology/pharmaceuticals	9
Consulting	5
Scientific instruments	4
Artificial intelligence (AI)	3
Material sciences	3
Energy technology (energy-tech)	2
Carbon capture	1
Cloud computing	1
Computer/mobile gaming	1
Multimedia	1
Physics	1
Product prototyping	1
Quant investment	1

Table 4-92 Notable ICL spin-offs identified from U-I co-publication analysis (2009-2018)

Name	University	Profile
Econic Technologies	ICL Oxford	Econic Technologies is a carbon-capture technology company aiming to utilize catalytic chemistry to turn waste CO2 into positive economic and environmental potential. This is achieved by applying waste CO2 as a feedstock for polymer preparation based on the company's novel catalysts. In turn, the company's technological innovation may enable eventual reduction on both fossil fuel and plastic consumption. The company was based on research at the Imperial College London (ICL) and the University of Oxford by

		professor Charlotte Williams, who has also moved from ICL to Oxford.
DeltaDOT	ICL	DeltaDOT is a life science company that specializes in the development & commercialization of biomolecule separation and analysis-related scientific instruments. Spun off from research at the Imperial College London (ICL), the company is developing technologies based on their innovation in High Performance Capillary Electrophoresis (HPCE), for which their applications are in the areas of analytical services by contract research organizations (CROs). The company is currently based in the London Bioscience Innovation Center (LBIC). It was founded in 2000 by Professor John Hassard (based in the university's Department of Physics) and Carolyn Hyde, a researcher at the UK Medical Research Council Clinical Sciences Center.
DNAnudge	ICL Univ of Glasgow	DNAnudge is a medical device company with a concentration in DNA testing technologies. It began to gain popularity in 2020 when they developed COVID Nudge, a rapid RT-PCR testing kit for COVID-19 that can provide accurate results within 90 minutes. It was established in 2015 by Professor Chris Toumazou (from ICL's Department of Electronic Engineering) and Maria Karvela, a postdoctoral researcher from the University of Glasgow.
Guided Ultrasonics	ICL	Guided Ultrasonics Limited (GUL) is a scientific-instrument company specialized in the development and manufacturing of guided-wave inspection and monitoring equipment. It pioneered the Guided Wave Testing (GWT) technology, a novel non-destructive testing (NDT) method that is useful in pipe testing, pipeline inspection, and related applications. It was established in 1999 as a spin-off from a research team at the Imperial College London's Department of Mechanical Engineering.
IXICO	ICL KCL UCL	IXICO is a company devoted to bringing healthcare innovations in the area of neuroscience. The company utilizes medical image analysis and digital-health data analytics for the purpose of enhancing investigational

		therapies in relation to the treatment of neurological diseases. The company's core technology is specialist data analytics services that enable them to identify and measure unique biomarkers, complemented with biosensor data from their specialized wearables. It was founded as a spin-off from a joint research project by professors based in the Imperial College London, King's College London, and the University College London.
Maxeler	ICL	Maxeler Technologies is a company providing data-flow computing and high-performance computing platform solutions and related appliances. Their products and/or services have been deployed in a wide range of sectors, e.g. finance (stock trading, banking transactions), networking, defense, government services, media, etc. It was founded in 2003, and is currently led, by Oskar Mencer, formerly a professor of computer science at the Imperial College London (ICL).
MiNa Therapeutics	ICL NTNU (Norway) City of Hope (US)	MiNa Therapeutics is a biotechnology company that aims to make use of small activating RNAs (saRNA) to build new medicines and therapeutic treatments which can restore normal function to cancer patients' cells. In addition to cancer diseases, the company aspires to utilize saRNA to treat rare diseases. Their achievement has been transforming saRNA medicines from an idea to clinical trials in under two years. It was founded in 2008 by Pal Sestrom (a professor at NTNU, Norway) and John Rossi (a professor at City of Hope Medical Research Institute, California, United States). It is presently led by Nagy Habib (professor at ICL) as the company's chairperson and his son, Robert Habib, a former investment banker, as the firm's CEO.
Q-Bot	ICL	Q-Bot is a robotics and AI company that develops intelligent tools and solutions to investigate, examine, and manage the stability of buildings and various kinds of infrastructure. With its expertise in robotics and AI, Q-Bot aspires to be a major contributor to innovation in construction-related technologies. The company was founded in 2012 by Matthew Holloway, Tom Lipinski, and Peter Childs. Peter Childs is a professor of

		engineering design at ICL, and before entering academia, was a successful serial entrepreneur in the areas of robotics and AI.
Sensor Coating Systems	ICL	Sensor Coating Systems (SCS) is a company that pioneers innovations in temperature measurement technologies based on their research in thermal memory materials, thermal history coatings, and thermal paint. The technologies have been applied in a wide range of industrial sectors, namely: 1) aerospace (turbine blades, rotors); 2) automotive (turbocharger wheels, pistons); 3) power generation (combustion chambers, blades, etc); 4) industrial processes (maintenance and service), and; 5) oil and gas (high-temperature pipework, valves, pumps, etc). It was founded in 2012, and is currently led, by Jorg P. Feist, a PhD graduate of ICL and a former researcher at the US Office of Naval Research – London branch.
Unilase	ICL	Unilase is a company involved in the design, development, and manufacturing of diode-pumped solid-state lasers and amplifiers (at 1064 nm). In addition, the company is also expanding into the area of low-repetition-rate high-pulse energy, as well as high-repetition-rate, and short-pulse diode-pumped Alexandrite lasers. The company's products are particularly relevant in slab architectures. It was founded in 2013 by Ara Minassian, a former postdoctoral research fellow at ICL, and is also a serial entrepreneur, having founded another similar company based on his research in the university.

FINANCING SUPPORT FOR LOCAL TECHNOLOGY COMPANIES: EVIDENCE FROM CRUNCHBASE DATA

Afterwards, our attention turns towards investment ecosystem in London. The city, at present, hosts the largest venture capital (VC) ecosystem in Europe, establishing a solid position in facilitating the growth of promising start-up companies, especially in the area of financial technologies (fintech). In comparison to other existing innovation hubs covered in the report, London has better regulatory environment, as well as a broad talent pool, for supporting investments and other financing activities. As an illustration, in 2020 alone, technology start-ups and established companies in the UK attracted a total of US$15 billion in VC (**Tech**

Nation, 2021). While the figure lags behind those of leading countries within the same year, such as the US (with US$144.3 billion worth of financing deals) and China (over US$44.5 billion), the country remains among the largest recipient hubs for VC investment activities. Slightly over 70% of UK's VC investment flows (approximately US$10.6 billion) were concentrated within London metropolitan region, placing the city fourth globally in terms of the total amount of financial capital support for technology companies and start-ups.

We relied on Crunchbase to collect information on London-based investors. Our particular motivation is to examine the extent to which these investors will allocate their resources to support co-located technology companies, following **Sorenson and Stuart (2001)**; this indicator has been a particularly useful measure in assessing the degree of resource regeneration within an entrepreneurial ecosystem (**Stam and Spigel, 2016**). Using this database, we managed to identify a total of 7,184 financial investors (venture capitalists, private equity firms, angel investors, other institutional investors, etc) based in the city. In comparison to our finding in Hong Kong, London's figure is over 5x higher than that of the former. However, approximately 54% of the Crunchbase-listed London-based investors have no information regarding their prior and/or existing financing track records. Another 21% of these investors (N = 1,535) are one-time investors only, with the reminder (close to 25%) occupied by those with experiences in at least two cumulative investment activities. While all London-based investors, in aggregate, accounted for 30,061 financing agreements in 23,962 technology companies collectively, the top 1,000 were responsible for 26,685 such activities (over 88% of all financing by London-based investors) in 20,897 companies locally, domestically, and globally (approximately 87% of all portfolio organizations supported by London-based investors).

Table 4-93 Information about investors in London (source: Crunchbase)

Size of investment activities	Number of investors
No information about investments	3,891
1 investment only	1,535
2-9 cumulative investments	1,202
10-25 cumulative investments	321
26-50 cumulative investments	113
51-99 cumulative investments	69
100-999 cumulative investments	53
1,000 or more cumulative investments	0
TOTAL	7,184

We further concentrate our analysis by taking into account the top-25 investors (based on their cumulative investment activities). Our descriptive statistics shows their collective involvement in 6,974 financing deals (equivalent to 23% of all London-based investment activities) in 4,943 technology companies worldwide (approximately 20% of the top-25's portfolio organization lists). One finding of particular interest is the high number of investors with accumulative experiences at over 100 investment deals (N = 53), a figure that is highly representative of

London's reputation as a globally leading financial services hub. Of these nearly 7,000 investment activities, we estimated about 30% (N = 2,104) of them were channeled towards 1,477 locally-based technology companies, which also represented about 30% of the top-25 investors' portfolio. In comparison to Hong Kong, the proportion of investments targeted for local technology start-ups in London were about 3x higher. In other words, more efforts in Hong Kong have to be introduced to incentivize existing VCs and other investors to provide financing support for local technology companies.

Box 3. Notable start-up unicorns in London

An interesting feature of London's innovation ecosystem has been the fairly high number of start-up unicorns (pre-exit companies with total valuation surpassing US$1 billion). Of 958 such unicorns globally that were identified by CB Insights as of end-December 2021, 24 of them were based in London (Failory, 2021), equivalent to about 2.5% of all such firms worldwide. In aggregate, the total valuation of these London-based unicorns was close to US$130 billion, of which nearly half was concentrated at 3 companies alone (Revolut, Checkout.com, and Global Switch). Precisely half (N = 12) of those unicorns are involved in financial technology-related (fintech) sectors, ranging from mobile payment, transaction processing, currency exchange, lending, insurance technology (insurtech), etc. Other unicorns are concentrated in largely consumer- and IT-oriented sectors, such as food delivery, enterprise software, cloud computing, car-sharing, gaming, mobile apps, etc. Only 2 unicorns, in turn, could be considered as originating from science-driven industries, namely: 1) Octopus Energy, a company offering energy-efficiency solutions which was formerly a corporate spin-off of Octopus Group, an asset-management firm, and; 2) BenevolentAI, an early-stage company seeking to utilize advances in artificial intelligence (AI) to accelerate drug discovery processes and neuroscience-related research. Interestingly, two other unicorns (Rapyd and Snyk) were originally founded in Tel Aviv (Israel), but the founders have broadened their headquarters and included London as their bases. Further elaboration on Israeli founders' motives to either add or relocate their headquarters will be provided in the Tel Aviv case study in this report.

Table 4-94 List of start-up unicorns in London (as of July 2021)

Name	Valuation (US$ billion)	Sector
Revolut	33.0	Fintech, mobile payment
Checkout.com	15.0	Fintech, transaction processing
Global Switch	11.1	Data center, cloud computing
*Rapyd**	*8.7*	*Fintech, mobile payment*
*Snyk**	*8.5*	*Application security*
Hopin	7.8	Meeting software, video conference
Blockchain.com	5.2	Blockchain, cryptocurrency

Hyperion	5.0	Insurtech, auto insurance
Wise	5.0	Fintech, currency exchange
Greensill Capital	4.0	Fintech, lending
OakNorth	2.8	Fintech, lending, AI
Octopus Energy	2.8	Green-tech, energy efficiency
Monzo	2.5	Fintech, marketplace
Cazoo	2.5	Car-sharing, car rental, e-commerce
Babylon Health	2.0	Health diagnostics, mobile app, AI
Improbable	2.0	Gaming, software, virtual world
Starling Bank	2.0	Fintech, banking
BenevolentAI	1.9	AI, drug discovery, neuroscience
Como	1.5	Big data, SMEs, enterprise software
Gett	1.5	B2B, enterprise software, transport
Zego	1.0	Insurtech, auto insurance
Gousto	1.0	Food delivery, subscription
Infobip	1.0	Enterprise software, messaging
Lendable	1.0	Fintech, lending, mobile payment
PPRO	1.0	Fintech, mobile payment

* Rapid and Snyk have multiple headquarters: they have main offices in Tel Aviv and Boston, and were founded by Israelis based in the UK and the US

Another interesting aspect we identified from London's investment landscape is the high density of institutional and individual investors offering either seed-stage or early-stage financing support for these technology companies. Of all 7,184 London-based investors, we found at least 745 of them are concentrated in providing these types of support. About 11 of such investors (namely Seedcamp, Pitch@Palace, SFC Capital, LocalGlobe, Octopus Ventures, Ascension Ventures, Northzone, Apax Partners, Atomico, Bethnal Green Ventures, and MMC Ventures) were listed in the top-25 list shown in Table 4-95 below. Our finding aligns with the observation by **Del-Palacio and Chapman (2014)**, who argued that the rapid growth of such early-stage investment funds was enabled by a series of reforms enacted by the UK government in 2010 to accelerate the development of start-up ecosystems across the country (and especially in London). One of these reforms was the introduction of Seed Enterprise Investment Scheme (SEIS), by which investors (whether individual or organizational) with seed investments up to £100,000 are eligible for up to 50% tax relief; other major reforms enacted included a special scheme for 'entrepreneur visas', reform of intellectual property (IP) law, and incentives for the establishment of investment funds in the UK.

Furthermore, another unique characteristic of London's investment ecosystem is related to the existence of specialized VC funds for technology spin-offs originating from research at universities and/or public research institutes, notably Parkwalk Advisors and IP Group plc. While their portfolio spans hundreds of such companies from various top research universities across the country, approximately 16% of them have ended up channeled towards London-based spin-offs, thanks to the two funds' close relationship with major research universities in

the city (notably ICL, KCL, and UCL).[239] Specific for IP Group, their background is particularly relevant given their origin as an investment arm spun off from the technology transfer office of the University of Oxford (**Hockaday, 2020**).

Last but not least, London has also been 'home' to several investment funds, start-up incubators, and accelerator programs with either a pan-European or global focus. Notable examples include Startupbootcamp, which has launched multiple batches of 'bootcamp' programs by attracting early-stage companies worldwide to undergo incubation in the city, followed by Eight Roads Ventures, Entrepreneur First, Octopus Ventures, 83North, Entrée Capital, Atomico, Molten Ventures, Bethnal Green Ventures, Abingworth, etc. SoftBank Vision Fund, a US$100 billion VC arm by the Japanese-based multinational group, also establishes one of their main offices in London.

Table 4-95 Top 25 investment funds in London and proportion of investments in London technology companies

Name	Summary	No. of investments	Investments in London	No. of portfolio organizations	Portfolio organizations in London
Startupbootcamp	A global network of start-up accelerators that provide investment and mentorship services to accelerated firms	540	48 (8.9%)	522	47 (8.9%)
3i Group	An investment company that provides private equity funding, infrastructure, and debt management to companies	463	23 (5.0%)	328	20 (6.1%)
Eight Roads Ventures	A seed fund that provides support for European-based early-stage start-up founders	429	28 (6.5%)	305	18 (5.9%)
Pitch@Palace	An investment company that provides seed capital and firm-building strategy advice for early-stage firms, while taking no equity or shares from them	410	155 (37.8%)	407	154 (37.8%)
Business Growth Fund	An investment company that offers equity capital for promising SMEs, both in the UK and in Ireland	356	82 (23.0%)	310	68 (21.9%)

Balderton Capital	A venture capital fund focused exclusively on supporting European-based start-ups	349	122 (35.0%)	185	61 (33.0%)
SFC Capital	A network of angel investors and seed-fund supporters that invests in SMEs included in UK government's SEIS (seed enterprise investment scheme) and EIS (enterprise investment scheme)	340	204 (60.0%)	251	151 (60.2%)
LocalGlobe	A venture capital firm offering both seed-stage and impact investments for start-ups	298	168 (56.4%)	227	113 (49.8%)
Entrepreneur First	An accelerator and investment fund that brings forward tech entrepreneurs to build globally ambitious technology firms	293	138 (47.1%)	232	106 (45.7%)
SoftBank Vision Fund	A US$100 billion VC fund by Japanese-based SoftBank, one of the world's largest ICT firms	293	12 (4.1%)	234	11 (4.7%)
Seedrs	A UK-based platform for various funding opportunities, from crowdfunding, angel investments, etc.	288	178 (61.8%)	215	127 (59.1%)
Octopus Ventures	A VC fund specifically focused on Europe-related investments in start-ups as diverse as deep-tech, fintech, life sciences, health, etc	285	173 (60.7%)	176	101 (57.4%)

Ascension	An early-stage VC fund founded by exited entrepreneurs to support emerging start-ups and aspiring tech entrepreneurs	263	197 (74.9%)	161	116 (72.0%)
Parkwalk Advisors	An investment and management firm specifically focused on technology spin-offs based on research at UK universities and research institutes	255	41 (16.1%)	141	21 (14.9%)
Northzone	A VC fund providing early-stage investment options for start-ups with technologies that promise multiple life-cycle disruptions	232	35 (15.1%)	128	19 (14.8%)
IP Group plc	An IP commercialization and investment-funding company established originally from tech transfer office of the University of Oxford	226	36 (15.9%)	128	23 (18.0%)
Apax Partners	An international investment partnership firm focused solely on long-term investments in promising technology firms	221	8 (3.6%)	157	6 (3.8%)
83North	A global VC firm with over US$1.8 billion of assets under management, focused on investing in global start-ups	197	20 (10.2%)	66	9 (13.6%)
Entrée Capital	A VC firm that offers multi-stage investments for various	192	28 (14.6%)	113	19 (16.8%)

	technology start-ups at different stages globally				
Atomico	An investment firm that provides capital support and strategies for deep-tech start-ups to scale their business globally	188	38 (20.2%)	112	26 (23.2%)
Anthemis Group	An investment fund that offers financial support for businesses seeking to disrupt the existing global financial system	187	68 (36.4%)	111	40 (36.0%)
Draper Esprit (now Molten Ventures)	One of Europe's largest, publicly listed VC firm that invests in some of the most promising tech start-ups there	172	51 (29.7%)	104	34 (32.7%)
Bethnal Green Ventures	One of Europe's leading VC firms that invests in promising green-tech, clean-energy startups	170	145 (85.3%)	141	122 (86.5%)
Abingworth	A global investment fund that specifically focuses on life sciences- and biotech-related start-ups globally	164	10 (6.1%)	103	6 (5.8%)
MMC Ventures	A VC firm that invests in start-ups in seed-stage and Series A funding programs	163	113 (69.3%)	86	59 (68.6%)
TOTAL (for top 25 funds)		6,974	2,121 (30.4%)	4,943	1,477 (29.9%)

4.4.9.5.DISCUSSIONS AND CONCLUSIONS

Based on the three analyses we performed in the previous pages, we have acquired some major insights about London. In the analysis of patent data to uncover the dynamics and evolution of inter-organizational networks within the city's innovation ecosystem, we identified a noticeable shift in the types of innovation actors involved, from UK-based domestic industrial conglomerates in the 1970s and 1980s to the increasing dominance by foreign multinational (especially US-based) enterprises and research universities. These results largely align with the observation by **Power and Malmberg (2008)** on the importance of enriching linkages with non-local actors and research universities in building thriving innovation hubs.

This finding was further reinforced in our analysis of joint U-I co-publications between Imperial College London (ICL) – which we have covered extensively in the preceding Task 2 report – and industry actors. Over time, the proportion of co-publications between ICL researchers and their counterparts at foreign enterprises has largely stayed constant within the 60-70% range, and a large proportion of ICL's U-I co-publications with local firms (which we define as those headquartered within London metropolitan area) were primarily with British multinational corporations, notably GlaxoSmithKline (GSK) and Royal Dutch Shell. However, ICL scientists have also maintained consistent ties with the resulting research-based spin-offs, and such ties are reflected from the academic publications they have co-authored. Moreover, many of these spin-offs were not necessarily the 'fruit' of research performed at the university alone; some of these companies were born out of joint scientific collaboration between ICL scientists and their counterparts elsewhere, whether within or outside the United Kingdom.

One major strength of London has been the proliferation of financing vehicles that provide investments, loans, and other types of support for technology companies based in the city. As we have mentioned in the previous pages, we identified a total of close to 7,200 investors in London (whether individual or organizational), a figure that is 5x bigger than those in Hong Kong in spite of their near-similar size (London's population being close to 9 million, and Hong Kong's approximately 7.5 million) and status as globally leading financial service hubs. Much of this was enabled by the Seed Enterprise Investment Scheme (SEIS), which provides attractive tax breaks for those with seed investments up to £100,000 (**Del-Palacio and Chapman, 2014**). Indeed, many of the world's aspiring technology enterprises have turned to London for incubation, acceleration, mentorship, and/or investment support, given the large number of incubator-cum-investors with either a pan-European or global focus, as well as specialized VC funds dedicated for supporting university-based spin-offs.

Nevertheless, London – similar to other globally-leading hubs – is not free of challenges either. As pointed out by **Del-Palacio and Chapman (2014)**, these major challenges being encountered by the city – on top of exorbitant living costs – include: 1) the discrepancy in the availability of different types of capital (in terms of excesses in angel investors and dearth of more advanced smart capital); 2) inadequate support for 'bridging capital' (specifically for start-ups having secured seed investments that require additional financial support between £0.5 and £1.5 million for further expansion); 3) immature capital markets (a consequence resulting from points 1 and 2); 4) a still-nascent record of successful technology start-ups subsequently acquired by incumbent firms, and; 5) supplies of skilled digital and high-tech

employees that struggle to keep up with labor demands by technology start-ups. Last but not least, ongoing political and economic repercussions from the UK's decision to withdraw from European Union (EU) – also known as 'Brexit' – have imposed further challenges for London in terms of retaining their international reputation.

Based on the three analyses that we conducted for London, we identify three major lessons that innovation-related stakeholders in Hong Kong (academics, industries, and government policymakers alike) can consider. First, provided the right condition and course of action, regions with declining and/or maturing industries can successfully transition into thriving innovation hubs. A major commonality between London and Hong Kong – on top of their position as world-class financial-services hubs – has been their past strength in industrial and manufacturing capabilities. While resurrecting traditional manufacturing industries is an unlikely option for both cities, Hong Kong can learn from London by providing favorable incentives for major multinational corporations worldwide to establish R&D centers in the city, as well as build collaborative linkages with the city's leading research universities. One possible strategy is to complement the InnoHK scheme with one tailored specifically for university-industry collaboration, especially with foreign firms.[240] Second, London's Seed Enterprise Investment Scheme (SEIS) could be replicated, as well as adapted, to Hong Kong-specific contexts; this could serve as one possible strategy for policymakers in encouraging more seed investments by local investors and VC firms in supporting the burgeoning community of technology start-ups within the city. Third, and specific for investor and VC communities in Hong Kong, the creation of specialized funds to support emerging spin-offs from universities and research institutes – in close collaboration with these institutions – could be one possible strategy to consider.

4.4.10. Seattle

Introduction

Seattle is the largest city in the state of Washington, as well as one of the largest in the broader Pacific Northwest region. The city is located on the southeastern shore of Puget Sound, close to Lake Washington, and the United States-Canada border. Specific to the city of Seattle itself, their land area encompasses 217 square kilometers. For the remainder of the case study, we refer to Seattle not only within their municipal limits, but also the broader metropolitan region, with reference to 'Seattle-Tacoma-Bellevue metropolitan statistical area' (MSA) as defined by the US Office of Management and Budget (OMB). The entire MSA itself covers a total of 15,209 sq km in land area, covering Seattle's satellite cities such as Tacoma, Bellevue, Kent, Everett, Renton, as well as three other counties (King County, Snohomish County, and Pierce County), and a total population of 4 million people.

Seattle's economy has expanded at a relatively high rate since the end of 20th century, aided by the influx of tens of thousands of skilled and educated workers as well as the agglomeration and spawning activities of the locally headquartered businesses (**Lorenzen et al., 2020; Mason & Brown, 2014; Mayer, 2013**). Notably, the region's flagship firms, Boeing, Microsoft, and Amazon, have been powerful forces in shaping labour pools and establishing the foundation for hub-and-spoke clusters (**Gray et al., 1996; He & Fallah, 2011; Mayer, 2013**). Multiple platforms providing coaching and technical guidance were founded by these industry giants, nurturing a thriving innovation system for startups. A higher concentration of engineering jobs has also emerged, as reflected in the percentage of city residents employed directly in science, technology, engineering, and mathematics (STEM) occupations in 2019, with approximately 89,700, representing nearly 19% of the city's total workforce (**ILN & UW, 2021**). In addition, the city has also demonstrated their strengths in life science and biotechnology-related industries, thanks to research activities performed in top world-class universities (e.g., the University of Washington (UW)), research organizations (e.g., Fred Hutchinson Cancer Research Center (Fred Hutch)), governmental laboratories, as well as the establishment of ZymoGenetics spun out from UW, one of the world's first biotechnology firms (Bochniarz, 2020).

Furthermore, Seattle is one of the 20 most populous cities in the United States with a population of approximately 740,000 people (within the municipal limits, as of 2020 United States Census). It has – over the last two decades – been one of the fastest-growing cities in the country, with a cumulative population growth of 25% since 2010. Relative to the rest of the country, Seattle's population is also largely 'youthful'; according to the latest Census data, nearly 1/7 (14.5%) of the city's population is aged under 18. Seattle is also one of the most ethnically and racially diverse cities in the country; according to 2014-2018 American Community Survey (ACS), ethnic and racial minorities, in total, accounted for over 35% of Seattle's population. The educational attainment of Seattle residents, on average, is also higher than in the rest of the country; according to the **2019 American Community Survey (2020)**, 36.7% of residents in Seattle obtained Bachelor's degree, and 27.4% had a graduate degree (inclusive of Master's, PhD, MBA, and relevant degrees). Simultaneously, the proportion of

the entire US population with at least a bachelor's degree was slightly above 28%; in this regard, Seattle could be considered as among the country's most educated cities.

Historical development of Seattle

The city's origin could be traced back to September 25, 1851, when Seattle was formally established. Initially, the city served as a major port in the Northwest region of the United States, and throughout its history, has undergone through several periods of boom and bust (**Sale, 1976**). In addition to trading, Seattle also relied heavily on farming and timber industries. The city's initially strong dependence on these two sectors would catalyze the establishment of urban infrastructure, particularly in railway development. A breakthrough occurred in 1884 when the first railroad network in Seattle – linking it into the Great Northern Railway – was opened. Such event allowed the city to engage in freight competition with other emerging cities during that era. Throughout the 19th century, lumbering was the most dominant industry in Seattle.

The ongoing Gold Rush in the West Coast (notably in California) also resulted in a large wave of immigration and downtown expansion to Seattle. A larger port was established in 1911 to supplement the existing configuration of private rail lines. With the United States' participation in World War I, Seattle also grew fast due to a surging demand for lumber and maritime-related industries. This was further enabled with the city's adoption of containerized shipping – one of the first in the world – which allowed them to expand trading activities within the Asia-Pacific region. From early 20th century onward, Seattle began to transition as a major manufacturing hub in the United States, with main industries including food processing, banking, insurance, as well as transportation (in large part attributed to their role as a maritime and an emerging aviation hub). Boeing would emerge as one of the largest industrial actors, with their focus on manufacturing and assembling commercial jetliners, military aircraft, and more recently, spacecraft. Relatedly, military-related industries also began to emerge, given that Seattle hosts a significant number of military bases, e.g., US Army Fort Lewis Base, Puget Sound Naval Shipyard, Kitsap Naval Base, McChord Air Force Base, and Everett Naval Station.

While the city suffered a significant blow from the Great Depression in 1929 as well as slowdown from industry demand, World War II provided another impetus for Seattle's strong growth. Following the United States' entry into the war, Boeing – already a long-established player in Seattle's economy – would also turn the city's fortunes around, with the federal government procuring thousands of warplanes from the plane-maker throughout the war period, as well as the construction of numerous battleships and other carriers for the US Navy (**Sale, 1976**). The strong military-industry nexus that followed throughout the Cold War and Vietnam War would continue until the early 1970s, when military withdrawal and oil crisis – accompanied by economic stagnation and persistently high inflation – flipped over Boeing's, and in turn Seattle's, fortunes. Seattle was once again transformed with the relocation of Microsoft (their origin by which we will cover shortly) from the early 1980s onward, and more recently, by Amazon. The global adoption of software, ICT, Internet, and e-commerce would catapult these two companies into the world's largest technology giants.

Tech talent in Seattle

According to the 2021 Scoring Tech Talent report by CBRE, one of the largest real-estate consultancy firms in the U.S., Seattle ranked second highest nationwide in terms of their job market and real-estate prospects. It was estimated that in 2020, the metropolitan region (in addition to the city of Seattle) supplied 185,000 high-technology jobs, with an average annual wage of US$126,730. The report stated that relative to 2015 figures, Seattle has experienced 35.4% increase in high-technology jobs, as well as 15.3% growth in annual average wages, much of which was enabled by the significant expansion of business, R&D, and operation centers by Silicon Valley-based technology giants, as well as the extraordinary growth of Amazon and Microsoft, and the emergence of local, home-grown start-ups (especially those relating to cloud computing and enterprise solutions).

Universities/research

As a strongly science-driven innovation ecosystem in recent years, Seattle hosts a high number of world-leading research institutions, as well as the University of Washington (UW), one of the largest research universities in the United States. UW has consistently topped the ranks in terms of the amount of research funding received. For example, since 2008, UW's research grants and contract amount have topped US$1 billion annually. In the 2020 fiscal year, UW researchers collectively secured grants and contracts worth US$1.6 billion.

Other notable research institutions located within Seattle metropolitan region include:

- Allen Institute for Brain Science
- Bill and Melinda Gates Foundation (Gates Foundation)
- Center for Global Infectious Disease Research (formerly known as Seattle Biomedical Research Institute)
- Fred Hutchinson Cancer Research Center (Fred Hutch)
- Infectious Disease Research Institute
- Institute for Systems Biology (partly operated by University of Washington)
- Pacific Northwest Research Institute
- PATH (a leading global health non-profit research organization)
- Seattle Children's Research Institute
- SightLife (a globally leading eye bank and eye-related research institution)
- Washington Biotechnology and Biomedical Association
- Allen Institute for Artificial Intelligence
- Pacific Northwest National Laboratory – Seattle Research Center

Box 1. Innovating for global impact: non-profit foundations in Seattle

Another interesting aspect of Seattle's innovation and entrepreneurial ecosystem has been their strong concentration in social innovation and entrepreneurship (**Thompson et al., 2018**), much of which is enabled by the city's strong adherence to progressive and liberal values in addressing the existing societal issues. In addition to the high density of social innovation-related enterprises focused on Seattle-wide issues (e.g. homelessness, poverty in low-income migrant communities, etc.), the city – and the broader metropolitan region – also serves as a 'home' for several non-profit organizations that have been specifically dedicated to address global challenges, primarily in overcoming the impacts of climate change, poverty, and global health challenges. Some of the most notable examples are:

- Gates Foundation: established by Bill and Melinda Gates, it is currently the world's largest charitable foundation in terms of their current endowment size (estimated to be worth nearly US$50 billion as of 2019). The Foundation has provided funding grants to thousands of projects that seek to apply innovative technology-based solutions to address global challenges, primarily climate change, global health issues (especially in developing and less-developed countries), and poverty. Notable achievements from the foundation include funding for vaccine development for COVID-19 Vaccines Global Access (COVAX), development of malaria vaccines, establishment of libraries worldwide, and grant support for foldable paper microscope ("Foldscope") development at Stanford University.

- Center for Global Infectious Disease Research (CGIDR): at present an affiliate organization under Seattle Children's Research Institute, CGIDR is a leading research institute that focuses exclusively on infectious diseases in developing and less-developed countries around the globe. Furthermore, the institute also conducts research on pediatric infectious diseases in the United States. Their research areas range from malaria, human papillomavirus (HPV), streptococcus bacteria, to coronavirus families. The institute is led by public health experts who are also full-time cross-disciplinary faculty members from UW, namely: John Aitchison (pediatrics and biochemistry), Lisa Frenkel (laboratory medicine and global health), and Stefan Kappe (pediatrics, global health, and public health)

- PATH: the organization, previously known as Program for Appropriate Technology in Health (and founded in 1977 under the name 'Program for the Introduction and Adaptation of Contraceptive Technology), is one of the largest non-profit global health-oriented organizations in the world. Since its establishment in 1977, the NGO has been serving 70 countries worldwide (including the United States) in a wide range of areas in addition to contraceptive health, e.g. advocacy and policy, affordable medical device development, diagnostics, digital health, affordable

drugs, healthy behavior, market development, monitoring and evaluation, primary health care, and vaccine development

- SightLife: established in 1969 under the original name 'Northwest Lions Eye Bank', SightLife is now one of the largest eye banks in the United States – and in the world. The organization conducts medical assessment and manages cornea donation and distribution, as well as performs eye surgeries in various parts of the world. One interesting aspect about the NGO is their emphasis on retaining communication between corneal donors' families, and the subsequent recipients of these corneas. The NGO aims to eradicate corneal blindness issue globally by 2040

INTER-ORGANIZATIONAL NETWORKS: EVIDENCE FROM USPTO PATENT DATA

Here, we pay attention on the growth and evolution of innovation networks in Seattle metropolitan region. We collected USPTO patent data for a 36-year period (1983-2018) that covers not only the city of Seattle, but also other cities and towns comprising the metropolitan area across three counties (King County, Snohomish County, and Pierce County). Having excluded no-assignee and design patents, we managed to extract a total of 125,943 patent filings from this region throughout the 36-year period, as shown in Table 4-97.

Overall, a large proportion of these patent filings could be attributed to a small number of technology firms, notably Microsoft, Boeing, and more recently, Amazon. The top-10 assignees occupied nearly 60% of Seattle metropolitan area's patenting output throughout the 36-year period, with Microsoft and Boeing alone responsible for almost 30% and 9% of the patent filings, respectively. In addition, the University of Washington (UW) also serves as an influential organization in Seattle innovation ecosystem, with their cumulative patent filings of nearly 1,900, or approximately 1.5% of the entire patent output in Seattle. Interestingly, two of the top-10 assignees – Invention Science Fund and Elwha – happen to be 'patent aggregators', or more notoriously known as 'patent trolls'.[241]

Table 4-96 List of top-10 patenting assignees in Metro Seattle (all-time)

Name	Patent filings (125,943)
Microsoft	37,329
Boeing	11,033
Amazon	9,700
Intel	2,377
AT&T	2,239
Invention Science Fund	2,078
University of Washington	1,867
Elwha	1,770
Google	1,657
Facebook	925
Share of top 10	56.4%
No. of organizations	6,355

We further break down our analysis into six different periods, each spanning for 6 years, the results by which are displayed in Table 4-97 below. Throughout the 1980s and mid-1990s (1983-1988 and 1989-1994, respectively), Boeing was the most influential node within Seattle's innovation ecosystem. Indeed, at one time the planemaker controlled almost 1/3 of the metropolitan area's patenting output in the 1980s. Moreover, manufacturers dominated Seattle's innovation landscape during that period, with the presence of firms such as Sundstrand (an aerospace component maker), Weyerhaeuser (timber processing company), Honeywell (an industrial conglomerate focused on aerospace, buildings, and new materials), and John Fluke Manufacturing, now better known as Fluke Corporation (a manufacturer of diagnostic and testing equipment). It was in the same period that life sciences industry cluster began to emerge, notably with the rise of ZymoGenetics, one of the first biotechnology spin-offs by the University of Washington (UW).[242] Other major life-science firms included NeoRx, Immunex, and Oncogen.

From the 1989-1994 period onward, there has been a major shift in the composition of the top patenting assignees, with the emergence of Microsoft and UW as the new innovation actors in Seattle's innovation ecosystem.[243] Microsoft's ascent, in particular, has been nothing short of spectacular, with their patent filings multiplying from 321 in the 1989-1994 period, to 3,452 in 1995-2000, and 12,279 in 2001-2006, before eventually stabilizing at 12,321 in 2007-2012 period, and decreasing to 8,937 in the most recent 2013-2018 period. The 'explosion' in patenting output by Microsoft corresponded with its rise as one of the world's most valuable companies, especially given their significant control of the operating system (OS) market with their series of Windows packages. Microsoft's significance to the metropolitan region was not solely limited to their innovative output; the company has also been the most influential node in Seattle's innovation networks given that their betweenness centrality scores have been the highest since early 2000s.

UW has also been consistently ranked within the top-10 patenting assignee lists since the 1989-1994 period; albeit their patenting output was considerably less than the likes of Microsoft, their betweenness centrality score (a measure of influence exerted by knowledge flows between any nodal pairs passing through the node of interest) has been constantly placed as either the first or second largest since the early 1990s. In other words, UW has played a pivotal role in facilitating knowledge production, and more substantially, in knowledge dissemination and spillover for other entities in Seattle. While Microsoft has overtaken UW as the most influential node under this measure, the university continues to provide significant contribution to innovative activities in the region.

In addition, Amazon has emerged as a new core node in Seattle's innovation network. The number of patent filings originating from the e-commerce firm has surged rapidly from 364 in 2001-2006 period to 2,792 in 2007-2012, and more recently to 6,488 in 2013-2018, rapidly closing their patenting gap with Microsoft. Should the current trajectory continue, it is not unlikely that in the near future Amazon may surpass Microsoft as the largest patenting assignee in Seattle metropolitan area. Simultaneously, Silicon Valley-based firms (notably Facebook, Google, and Intel) have established their stronghold in the region, as indicated in their entries into the top-10 patenting assignee lists since the early 2000s. Indeed, Facebook and Google have positioned themselves as two of the city's largest employers; Seattle at present hosts the 2nd largest employee base for Facebook (after their Menlo Park, CA-based headquarters) with

7,000 employees, whereas Google currently employs 6,300 professionals and is expanding their operation there.[244]

We suggest one major caveat regarding our findings, particularly in comparison to Silicon Valley (the next case study): while Seattle was originally conceived to have a bigger potential as an innovation hub than the latter, the Bay Area eventually surpassed expectations, and much of this could be attributed to the region's very rich inter-firm linkages, both at the local and global level (**Powell et al., 2012**). Despite the earlier presence of major research – and in particular life-science R&D – clusters (concentrated at UW's School of Medicine, Fred Hutch, and other relevant institutes), Seattle's innovation dynamics were considerably less significant than those taking place in Boston, Silicon Valley, and San Diego. Further elaboration – on why Silicon Valley excels – will be provided in the next case discussion.

Table 4-97 List of top-10 patenting assignees in Metro Seattle throughout different time periods (patent filings indicated in brackets)

1983-1988 (2,371)	1989-1994 (4,303)	1995-2000 (12,356)	2001-2006 (26,918)	2007-2012 (36,736)	2013-2018 (40,880)
Boeing (822)	Boeing (685)	Microsoft (3,452)	Microsoft (12,279)	Microsoft (12,321)	Microsoft (8,937)
Sundstrand (84)	Microsoft (321)	Boeing (715)	Boeing (1,764)	Amazon (2,792)	Amazon (6,488)
Weyerhaeuser (81)	Univ of Washington (115)	Univ of Washington (378)	Intel (598)	Boeing (2,611)	Boeing (3,517)
John Fluke Mfg (50)	Weyerhaeuser (106)	ZymoGenetics (242)	Invent Sci Fund (448)	Invent Sci Fund (1,504)	Elwha (1,245)
NeoRx (28)	Sundstrand (65)	AT&T (218)	Amazon (364)	Google (777)	AT&T (1,108)
Washington Res Fdn (27)	Immunex (63)	Intermec (197)	Univ of Washington (350)	Intel (750)	Intel (898)
ZymoGenetics (26)	ZymoGenetics (63)	Immunex (175)	ZymoGenetics (268)	AT&T (696)	Google (806)
Honeywell (25)	NeoRx (59)	Corixa (150)	Honeywell (218)	Univ of Washington (559)	Facebook (789)
Immunex (24)	Nat'l Semiconductor (58)	Intel (127)	Cypress Semicond (214)	Elwha (524)	T-Mobile (607)
Oncogen (22)	Digital Equip Corp (57)	Siemens (108)	AT&T (206)	IBM (298)	Univ of Washington (423)
Share of top 10: 50.1%	Share of top 10: 37.0%	Share of top 10: 46.6%	Share of top 10: 62.1%	Share of top 10: 62.2%	Share of top 10: 60.7%
No. of organizations: 523	No. of organizations: 856	No. of organizations: 1,517	No. of organizations: 1,844	No. of organizations: 2,218	No. of organizations: 2,291

Table 4-98 List of top-10 patenting assignees in Metro Seattle in terms of betweenness centrality scores (scores indicated in brackets)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
Boeing (1233)	UW (10215)	UW (61390)	Microsoft (109345)	Microsoft (177027)	Microsoft (130631)
US Dept of Energy (953)	DEC (3246)	Microsoft (36329)	UW (83696)	UW (124327)	UW (86710)
UW (821)	Microsoft (3181)	Boeing (18605)	ZymoGenetics (18400)	Amazon (41546)	Amazon (60355)
Washington Res Fdn (622)	Hewlett-Packard (2357)	Siemens (6718)	Boeing (18073)	Boeing (38615)	Boeing (26045)
Washington Tech Ctr (359)	NeoRx (2060)	BMS (4989)	Seattle Genetics (16946)	Boston Scientific (17170)	Elwha (17864)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
Flow Industries (335)	Ariel Electronics (1924)	Transvascular (4068)	Philips (14924)	Mirabilis Medica (14603)	Google (13317)
Flowmole Corp (232)	Boeing (1891)	Intermec (3962)	Scimed Life Sys (14095)	Google (12692)	Intel (12777)
Adv Tech Labs Inc (230)	BMS (1586)	Philips (3939)	Intel (12416)	Inv Sci Fund (12506)	Facebook (11307)
Genetic Systems (173)	Fred Hutch Cancer (1523)	ZymoGenetics (3913)	Ekos Corp (11607)	Elwha (12133)	Boston Scientific (10036)
Dow (171)	Univ of Texas (1363)	US Surgical Corp (3593)	Poniard Pharma (10652)	GME Delaware (12112)	T-Mobile (8180)

We also assessed the importance of the core nodes constituting Seattle innovation ecosystem using another centrality measure: degree centrality. This simple measure refers to the number of direct linkages a node has with other nodes in a network; in other words, the figures shown in Table 4-99 below correspond to the number of organizations with which linkages take place with the nodes of interest in the first column of the table. Nevertheless, we advise some caveats with regard to the degree centrality scores, as these inter-organizational linkages (for instance, Microsoft's relationship with 156 other organizations in 2001-2006 period) may represent some possibilities listed in the bullet points below, following the arguments by **Laforgia and Lissoni (2009)**:

- It is possible that such linkages are attributed to career moves, whether from node A to B, or vice versa (from node B to A);
- There may be instances of patents with two – or more – applicant organizations, an indication of formal inter-organizational collaboration between, say, nodes A and B
- The existence of linkages, especially with universities, may imply two additional possibilities: 1) either (a) university researcher(s) is/are engaged in contract and/or collaborative research work on behalf of the organization(s) of interest, or; 2) the researcher(s) may have engaged in career mobility by moving to another firm or launching a start-up
- We also do not rule out the possibility of informal, cross-organizational collaboration between different inventors (who may have been colleagues in the same, previous workplace) in the absence of formal agreements between their employers
- Mergers and acquisition (M&A) – in the form of two or more firms merging into a new entity or a larger company acquiring a start-up – may also explain the linkages

Unless we perform detailed surveys of the inventors, we may not be able to accurately interpret the nature of these linkages. Nevertheless, overall, the degree centrality scores displayed below do suffice for us to examine the magnitude with which these nodes have contributed to the innovation ecosystem in terms of the inflows and/or outflows of knowledge.[245] The higher the degree centrality scores of these organizations, the more significant their roles as knowledge hubs within the region.

The table below highlights the five patenting assignees in Seattle with the highest degree centrality scores since early 2000s. Quite similar to what we identified in Table 4-98 [the one highlighting top organizations with highest betweenness centrality], the lists were dominated by the city's four major innovation actors: Microsoft, UW, Amazon, and Boeing. The cases of Microsoft and Amazon are, in particular, outstanding: the former has expanded their linkages with other organizations (from 156 in 2001-2006 period to 201 as of 2013-2018), whereas the latter has recorded an even more sizable increase (from 11 in 2001-2006 – not shown in the table, to 61 in 2007-2012, to eventually 99 as of 2013-2018 period). Interpreting these findings, we can observe that major firms such as Microsoft and Amazon (and Boeing to a certain extent) have been thriving on a rich exchange of knowledge with other innovation actors, whether through formal dissemination (e.g. research collaboration, joint technology development, scientific exploration, M&A), or knowledge spillover (e.g. career mobility and informal interaction). UW has also been a pivotal driving force, particularly in translating university research into commercialization, as shown from some of the spin-offs listed in Table 4-99 below; in this regard, some of the university inventors have either moved to these enterprises,

or maintained their collaborative activities after these start-ups were spun off. We will highlight some of these notable spin-offs in the next few pages shortly.

Table 4-99 Top-5 patenting assignees in Seattle by degree centrality (2001-2018)

Period: 2001-2006		
Name	Degree centrality	Notable inter-organizational linkages
Microsoft	156	Amazon, Boeing, Panasonic, Xerox, HP
Univ of Washington	77	VisionGate*, Microsoft
Boeing	34	Honeywell, United Technologies, Dept of Defense
Intel	23	Hewlett-Packard, Marvell, Honeywell, Google
Microvision	21	Searete, Invention Science Fund
Period: 2007-2012		
Name	Degree centrality	Notable inter-organizational linkages
Microsoft	199	Amazon, Adobe, Facebook, AMD, NVIDIA
Univ of Washington	129	VisionGate*, PhaseRx*, EnerG2*, Microsoft
Amazon	61	Google, Oracle, Yahoo, Disney
Boeing	50	Microsoft, General Electric, Univ of Washington
Invent Science Fund**	36	Salesforce, Vulcan
Period: 2013-2018		
Name	Degree centrality	Notable inter-organizational linkages
Microsoft	201	Facebook, Google, AT&T, Oculus VR
Univ of Washington	121	Ricoh, Magic Leap Inc, Fred Hutch, EnerG2*
Amazon	99	Facebook, Google, Oracle, AT&T
Elwha**	49	Uber, MIT
Boeing	47	Amazon, Microsoft, Honeywell, Philips

*spin-offs of University of Washington (UW)
**Invention Science Fund and Elwha are patent-aggregator firms (often infamously labeled as 'patent trolls'); it is possible that inter-organizational linkages with these firms largely involve transfer of patent ownership

It is worth noting that the rise of anchor firms such as Boeing, Microsoft, and Amazon is also partly attributed to the role of history and serendipities. Boeing has established their presence in Seattle since 1916, only slightly over a decade after the first humanflight experiment by Wright brothers; their position was strengthened due in large part to the First and Second World Wars, which fed the demands for military aircraft. The founding of Microsoft and Amazon also had very little to do with the research excellence at UW; while Microsoft was founded in 1975 by Seattle natives Bill Gates and Paul Allen, it was originally established in Albuquerque, New Mexico (**Allen, 2011**). By the time Microsoft was launched, Allen had recently graduated from Washington State University, while Gates was a drop-out of Harvard University.[246] Likewise, Amazon was established in 1994 by an Albuquerque native, Jeff Bezos. A graduate of Princeton University, Bezos worked in several firms (notably Intel and Bell Labs) and led a hedge fund before founding Amazon (**Robinson, 2010**).

UW's role in Seattle innovation ecosystem was primarily centered on the seeding of life-science industry cluster in the region (**Powell et al., 2012**). Nevertheless, the cluster did not achieve as significant a success as other burgeoning clusters in Boston, San Francisco Bay Area, and San Diego, due largely to the lack of inter-organizational networks in life sciences (whether for career mobility or knowledge exchange). Nevertheless, UW remains pivotal in terms of providing companies in Seattle and beyond with their abundant supply of graduates.

Afterwards, we turned our analysis towards joint U-I co-publications involving UW (Seattle's major research university) and industry collaborators, with our particular focus on academic journal articles published throughout the 10-year, 2009-2018 period. Collectively, a total number of 91,016 scientific publications involving UW researchers were published within this time range, of which 6,833 (approximately 7.5%) involved joint scientific collaboration with industry researchers. Judging from this finding, UW's position was slightly above the annual global average of 6-7% of journal articles worldwide involving U-I collaboration (**Tijssen et al., 2009**). We further break down our analysis by taking into consideration the geographical origins of the collaborating firms.[247] From our observation, we found that UW's researchers primarily engage in collaboration with US-based firms, and mostly enterprises based outside the state of Washington; in total, the number of U-I co-publications between UW-affiliated researchers and both local and domestic non-local industries were 1,254 and 4,161, respectively. For co-publications involving at least one foreign enterprise, we identified a total of 2,221 such works. When the annual figures were further visualized in Figure 4-33, we found the number of joint publications involving domestic non-local and foreign industries was growing more rapidly (albeit the figures have somewhat stagnated since 2015) compared to those with local-firm collaborators, which rose comparatively sluggish, and recorded a noticeable decline in 2018.

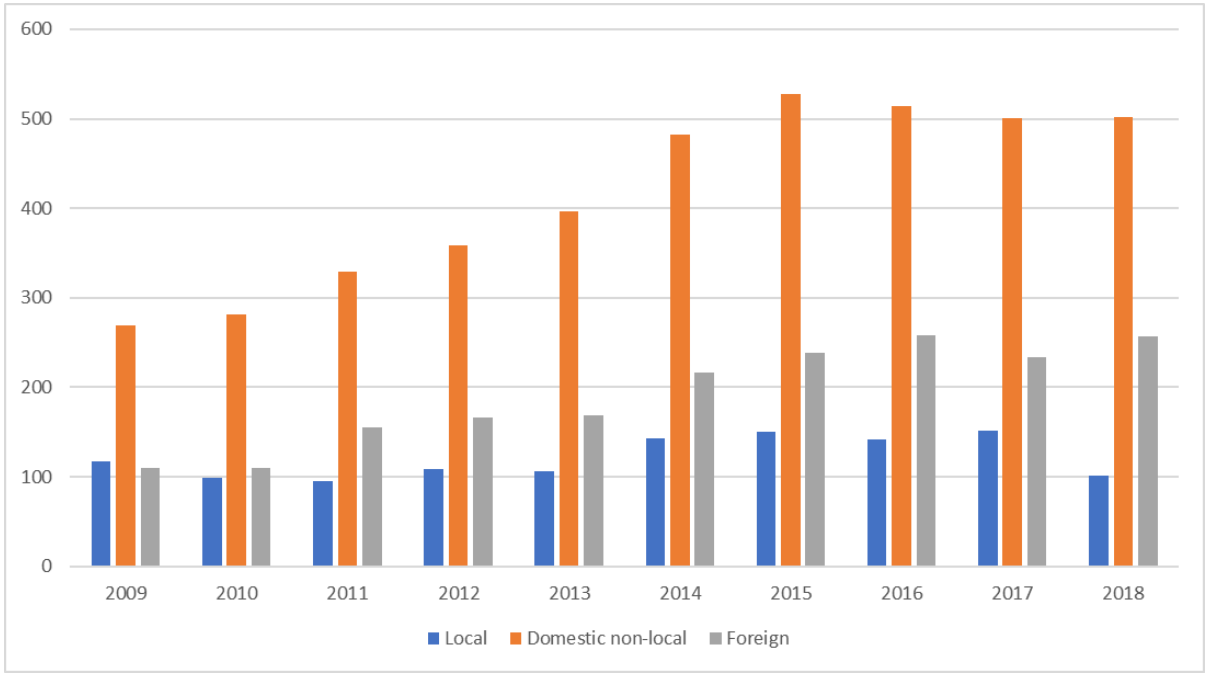


Figure 4-33. Types of U-I co-publications involving UW (2009-2018) based on the geographical origins of collaborating firms

Moreover, we listed the top-10 industry collaborators for each of the three types of co-publications in Table 4-100. Regarding the first (collaboration with local firms), Microsoft appeared to be the most frequent repeat-collaborator with UW researchers, and this could be partly attributed to geographical proximity. There were also joint scientific works involving researchers from Boeing (N = 22) and Amazon (N = 12), but their extent of collaboration was

comparatively more limited than that of Microsoft. Whereas for domestic non-local and foreign multinationals, the top-10 collaborator lists were overwhelmingly dominated by large pharmaceutical giants; these corporations occupied 7 of the top-10 position for domestic non-local firms (with the exception of Raytheon, Intel, and IBM), and 8 of the top-10 list for foreign companies (excluding Philips and Carl Zeiss). We speculate that such pattern could also be related to the presence of a large medical school and health center within UW, which facilitate clinical trials, joint drug discovery and development, biomedical engineering, etc.

Table 4-100. Top 10 collaborating firms with University of Washington (UW) in U-I co-publications (2009-2018 period, number of co-publications indicated in brackets)

Local firms (N = 1,254)	Domestic non-local firms (N = 4,161)	Foreign firms (N = 2,221)
Microsoft (189)	Merck (168)	Novartis (135)
Mountain-Whisper-Light (27)	Pfizer (151)	Philips (111)
Boeing (22)	Amgen (147)	Janssen Pharmaceutica (78)
Spectrum Research (17)	Bristol-Myers Squibb (130)	GlaxoSmithKline (68)
Amazon (12)	Genentech (125)	UCB Biopharma (52)
Dendreon (11)	Eli Lilly (94)	Hoffmann-La Roche (51)
NanoFacture (9)	Raytheon (78)	AstraZeneca (43)
Talaria (9)	Celgene (61)	Boehringer Ingelheim (38)
NanoString Technologies (8)	Intel (55)	Bayer Healthcare (36)
Axio Research (7)	IBM (54)	Carl Zeiss (26)

Box 2. Case study: University of Washington's long-standing partnership with local industries: the cases of Microsoft and Boeing

As we have highlighted in the beginning of this section, Seattle's innovation ecosystem has been – by and large – driven by four 'core' organizational actors: UW, Microsoft, Boeing, and Amazon. While we have yet to identify instances of formal collaboration at the organizational level between UW and Amazon through our desktop research, we have identified a noticeable number of formal research efforts involving UW scientists and their counterparts in Microsoft and Boeing.

With specific regard to Microsoft, their collaboration with researchers has spanned various disciplinary fields and technology applications, some illustrations by which were displayed in the bullet points below:

- In 2016, both organizations announced that their researchers have successfully set a new record in DNA data storage, in which they encoded – and subsequently decoded – a music video, a UN declaration translated into 100 languages, 100 most-read books from Gutenberg Project, and a crop seed database – into strands of DNA molecules.[248] Their invention paved the future potential application of DNA as not only carriers of genetic information, but also media for storing large-scale data. The research was carried out in UW's Molecular Information Systems Lab (by computer science professors Georg Seelig and Luis Ceze), in collaboration with

Microsoft researcher Karin Strauss, and their counterparts in Twist Bioscience, a biotechnology company specialized in manufacturing synthetic DNA

- In 2020, UW launched the latest Center for Research and Education on Accessible Technology and Experiences (CREATE), with an initial US$2.5 million funding support by Microsoft. The center is focused on promoting technological innovation in terms of automated, personalized mobility, accessibility, and wearable technologies for communities living with disabilities.[249] The center includes faculty members with interdisciplinary backgrounds, namely School of Computer Science and Engineering, The Information School, School of Medicine, Department of Mechanical Engineering, Human-Centered Design and Engineering, as well as Disability Studies Program.
- More recently, in early 2021, Microsoft awarded a grant worth US$5 million to researchers at UW's Institute for Protein Design.[250] This grant will be utilized to further their studies that seek to utilize artificial intelligence (AI) approaches to accelerate the identification and design of proteins that will be subsequently useful for the development of drugs and therapeutics in anticipation of future pandemics and other emerging diseases. One current related research work that the institute is conducting relates to the application of artificial proteins for creating more potent vaccine candidates against new variants of coronaviruses.

In the case of Boeing, the company has established – and jointly operated – a research center within the UW campus since 2014.[251] Known as Boeing Advanced Research Center (BARC), the center is primarily responsible for industrial application-oriented research projects on topics linked to aircraft manufacturing and assembly. Nevertheless, in recent years, BARC has also been implementing research projects related to machine learning, 3D printing, as well as robotics, all of which are aimed to make aircraft production more efficient and safer. Members of the research center include students and faculty members from the departments of aerospace, material science and engineering, mechanical engineering, industrial and systems engineering, as well as environmental and occupational health sciences. Through BARC, UW researchers and students have the opportunities to conduct research side-by-side with their counterparts from Boeing.

Beyond research, BARC also runs education-related programs, through seminars, continuing education programs, as well as Boeing Technical Fellowship program.[252] Seminars organized by BARC entail two-way knowledge exchange, with UW researchers presenting their latest research at Boeing facilities, and Boeing researchers and engineers sharing their works in the UW campus. Furthermore, BARC offers certification- and degree-bearing programs for Boeing's current employees by taking courses at UW, in fields ranging from aircraft composite materials, structural design and analysis, to project management. Most importantly, Boeing also offers their Technical Fellowship program, in which PhD graduates (from any university) compete to obtain postdoctoral research positions in the company.

Afterwards, we focused our attention on the presence of university spin-offs as industry collaborators in the U-I co-publication dataset. Through desktop research, we identified a total of 74 UW-related spin-offs (which we proxy as companies with at least one co-founder as a professor / ex-professor / alumnus / graduate / former PhD student / postdoctoral researcher) and 340 joint publications with UW researchers. Table 4-101 below highlights the sectoral specialization of these companies. We caution that not all these companies were affiliated with

CoMotion, the university's signature start-up incubation and research commercialization program; some of these were founded as early as 1980s, and some of them (especially consulting and research contracts) are sole proprietorships, with the founders serving as sole employees for these businesses. Moreover, not all CoMotion-incubated firms necessarily have joint academic works with UW researchers. Overall, almost half of these identified spin-offs are specialized in biotechnologies, life sciences, as well as pharmaceutical-related industries. Another 20 companies are involved in consulting and research contracts/services. Interestingly, we also identified several material science-related start-ups, which could be partly attributed to the city's long-standing competitive advantage in materials-related industries (e.g. aerospace manufacturing).

Table 4-101. Specialization of UW spin-offs identified from U-I co-publications (2009-2018)

Sector	Number (N = 74)
Biotechnology/pharmaceuticals	32
Consulting	12
Research contracts and services	8
Material sciences	7
Chemistry/chemical engineering	4
Software/enterprise/AI	4
Environmental conservation	3
Edu-tech (education technology)	1
Property-tech (real estate technology)	1
Manufacturing	1
Product development	1

Table 4-102 below lists out some of the notable examples of spin-offs from UW, including ZymoGenetics (one of the world's earliest biotechnology firms). We also caution, however, that nearly 20% of the spin-offs we identified have, as of the date this case study was written, permanently shut down, or were acquired by major corporations.

Table 4-102. Notable UW spin-offs identified from U-I co-publication analysis (2009-2018)

Name	University	Profile
VisionGate	UW	VisionGate is a clinical-stage oncology pharmaceutical and diagnostics company currently developing new products for the early detection, prevention and treatment of cancer, including lung cancer and lung dysplasia. The company's advantage lies on their Cell-CT platform technology that aims to enhance the chances of identifying biosignatures that would classify cells that detect abnormal cell detection and prediction of disease. Furthermore, the company is developing a LuCED® lung test, a non-invasive sputum-based test that detects abnormal cells to detect early risks of lung cancer and lung dysplasia. The LuCED test utilizes the Cell-CT platform and is in development for the early detection of lung cancer, bronchial dysplasia, and the assessment of indeterminate pulmonary nodules (IPN). It was

		founded in 2009, and is currently led, by Dr. Alan Nelson, based on his PhD research in the university. He was, at one point, a professor at UW.
ZymoGenetics	UW	ZymoGenetics was one of the earliest biotechnology firms in the world. The company pioneered the development of recombinant proteins as an application of recombinant DNA technology for therapeutic-related purposes. It was founded in 1981 by two UW professors (Earl W. Davie and Benjamin D. Hall) and one professor from University of British-Columbia / UBC (Michael Smith). It was acquired by Danish pharmaceutical giant Novo Nordisk in 1988, and was sold to Bristol-Myers Squibb in 2010, and was permanently closed by the parent company in 2019.
Kineta	UW	Kineta is a clinical-stage biotechnology company which leverages on their expertise in immunology to develop a specialized pipeline of investigational drugs in oncology, neuroscience and virology. The company proactively establishes strategic partnerships with leading science-based organizations to accelerate the deployment of novel immunotherapy-based treatments. Kineta was founded in 2008 by Charles Magness and Shawn Iadonato. Shawn is a serial entrepreneur and scientist. He was a former professor and director of Human Genome Center at the University of Washington (UW).
EnerG2	UW	EnerG2 pioneers advanced nano-structured carbon materials for breakthroughs in the energy storage. The company's primary innovation lies on engineered material solutions in the form of customizing electrode materials to maximize power density in the ultracapacitors, in which their technologies seek to control the molecular structure and assembly process of engineered materials to enhance the amount of energy stored, as well as to save costs. Furthermore, these innovations enable batteries to have a longer shelf life. EnerG2 was founded in 2003 to commercialize research on carbon materials at UW by Chris Wheaton and Rick Luebbe. Chris has experience working in technology companies in Silicon Valley, whereas Rick is a serial entrepreneur. The company was acquired by BASF, a German multinational chemical company.
PhaseRx	UW	PhaseRx is a biotechnology company focused on the delivery of siRNA (small interfering RNA) and other macromolecular therapeutics. Through these innovations, the company aimed to develop therapeutic treatments to cure patients – in particular child patients – with life-threatening liver cancer. PhaseRx was founded in 2006 by its President, Robert Overell, Patrick Stayton and Allan Hoffman of the University

		of Washington (UW), Oliver Press of Fred Hutchinson Cancer Research Center, and Paul Johnson, the Company's Chief Scientific Officer. Robert Overell is a serial entrepreneur. It was acquired by Roivant Sciences in 2018 after declaring bankruptcy.
CTI Biopharma	UW	Cell Therapeutics (CTI) is a bio-pharmaceutical company focused on the development and commercialization of novel therapeutic treatments tailored towards unmet medical needs for patients with blood-related cancers (notably myelofibrosis). Cell Therapeutics was founded in 1991 by James A. Bianco, an American scientist, academic, and serial entrepreneur. Before establishing the company, James was previously an assistant professor of medicine in UW. It is currently led by Adam R. Craig, a British scientist with PhD training from the University of Leeds in the UK.
LumiSands	UW	The company specializes in innovations in material sciences by providing a cost-effective, non-toxic, and eco-friendly rare-earth element (REE)-phosphor technology for silicon quantum dot-related applications. The innovations are intended to address the issues related to phosphor – one of the core ingredients for LED lighting – derived from rare earth, which tend to generate environmental hazards throughout their extraction and processing cycles. LumiSands was established in 2013, and is currently led, by Chang-Ching Tu based on his PhD and postdoctoral research at the university.

FINANCING SUPPORT FOR LOCAL TECHNOLOGY COMPANIES: EVIDENCE FROM CRUNCHBASE DATA

Finally, we also study investment activities in Seattle metropolitan region's technology companies, with a particular interest in the proportion of financing activities originating from locally-based investors. Relying on Crunchbase, we identified a total of 1,318 organizational and institutional investors. As shown in

Table 4-103, almost 45% of these entities provide no information about their past and/or existing investment portfolio, and another 27% are solely one-time investors (with a portfolio of no more than one investment deal). Those with a cumulative portfolio of more than 50 investment activities, in turn, occupied less than 2% of the entire list. Proportion-wise, the financing community in Seattle is hardly unique in comparison to what we have observed in Hong Kong, with the regional innovation ecosystem largely dominated by small-and-medium-sized investors. In aggregate, all the Seattle-based investors have been involved in 6,928 investment deals at 5,256 organizations, both within and outside the metropolitan area.

Table 4-103. Information about investors in Seattle (source: Crunchbase)

Size of investment activities	Number of investors
No information about investments	590
1 investment only	358
2-9 cumulative investments	264
10-25 cumulative investments	58
26-50 cumulative investments	23
51-99 cumulative investments	9
100-999 cumulative investments	16
1,000 or more cumulative investments	0
TOTAL	1,318

The top 25 investors – as listed in Table 4-104 below – occupy a total of 3,906 investment activities (approximately 56.3% of all deals from Seattle-based funds) that were spread over 2,689 organizations (51.2% of all invested organizations by these investors). With specific regard to these largest investors, slightly over one-third of their investment deals (N = 1,324) were aimed at Seattle-based enterprises, the total number by which was 822 (approximately 31.4% of their aggregate portfolio). In comparison to our baseline case (Hong Kong), more capital was allocated towards supporting local enterprises at a proportion over 3x higher than that of Hong Kong, for which the allocation rate was only around 10%.

Furthermore, another observation of particular interest relates to the involvement of Microsoft and Amazon (and to some extent, their founders) in venture investments. Of Seattle's top 25 investors, 6 of them, notably Microsoft Accelerator, Microsoft, Amazon Alexa Fund, Amazon, Bezos Expeditions, and Bill Gates, are – directly or indirectly – linked to these innovation actors. However, of their cumulative 774 financing activities, only 99 (approximately 12.8%) of them were invested on Seattle-based technology companies. Instead, most of the investments are aimed towards promising enterprises whose technologies potentially complement the global business activities of either Microsoft or Amazon. Exceptions were shown, for illustration, by the case of Madrona Venture, an early-stage VC fund that is dedicated towards supporting technology firms based in Pacific Northwest region (covering the states of Washington and Oregon). Another example was shown by Washington Research Foundation, a non-profit foundation partially supported by the government of Washington state, as well as by UW and Washington State University; in addition to supporting postdoctoral research positions, the foundation also positions themselves as a supportive funder for early-stage efforts to commercialize academic research.

Table 4-104. Top 25 VC funds in Seattle (source: Crunchbase)

Name	Summary	No. of investments	Investments in Seattle	No. of portfolio organizations	Portfolio organizations in Seattle
Acequia Capital	Early-stage VC fund for entrepreneurs focused on software-related firms	426	65 (15.3%)	255	34 (13.3%)
Madrona Venture	Early-stage VC fund that invests in emerging technology, deep-tech start-ups in Pacific Northwest region	421	298 (70.8%)	215	141 (67.0%)
Lighter Capital	VC fund that provides financing support to companies without having to provide equity	320	26 (8.1%)	207	14 (6.9%)
Vulcan Capital	Private equity (PE) firm investing in technology, Internet, and biotech/life sciences companies	242	102 (42.1%)	156	62 (39.7%)
Microsoft Accelerator	A start-up accelerator by Microsoft, one of the world's largest software firms	235	23 (9.8%)	216	18 (8.3%)
Frazier Healthcare Partners	Investment firm focused on healthcare, biotech, and pharmaceutical companies	189	17 (9.0%)	103	8 (7.8%)
Alliance of Angels	A network of angel investors offering seed	185	138 (74.6%)	147	105 (71.4%)

Name	Summary	No. of investments	Investments in Seattle	No. of portfolio organizations	Portfolio organizations in Seattle
	investments in early-stage start-ups				
Keiretsu Forum Northwest	A network of angel investors focused on emerging-tech, real estate, and medical device companies	172	52 (30.2%)	167	48 (28.7%)
Voyager Capital	VC firm that provides financing support, resources, and networking support for invested firms	167	68 (40.7%)	94	42 (44.7%)
Microsoft	A corporate VC arm of Microsoft, one of the world's largest software firms	159	9 (5.7%)	142	9 (6.3%)
Charlie Songhurst	Founding partner of Katana Capital, a long-short hedge fund	151	10 (6.6%)	147	9 (6.1%)
Founders' Co-op	Seed-stage investment fund focused on technology start-ups	144	108 (75.0%)	102	77 (75.5%)
Techstars Seattle Accelerator	Start-up accelerator and investment fund to support emerging-technology start-ups	138	81 (58.6%)	128	74 (58.0%)
Amazon Alexa Fund	A specialized VC fund of Amazon focused on artificial intelligence (AI)	117	16 (13.7%)	93	12 (12.9%)

Name	Summary	No. of investments	Investments in Seattle	No. of portfolio organizations	Portfolio organizations in Seattle
	start-ups, particularly in voice recognition technologies				
OVP Venture Partners	VC firm that provides early-stage financing support for emerging-technology companies	117	57 (48.7%)	56	26 (46.4%)
Amazon	A corporate VC arm of Amazon, one of the world's largest e-commerce platforms	110	13 (11.8%)	77	5 (6.5%)
Bezos Expeditions	A personal VC fund on behalf of Jeff Bezos, the founder of Amazon	86	25 (28.7%)	55	15 (27.3%)
Trilogy Equity Partners	A closed, privately-held VC firm that invests in technology start-ups	86	60 (69.8%)	57	38 (66.7%)
Keiretsu Capital	A VC fund partly owned by Keiretsu Forum Northwest	85	29 (34.1%)	58	18 (31.0%)
Bill Gates	A personal VC fund on behalf of Bill Gates, the founder of Microsoft	67	13 (19.4%)	35	6 (17.2%)
Unlock Venture Partners	A VC firm that offers seed-stage investments for early-stage start-ups	62	32 (51.6%)	23	11 (49.5%)
Elevar Equity	A VC firm that provides early-stage investments for businesses with	62	0 (0.0%)	34	0 (0.0%)

Name	Summary	No. of investments	Investments in Seattle	No. of portfolio organizations	Portfolio organizations in Seattle
	potential of high returns and high impacts				
Arrington XRP Capital	A digital-asset management firm focused on blockchain-related capital markets	61	0 (0.0%)	53	0 (0.0%)
Washington Research Foundation	A state-funded non-profit entity supporting commercialization of research in life sciences, physical sciences, ICT	54	45 (83.3%)	38	30 (79.0%)
Second Avenue Partners	An investment firm offering capital support, strategy, and management advice for early-stage firms	50	37 (74.0%)	31	20 (64.6%)
TOTAL (for top 25 funds)		3,906	1,324 (33.9%)	2,689	822 (30.6%)

4.4.10.1. Discussions and conclusions

The story of Seattle has been one of both regeneration and regional resilience. Established in the 19th century as a hub for timber processing and trading, the city has undergone through numerous industrial transformations throughout its existence, and has managed to not only survive the ups and downs of global economy, but also thrive on these changes. The city's industrial structure shifted from timber to manufacturing, to then partaking opportunities in the burgeoning aviation industry (as has been shown from the rise of Boeing as one of the world's leading airplane giants), to eventually venturing into ICT and life science industries. Our analysis of USPTO patent data to observe the co-evolution of these inter-organizational networks within the metropolitan region, by and large, reflects the distinctive historical phases that Seattle has gone through, especially over the last four decades. With Boeing's influence gradually waning in the 1980s – due in large part to economic stagnation and military withdrawal in the 1970s, the new emerging nodes began to step in and exert their influence as the new anchors in the knowledge flow circulation. Microsoft has since then ended up as the most pivotal node in the innovation ecosystem, largely attributed to a high degree of job mobility, as well as research collaboration – whether formally or informally – with other organizations. In recent years, Amazon has begun to challenge Microsoft's dominant position, and in the near future, it is likely the former will end up as the 'top node'.

The fact that Microsoft and Amazon become so integral in the global economy – as well as our daily activities – can also be attributed to the role of historical serendipities; the world in the 1990s only started to experience an early revolution in ICT and the proliferation of Internet, and first-mover pioneers (mainly technology companies in a few concentrated local clusters in the United States) began to take advantage of such unprecedented opportunities (**Dunning, 1998**). Despite the dot-com bubble that would ensue in the early 2000s, a tiny proportion of these firms would survive, and indeed strengthen their market dominance. But most importantly, the decisions by Bill Gates, Paul Allen, and Jeff Bezos to relocate and establish their long-term presence in Seattle would considerably alter the city's fortunes in the long run. More often than not, major breakthroughs in science, technology, and innovation occur due to 'happy accidents' (**Roberts, 1989**).

We do not neglect the importance played by universities, nevertheless. Specific to the University of Washington (UW), while their patenting output is considerably fewer than those of Boeing, Microsoft, or Amazon, the institution has played a pivotal role in bridging and facilitating knowledge flows to and from different organizations within the Seattle innovation ecosystem. This was demonstrated by their very high betweenness centrality score, which placed the university almost on par with Microsoft, the most actively patenting entity in the region. Numerous UW researchers have either engaged in collaborative research with industries and other non-profit/government organizations or disseminated their technological expertise through career mobility to other firms/organizations, whether in the form of patents, joint academic publications, or collaboration with international NGOs seeking to address global challenges. Moreover, there has been a rich series of collaborative activities among the four major innovation actors in Seattle (UW, Boeing, Microsoft, Amazon) themselves, ranging from patents, co-publications, to dissemination activities in the form of two-way seminars,

workshops, and/or conferences.

In terms of re-investment of resources towards local ecosystems – which we proxy with the proportion of financial support by local investors for co-located firms (**Sorenson and Stuart, 2001**), over 1/3 of investment activities by Seattle-based investors were targeted towards locally-based technology companies. While this proportion has been dropping since its peak at 67% in the early 2000s (**Horvath, 2004**), in comparison to our baseline case (Hong Kong, the similar proportion by which was only 10%), Seattle's proportion is considerably higher. Microsoft and Amazon, as well as their co-founders, have allocated a smaller percentage of their investment activities towards Seattle-based start-ups (which we estimated to be no more than 13% of their portfolio, collectively), but such limitation was compensated by the presence of numerous VC and private-equity firms, as well as associations of angel investors, that are strongly catered towards innovation ecosystems within the state of Washington, or in the Pacific Northwest region more broadly.

There are two major lessons from the Seattle write-up that are of relevance for Hong Kong. First, adaptation to industrial transformation is key towards not only regional survival, but also regional resilience. Given the nascent stage of emerging-technology industries in the city, proactive government support will be vital. Second, our findings from Seattle have made evident the importance of not working in 'silos'; inter-organizational collaboration (especially with universities), and openness to new ideas, are also pivotal in facilitating innovative efforts. As attested by the highly enriched knowledge exchange activities between UW and Microsoft and Boeing in Box 2, Hong Kong universities can initiate further research endeavor with some of the leading, first-generation technology start-ups within the city. Schemes such as InnoHK represent the first right step.

4.4.11. Silicon Valley

Introduction

Located in California, Silicon Valley is renowned for being a high-tech industry cluster for decades. Shaped by several waves of technological revolution, it came into being as one of the foremost, leading innovation hubs across the globe, periodically producing disruptive technologies and high-growth industries**(Henton, 2001; Kushida, 2015**). The region is notable for its proliferation, and co-location, of some of the world's most influential high-technology companies that play a significant role in our daily lives (e.g., Facebook, Apple, Google, Netflix). It is also considered as an international magnet for attracting talents, technologies, and ventures, constantly generating a large number of start-up companies and venture capital organizations. In addition, the region hosts some of the world-class public and private universities such as Berkey and Stanford that have had strong entrepreneurial mindsets and close collaboration with industry, hastening a variety of novel and innovative inventions and applications(**Ester, 2017; Piqué et al., 2020**). Today, it has represented an archetype of a regional innovation and entrepreneurship system, and served as an aspirational value for numerous policymakers, regional planners, university leaders, as well as entrepreneurs seeking to replicate – and transplant – this region into their respective localities around the world, as perfectly illustrated by widespread efforts to disseminate "Silicon"-related moniker in regional development efforts across continents (**Castells, 1994**).

Unlike the other ten hubs we have covered in this report, Silicon Valley is an idiosyncrasy, and often referred to as 'the most definitionally challenged" in the U.S., due to the absence of consensus regarding its geographical delimitation (**Walker and Schaffran, 2015**). Its distinctiveness is thus unparalleled; this region does not 'exist on paper' (in the sense that federal / state / local governments never invoke this term for administrative purposes beyond marketing). Indeed, the term 'Silicon Valley' was actually invented by an *Electronic News* column by journalist Don Hoefler in 1971 to describe the then-burgeoning semiconductor industry in the region, and only gained its popularity beginning from the mid-1980s onward with the launching of personal computers (PCs) by IBM (**Malone, 2002**).[253] Given the open-ended operationalization of the geographical boundaries of Silicon Valley, we decide to conceptualize Silicon Valley as representing the entire San Francisco Bay Area, following **Guzman and Stern (2015)** and the Association of Bay Area Governments (ABAG). It is worth noting that the progenitor of Silicon Valley region was originally in the southern part of the Bay Area region, primarily within the boundaries of Santa Clara Valley. Afterwards, the cluster – originally centered on electronics and semiconductors – would expand across the San Francisco Bay Area.[254] In this regard, the term 'Silicon Valley' and 'Bay Area' will be used interchangeably throughout the remainder of this chapter.

Universities have been seen as important players in the development of high-tech Silicon Valley. The two most prestigious universities in the region, UC Berkey and Stanford University, have been highly valuable resources to the region's innovation development, not only supplying new knowledge and talent but also supporting technology commercialization with incubators, entrepreneurship education, and building community-university partnerships

(**Engel, 2015; Pique et al., 2018**).

Historical development

While there has been no agreement on defining an exact foundation 'date' for the creation of the region, the general consensus is that one can trace its early emergence and development back to the early 20th century (**Adams, 2020**), when military research played a crucial role, and gradually evolved into consumer goods and products by shifting to the civilian market. To understand its history, one can broaden the geographical boundary to include the Bay Area, or more broadly, the State of California, to get the full picture of how and why Silicon Valley was formed.

The dynamic environment in the Bay Area might have started much longer time ago back in the mid-19th century when California Gold Rush had resulted in the largest mass migration in the U.S. history. Along with the huge influx of worldwide immigrants, estimated to be more than 300,000 by the mid-1850s. The influx of manpower as well as gold has led to the rapid expansion of a wide range of industries including manufacturing, transportation, agriculture and retail which accelerated the economic growth in California and made it become the 31st state of the U.S. in 1850, within just two years after Mexico had ceded it to the U.S. Along with the drastic change of demographic structure, the Bay Area also welcomed various groups of people with adventurous appetite for risk in terms of establishing a variety of enterprises and new types of organizations. This can be shown by the style of two newly established education institutions, University of California, Berkeley (UC Berkeley) in 1868 and Stanford University in 1891, which served as spaces of interaction for new, ground-breaking ideas and inventions, especially for Stanford University which embraced business-education integration under the leadership of Frederick Terman. The rich interaction between the two universities and these diverse types of organizations had laid a foundation for the occurrence of technology innovation success.

The 20th century witnessed the growth and transition of Silicon Valley as a pioneer in leading waves of technological revolution, ranging from transistor, semiconductor, biotechnology, personal computer, Internet, to social media and artificial intelligence (c.f. **Adams, 2020; Azagra-Caro et al., 2017; Almeida and Kogut, 1999; Casper, 2007; Powell et al., 2012**). It had made significant contributions to the military research and development during World War I (WWI), World War II (WWII), and the Cold War when military research and infrastructure were considered as priority where the Federal government poured heavy spending in technologies that would lay the background for digital-era breakthroughs, such as personal computers, the Internet and more recently in the 21st century, social media.

During the war (WWI, WWII) and postwar (including Cold War) era, firms and research institutes in the Bay Area were able to significantly increase their investments in R&D due to huge government spending on military procurement and research. The Bay Area was initially known as a pioneering hub of radio production in the 1910s with a broad development and application of amateur radio which was for personal, non-commercial use. Once the invention caught the attention of the U.S. Navy, the technology became widely procured and applied

given the United States' involvement in World War I, and the military's demand for large power transmitter stations.[255] Although orders had decreased sharply or were scrapped after the war ended, vacuum tubes continued to evolve to become a key component in the electronic industry and were broadly applied in commercial radio broadcasting. One of the major technologies originating out of the region would be microwave tubes. During WWII, military orders for microwave tubes surged and the U.S. witnessed another expansion of the global radio communication systems, benefiting lots of Bay Area firms which produced related defense equipment (**Ester and Maas, 2016**).[256]

With the end of World War II, Silicon Valley again pioneered another technological breakthrough, given their entry into the field of aerospace and missiles as the Cold War began in the late 1940s, followed by an intense space race between the former USSR (Soviet Union) and the U.S. beginning from the 1950s. Corporations in the Bay Area that developed missiles technology, such as Lockheed Missiles and Space, led the region as a result of another wave of military spending by the Federal government that lasted more than two decades.

Apart from the heavy spending by the federal government on military, academia also played a significant role in carrying out research based on contracts awarded by the US Department of Defense, complemented with an encouraging culture of establishing businesses in the Bay Area based on the resulting technologies. UC Berkeley and Stanford University contributed significantly to knowledge creation and transfer in areas such as physics, electronics, aerospace (**Etzkowitz, 2012**).[257] Furthermore, the region's research infrastructure received further support from institutes such as Lawrence Berkeley National Laboratory, Los Alamos National Laboratory, and Lawrence Livermore National Laboratory. Stanford, in particular, has played a very proactive role in encouraging commercialization of research outputs, with Frederick Terman – an electrical engineering pioneer and a then-provost of the university – pioneering this approach (**Adams, 2020**).

Labour market and talent diversity in Silicon Valley

The immigrant culture, immigrant entrepreneurs, the image and reputation of silicon valley are among the factors that have attracted new ventures (**March-Chordà et al., 2021**). Similar to our observation from the case study of Seattle, Silicon Valley/San Francisco Bay Area is also one of the most populous, as well as most ethnically diverse, metropolitan regions in the country. As of the 2020 United States Census, the Bay Area's 9 counties recorded a total population of almost 7.8 million people, with 53% of the population categorized as White, nearly 24% Asian, 7% African-American, 24% Hispanic/Latino (of any races), and almost 1.5% Native American and Pacific Islander combined.

The ethnic/racial diversity of the region matters substantially for the dynamics of innovation activities in the region; based on our back-of-the-envelope calculation of more than half a million USPTO patents filed from the Bay Area, we found that approximately half of the most frequent 100 family names for the patent inventors happen to be Asian. Furthermore, according to the latest 2021 Silicon Valley Index, the region is also among the most highly-educated in the United States. It is estimated that slightly over half (53%) of adult population in the region

obtained at least a bachelor's degree, or higher.

Nevertheless, throughout the last two decades, population growth in Silicon Valley has slowed considerably, and this has been exacerbated by the ongoing COVID-19 pandemic. In contrast to the double-digit growth in the second half of the 20th century, the population has grown at a single-digit percentage (around 5% for 2000-2010 period, and 8% for 2010-2020 period). A massive surge in living costs, unaffordable housing, as well as growing income inequalities have pushed an increasing number of talents – and to some extent, small-scale businesses – to relocate from the region to elsewhere across the country. Moreover, Silicon Valley has also been faced with other structural issues, such as gender income and work-participation gap (e.g. women only accounting for 26% of the whole core working-age group), disparities in career opportunities for different racial groups (e.g. very small income gains among African-Americans and the lack of senior leadership positions occupied by ethnic minorities), as well as widening wage gap between those with college education and those with only high school diplomas, or lower qualification.

Universities in Silicon Valley

Universities and research centers in the Bay Area gradually shifted their focus during the post-war era. Two iconic individuals, Frederick Terman and William Shockley, were often widely regarded as the 'forebearers' of Silicon Valley for their contributions to the region in the late 1950s when semiconductor revolution took place. In 1951, Frederick Terman, the then Stanford University's Provost and Dean of Engineering, facilitated the creation of Stanford Industrial Park (now Stanford Research Park) in the City of Palo Alto that attracted many companies to move in and gradually made the region a center for technology innovation (Adams, 2020). Nevertheless, as Castells (1994) has argued, establishing a science park by itself was not sufficient to stimulate exchange of knowledge and ideas. An open culture supportive of university-industry collaboration was also no less vital; Terman's contribution, in this regard, has been about providing students with a stimulating entrepreneurial environment and acted as an early example of an incubator that became a prevalent model within and beyond the region.

Successful, highly-performing companies have often been credited as catalysts of growing viable entrepreneurial ecosystems (Feld, 2012), but failed businesses – more often than not – can also seed the creation of further entrepreneurial dynamics, with ex-employees leaving these enterprises with their own valuable insights that can be useful for 'regeneration' through starting up new businesses (Spigel, 2015). William Shockley's contribution appeared to be closely related to the latter, rather than the former. The inventor, based on his invention of transistor out of silicon instead of germanium, sought to commercialize the nascent technology by establishing Shockley Semiconductor in mid-1950s by recruiting the best semiconductor-related talents across the country. Nevertheless, for reasons that we will elaborate in the next section, the company subsequently failed (hint: due to leadership quality issues), and most of the employees – subsequently known as 'Traitorous Eight' – ended up leaving Shockley and built Fairchild Semiconductor in 1957. It was Shockley's 'failure' (as well as Fairchild's own eventual demise), ironically, that seeded the creation of Fairchild and the 90+ 'Fairchildren'

spin-offs that catapulted Silicon Valley at the global center stage, given the semiconductor revolution that ensued (Endeavor Insights, 2014). Moreover, Fairchild's establishment itself spearheaded a new, venture capital (VC)-led funding model, a financial innovation back in the 1950s and early 1960s (Adams, 2020). The new venture economy also attracted the entrance of law firms since the 1960s which specialized in services such as dealmaking and counseling on investment contracts, patents and intellectual property, IPOs, etc.

These issues aside, our write-up here will focus on drivers of innovation activities in Silicon Valley, and how these dynamics transform the region into the world's leading innovation hub. We will first engage in patent data analysis to identify historical evolution in the region's inter-organizational networks over time. Second, this is complemented with our analysis on universities' roles in driving scientific research in Silicon Valley, with a particular attention on UC Berkeley, which we have covered in Task 2 report. Third, we finally provide description on investment activities by Silicon Valley-based investors, and the proportion of these deals going to local start-ups. We conclude our analyses by discussing our findings and how Hong Kong can learn from it.

4.4.11.1. Three analysis

INTER-ORGANIZATIONAL NETWORKS: EVIDENCE FROM USPTO PATENT DATA

Afterwards, we focus our attention on examining the Silicon Valley innovation ecosystem by utilizing USPTO patent data. The first interesting insight we learned from our data analysis is that no single organization serves as a dominant 'anchor' in the ecosystem; throughout the 36-year period (1983-2018), the top-10 patenting assignees occupied no more than one-quarter of the entire patenting output from this region. Furthermore, when we break down our analysis into six-year periods – as shown in Table 4-106 in the next page, we observed a considerable shift in the listing of top patenting assignees. Throughout the first three 6-year periods (1983-1988, 1989-1994, and 1995-2000), IBM was consistently on top of the patenting assignee lists, confirming the finding by **Fleming and Frenken (2007)** regarding the company's crucial role in enabling the emergence of patent co-inventor networks in the region.[258] Nonetheless, IBM was far from being the only innovation actor catalyzing the rise of Silicon Valley; in order to understand this region, we need to take into consideration a set of multidimensional, co-evolutionary factors that explain the success of Silicon Valley.

Table 4-105. List of top-10 patenting assignees in Silicon Valley (all time)

Name	Patent filings (571,015)
IBM	19,680
Apple	18,118
Google	16,980
Intel	14,707
Hewlett-Packard	11,403
Cisco	10,902
Applied Materials	9,034
Oracle	7,241
Advanced Micro Devices (AMD)	6,885

University of California	6,325
Share of top 10	21.2%
No. of organizations	23,320

Universities have also been identified as playing a significant role in Silicon Valley's development. While neither Stanford nor University of California (which represents both UC Berkeley and UCSF) was on the top-10 patenting assignee lists since the early 2000s, these higher-education institutions were consistently ranked among the highest with regard to their betweenness centrality scores, an indication of their substantial roles in both direct and indirect knowledge dissemination and spillover to other organizations within the region.[259] Past studies, indeed, have backed up our findings, such as **Etzkowitz (2012)** who studied Stanford's role as a role model for 'entrepreneurial universities' worldwide; **Kenney and Goe (2004)**, whose work explored entrepreneurial professors in the electrical engineering and computer science (EECS) departments of UC Berkeley and Stanford; and **Jong (2006)**, who attributed the rise of biotechnology industry in Silicon Valley to the advances in biomedical research at Stanford, UC Berkeley, and UCSF.

Historical serendipities also appeared to contribute to the ascent of Silicon Valley. The region's excellence in electronic-related technologies could be attributed to multiple historical forces shaping its fortunes, beginning from the mining boom in the 19th and 20th century, which stimulated demands in new innovative technologies and equipment to better identify mineral reserves, to federal government's strategic support through defense procurement during World War II and Cold War, to eventually the diffusion of these technologies – originally for sole military applications – into civilian purposes, e.g. semiconductor, personal computers (PCs), and Internet (**Adams, 2020**). Relatedly, the integration of these technologies into the global economy – in large part enabled by the United States' global political, military, and economic dominance – helped to further catalyze the Silicon Valley innovation ecosystem.

Some scholars have attributed the idiosyncrasies of Silicon Valley's success to some major, core individuals. Frederick Terman (1900-1982), the former dean of engineering and provost of Stanford, has often been credited as the "progenitor" of the region (**Etzkowitz, 2012**). PhD-trained by Vannevar Bush at MIT in the 1920s – in which Bush would eventually serve as the 'founding father' of US National Science Foundation (NSF), Terman inherited the values of universities' close collaboration with multiple stakeholders (particularly industries) from his mentor. Such ethos subsequently served as his guidance when leading Stanford's school of engineering, and eventually the university. Throughout his tenure, Terman administration was credited for pioneering institutional innovations at Stanford, such as pioneering informal patent licensing practice (before a formal university TTO was established) and establishing Stanford Industrial Park and attracting some of the US' largest electronic firms to set up factories and R&D centers (**Etzkowitz, 2012**). Moreover, under Terman's leadership, Stanford also pioneered educational innovations that would serve as a 'role model' for other universities worldwide, such as Honors Cooperative Program (a program that allows Stanford students to gain employment in the surrounding local firms, while earning income and new skills) and Stanford Affiliates Program, which refers to a monetary incentive that provides stipends for firms – especially nearby companies – that hired Stanford graduates (**Adams, 2020**).

Silicon Valley's ascent was not isolated to 'mavericks' such as Terman alone; the region's pioneering of global semiconductor industry would not be possible without the invention of the transistor by William Shockley, as well as Shockley's subsequent 'shock' decision to establish his firm in the San Francisco Bay Area (**Endeavor Insight, 2014**). It was worth noting that back in the 1940s and 1950s, other cities had been considered more attractive hubs for the then-nascent electronics industry, notably Boston and Southern California (Los Angeles metropolitan region). Furthermore, Shockley invented the transistor while he was a researcher at MIT, and he only considered the Bay Area (his place of birth) solely because of his personal homesickness. Building Shockley Semiconductor was an incredibly difficult journey for him due to the lack of suitable talents in the region (despite Terman's best intention with his initiatives and programs at Stanford). Therefore, Shockley traveled nationwide to hire the engineers needed to run his company. Eventually, by 1956, he ended up with eight 'best talents' with major credentials that support their qualification: 3 PhD graduates from MIT, 2 PhD graduates from Caltech (California Institute of Technology), 1 PhD graduate from Stanford, and 2 professional engineers from New York City.[260]

Alas, Shockley Semiconductor had a shockingly short lifetime, and this was partly attributed to Shockley's paranoid, erratic leadership skills.[261] In 1957, slightly 1.5 years after their recruitment, these 'eight best talents' subsequently ended up as 'the traitorous eight', as they simultaneously left the company in protest against his abusive personality, and launched Fairchild Semiconductor afterwards. While Shockley Semiconductor's fate ended with an abysmal failure, Fairchild became a subsequent, spectacular success; by 1960, Fairchild's revenue has jumped from initially zero in 1957 to US$21 million in that year, and more than quadrupled to US$90 million as of 1965 (**Lecuyer, 2007**). Eventually, some of Fairchild's co-founders left the company and launched their start-ups; some of these companies would end up ranked among the world's most valuable companies, in both commercial and technological terms. The consequences of their decision are further elaborated in the following paragraphs below.

This leads to another contributing explanatory factor: the proliferation of corporate spin-offs. Indeed, corporate spin-offs have been shown to contribute more towards the development of Silicon Valley than simply university spin-offs launched by the likes of Stanford, UC Berkeley, and UCSF (**Adams, 2020**). Fairchild, in particular, appeared to be one of the biggest contributors of such corporate spin-offs; much of this was enabled by the open culture of 'spinning off ideas', as summarized by Gordon Moore, one of the 'traitorous eight' who would, with Robert Noyce (another member of the 'traitorous eight'), co-found Intel, now one of the world's largest memory-chip firms:

> "That's part of the legacy of Fairchild that maybe doesn't get the attention it should… Every time we came up with a new idea, we spawned two or three companies trying to exploit it." (Gordon Moore, as quoted from p.14, Endeavor Insight, 2014)

In addition to Intel, Fairchild has also generated numerous other notable spin-offs, such as Advanced Micro Devices (AMD), National Semiconductor, etc. It was estimated that Fairchild's founders and ex-employees alone had directly generated 65 spin-offs, which in turn further generated a total of over 2,000 companies within Silicon Valley, either through co-

founding or investment financing support through some of the VC funds they established (**Endeavor Insight, 2014**). We highlighted some of the examples in the bullet points below:

- Gordon Moore and Robert Noyce launched Intel, which at one point, was the world's most influential memory-chip firm;
- Jerry Sanders, and seven other ex-employees of Fairchild Semiconductor, co-founded Advanced Micro Devices (AMD), which builds their expertise centered on microprocessors, motherboard chipsets, and graphics processors
- Eugene Kleiner, one of Fairchild's co-founders, established Kleiner Perkins, which would be one of the world's earliest – and largest – VC funds, having invested in major technology companies such as Sun Microsystems and Symantec
- Don Valentine, a former executive at Fairchild and National Semiconductor, launched Sequoia Capital in 1972. Similar to Kleiner Perkins, Sequoia is also currently one of the world's largest VC funds, which, as of 2021, has engaged in almost 2,000 investment deals worldwide. Sequoia played a pivotal role in providing early financing support for technology companies such as Apple, Google, Oracle, YouTube, Facebook, Instagram, WhatsApp, LinkedIn, and PayPal
- Mike Markkula, a former engineer at Fairchild, was the first mentor for Steve Jobs in the first few years of Apple; Markkula would also eventually serve as the company's inaugural CEO

As Table 4-106 and Table 4-107 in the next page have attested, a substantial proportion of the most influential companies listed in these tables (in terms of innovative output and/or their centrality position) could be traced back – whether directly or indirectly – to Fairchild Semiconductor. Much of this was attributed to Fairchild's supportive culture of allowing employees and directors autonomy in spinning off their ideas into their own business ventures, a direct contrast to the stifling work culture at Shockley Semiconductor.

Relatedly, another idiosyncrasy explaining the appeal of Silicon Valley relates to their unique socio-cultural values (**Saxenian, 1994**). This is already shown by the imprinting effect of Fairchild's openness to spin-off ideas into new businesses, with co-founders and employees leaving the company to pursue and commercially exploit their own ideas. Oftentimes, this was complemented by experienced, senior leaders mentoring younger entrepreneurs, in which the latter were inculcated with the latest business and technology insights, advice on building companies, as well as financial support. Financial investments (e.g. through VC activities), in particular, frequently serve as the 'adhesive' that connects aspiring entrepreneurs with these senior professionals (**Sorenson and Stuart, 2001**). This has been evident with the founding of Fairchild itself, which would not have occurred without financing support from Arthur Rock and Sherman Fairchild, two of the world's first venture capitalists themselves (and who would connect Fairchild with major corporate clients such as IBM). Such practices are formalized through the abundance of VC funds established by serial entrepreneurs within the San Francisco Bay Area, with more elaboration to be shown in the next pages. By investing in the companies of interest, the VC investors are able to monitor company performance (often through investors sitting in the boards of these invested firms), as well as provide suggestions on improving the companies' business and management activities.

Nevertheless, in reality, VC investments more often end with failures than in phenomenal successes (the few successes by which determine the VC funds' long-term fortunes and outlook). This is because such companies – and in particular technology companies – are often

faced with the 'liabilities of newness', as well as considerable uncertainties, surrounding the commercializability and adoption of the technologies laying the basis for these businesses (**Stinchcombe, 1965**). Furthermore, most of the companies invested by these VC funds may not survive in the long run. Such phenomenon, however, also explains another cultural quirk of Silicon Valley: the openness – and 'celebration' – of failure (**Saxenian, 1994; Sotarauta and Srinivas, 2005**). Saxenian's ethnographic fieldwork in the region has showcased some examples of serial entrepreneurs who have founded multiple companies – many of which failed – but somehow continued to persist.

Last but not least, this also explains another interesting cultural aspect in the region: the willingness to 'move on', as demonstrated by its high degree of career mobility relative to other regions. **Saxenian (1994)** has provided preliminary evidence of the tendency of professionals in the region to rapidly shift workplaces, whether in search of new career development opportunities or to establish one's own business. In a follow-up, quantitative study of multiple metropolitan regions in the US, **Almeida and Kogut (1999)** discovered that among all metro areas studied, Silicon Valley stands out given its highest score in terms of the degree of career mobility. Such abundant mobility flows were enabled by what **Marx (2011)** argued as the non-enforceability of non-compete agreements (legal agreements that bar individuals leaving a company to work in the firm's competitors within the region for a specified period of time) in the state of California.

Table 4-106. List of top-10 patenting assignees in Silicon Valley throughout different time periods (patent filings indicated in brackets)

1983-1988 (13,027)	1989-1994 (25,343)	1995-2000 (80,897)	2001-2006 (120,520)	2007-2012 (153,957)	2013-2018 (162,614)
IBM (484)	IBM (1,261)	IBM (3,899)	Hewlett-Packard (4,006)	Google (6,808)	Google (9,252)
Chevron (479)	Hewlett-Packard (846)	AMD (3,181)	Intel (3,812)	Apple (6,787)	Apple (8,346)
AMD (384)	Nat'l Semicond (660)	Sun Microsystems (2,871)	Cisco (3,712)	IBM (4,792)	IBM (5,474)
Dow (357)	Univ of California (649)	Applied Materials (2,137)	IBM (3,119)	Intel (3,412)	Intel (5,018)
Hewlett-Packard (353)	Xerox (565)	Intel (1,880)	Sun Microsystems (2,900)	Cisco (3,213)	Cisco (2,692)
Raychem (350)	Apple (523)	Hewlett-Packard (1,864)	Applied Materials (2,342)	Hewlett-Packard (3,038)	Facebook (2,496)
Dept of Energy (262)	General Electric (411)	Univ of California (1,792)	AMD (2,117)	Oracle (2,836)	Applied Materials (2,223)
Stanford Univ (260)	Stanford Univ (390)	LSI Corp (1,279)	Oracle (1,975)	Marvell (2,671)	Qualcomm (2,079)
Syntex (257)	Sun Microsystems (381)	Xerox (1,271)	Broadcom (1,879)	Broadcom (2,059)	Amazon (1,957)
Xerox (220)	Intel (365)	Cisco (1,268)	Hitachi (1,712)	Qualcomm (2,006)	Oracle (1,893)
Share of top 10: 26.1% No. of organizations: 2,022	Share of top 10: 23.9% No. of organizations: 3,035	Share of top 10: 26.5% No. of organizations: 5,987	Share of top 10: 22.9% No. of organizations: 7,096	Share of top 10: 24.4% No. of organizations: 8,126	Share of top 10: 25.5% No. of organizations: 8,579

Table 4-107. List of top-10 patenting assignees in Silicon Valley in terms of betweenness centrality scores (scores indicated in brackets)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
Stanford Univ (57889)	Univ of California (192937)	Univ of Calif (1152291)	Univ of Calif (1180395)	Stanford Univ (1402132)	Google (1294980)
Hewlett-Packard (24153)	Stanford Univ (109638)	Stanford Univ (587493)	Stanford Univ (925608)	Google (1278712)	Apple (952304)
Univ of California (22197)	IBM (68523)	IBM (510260)	Intel (656016)	Apple (935293)	Stanford Univ (872347)
AMD (22037)	Nat'l Semicond (59666)	Sun Microsystem (393169)	Hewlett-Packard (613326)	Univ of Calif (853453)	Univ of Calif (600073)
IBM (18759)	Hewlett-Packard (51552)	Applied Materials (364294)	Cisco (566613)	Cisco (650771)	Cisco (454727)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
Xerox (16991)	Applied Materials (40217)	Hewlett-Packard (353995)	Applied Materials (444790)	Intel (502933)	Applied Material (291325)
SRI International (15104)	Apple (39531)	Apple (350476)	Apple (414434)	Hewlett-Packard (484968)	Facebook (290511)
Raychem (12550)	SRI International (39106)	Cisco (309554)	Agilent Tech (388310)	Abbott (468627)	Intel (287819)
Dept of Energy (11828)	Adv Cardiovasc (35767)	Intel (241458)	Broadcom (357881)	Applied Materials (468446)	Boston Scientific (267949)
Cetus (10290)	Raychem (32710)	Medtronic (208559)	IBM (327811)	Oracle (406157)	Covidien (229375)

Table 4-108. List of patenting assignees in Silicon Valley with the highest degree centrality scores (scores indicated in brackets)

1983-1988	1989-1994	1995-2000	2001-2006	2007-2012	2013-2018
Stanford Univ (50)	Univ of California (102)	Univ of California (316)	Univ of California (324)	Google (431)	Google (462)
Univ of California (33)	Stanford Univ (83)	Stanford Univ (230)	Stanford Univ (277)	Stanford Univ (412)	Apple (378)
SRI International (30)	Nat'l Semiconductor (52)	IBM (192)	Intel (251)	Apple (346)	Stanford Univ (290)
Hewlett-Packard (25)	IBM (47)	Sun Microsystems (183)	Hewlett-Packard (211)	Univ of California (295)	Cisco (221)
AMD (17)	Hewlett-Packard (41)	Hewlett-Packard (155)	Cisco (210)	Cisco (270)	Univ of California (205)
Xerox (17)	SRI International (41)	Apple (139)	Applied Materials (179)	Intel (256)	Intel (191)
Dept of Energy (17)	Apple (40)	Applied Materials (126)	Apple (177)	Oracle (216)	Facebook (186)
Cetus (17)	Genentech (37)	Intel (121)	Broadcom (173)	Hewlett-Packard (213)	Microsoft (154)
Raychem (16)	Adv Cardiovascular (36)	Cisco (119)	IBM (160)	Applied Materials (199)	Qualcomm (154)
Varian (16)	Chiron (34)	AMD (105)	Sun Microsystems (156)	IBM (199)	Marvell (149)
		Nat'l Semiconductor (101)	Oracle (153)	Qualcomm (190)	Applied Materials (146)
			Agilent Technologies (152)	Abbott (187)	Samsung (143)
			Medtronic (139)	Broadcom (186)	IBM (143)
			AMD (131)	Microsoft (157)	Amazon (131)
			Boston Scientific (115)	Medtronic (143)	Broadcom (128)
			Microsoft (113)	Marvell (140)	Oracle (123)
			Abbott (110)	Boston Scientific (140)	Western Digital (121)
			Philips (109)	Covidien (136)	Boston Scientific (114)
			Yahoo (108)	Yahoo (128)	SanDisk (106)
			Google (107)	Tyco (128)	VMware (103)
			NVIDIA (102)	Samsung (124)	Juniper Networks (102)
			KLA-Tencor (100)	Facebook (118)	
				Juniper Networks (116)	
				SanDisk (110)	
				Intuitive Surgical (107)	
				KLA-Tencor (107)	
				NVIDIA (105)	

Note: from 1995-2000 period onward, we focused on nodes with degree centrality scores of at least 100 or more (in other words, patent assignees with linkages with at least 100 unique organizational entities)

We further elaborate about the inter-organizational linkages within Silicon Valley innovation networks by focusing on the results from Table 4-108 above and Table 4-109 below. The former refers to organizations (firms and universities alike) with the highest degree centrality scores. In contrast to betweenness centrality, degree centrality simply measures the number of nodes with which a node of interest has direct linkages (**Freeman, 1977**). For example, when a node has a degree centrality score of 100, we can infer that this node of interest has direct relationships with 100 other nodes in a network. In other words, an organization with a degree centrality score of 200 has direct linkages with 200 other organizations within an innovation network. From Table 4-108 above, we can observe that universities – notably represented by Stanford, UC Berkeley, and UCSF – have consistently topped the most-linked organization lists within the Silicon Valley innovation network. It was only in the recent two periods (2007-2012 and 2013-2018) that Google and Apple surpassed the universities as the nodes with the highest degree centrality scores. While these direct linkages imply several possible scenarios (career mobility to and/or from these organizations, formal research collaboration, informal knowledge exchange, spin-offs, etc), the higher the degree centrality scores of these nodes, the more influential they are in knowledge dissemination.

Given that a significant number of organizations have degree centrality scores above 100, we can imply that a high proportion of inter-organizational linkages within the Silicon Valley region are concentrated in a small, but highly strategic, number of innovation actors. We conduct further analysis by identifying the lists of organizations that are most heavily linked with these nodes of interest (with details shown in Table 4-109 below). In this regard, we take into consideration the weight of these direct linkages (the frequency with which linkages occur between the pair(s) of nodes); the higher their weighted score, the more frequent their knowledge exchange ties. From this table, we can observe that these organizations develop very strong linkages primarily with their locally-based counterparts. Let us take Cisco as an illustration. In 2007-2012, 7 of the top 10 most-linked organizations with Cisco are fellow Silicon Valley-headquartered firms, namely Google, Nest Labs, Facebook, Hewlett-Packard, Broadcom, Seagate, and NVIDIA (whether through two-way career movements or formal research collaboration).

Table 4-109. Organizations with the most linkages with Silicon Valley patenting assignees with highest degree centrality scores (2001-2018)

	2001-2006	2007-2012	2013-2018
AMD	GlobalFoundries Fujitsu Applied Materials Broadcom SanDisk Sun Microsystems NASA NVIDIA* KLA-Tencor Intel	GlobalFoundries ATI Technologies Spansion VMware IBM Apple Broadcom NVIDIA Intel MasterCard	ATI Technologies Synaptics SanDisk Google EMC Corporation Dolby Apple NVIDIA Xilinx Qualcomm
Apple	AT&T Broadcom Palm Inc Thomson	Google Nest Labs Facebook Hewlett-Packard	Google Marvell Broadcom Silergy

	NVIDIA Microsoft Think Outside Inc Alcatel-Lucent Pixar* Yahoo	Broadcom Amazon Seagate Microsoft Monolithic Systems NVIDIA	Intel Square Inc Fujifilm Hitachi Facebook Qualcomm
Applied Materials	Lam Research Intel Air Product & Chem ASML Bio-Rad Broadcom KLA-Tencor EMC Corporation Cisco Hewlett-Packard	Intermolecular Salesforce Alta Devices Hewlett-Packard Lam Research Marvell Sony SanDisk IBM Intel	Ericsson Varian Lam Research SanDisk Plexxikon IBM Apple Facebook Univ of California Intel
Broadcom	AMD Apple Hewlett-Packard Sun Microsystems Oracle NVIDIA Cisco Infinera Finisar Marvell	LSI Corporation Cisco Apple Beceem Comm NetLogic Microsystem Marvell Agere Systems PixArt Intel Oracle	LSI Corporation Apple NetGear Marvell Seagate SK Hynix Qualcomm Facebook MediaTek Alibaba
Cisco	Applied Materials Broadcom Hewlett-Packard Intel Oracle Sun Microsystems Symantec Atheros Aspect Comm Avaya	Broadcom Juniper Networks Intel Apple Headway Technologies Hewlett-Packard Google Ericsson Avaya Qualcomm	Marvell Google PARC Apple Hewlett-Packard Avaya AppDynamics Jasper Technologies AT&T Avalanche Technology
Facebook	-	Google Apple AOL VMware Yahoo Hewlett-Packard Palm Inc Qualcomm Microsoft Cisco	Google Apple Oculus VR Broadcom IBM VMware Marvell Intel Qualcomm Applied Materials
Google	Stanford Univ Intel NVIDIA Microsoft Overture Services ArrayComm	Facebook Apple Nest Labs Oracle Microsoft IBM	Waymo* Apple Facebook Verily Life Sciences* Cisco Nest Labs*

	YesVideo Stratify Inc E.Piphany Inc PARC	Yahoo Hewlett-Packard Intel Stanford Univ	Microsoft Intel Amazon IBM
Hewlett-Packard	Stanford Univ Applied Materials Samsung Palm Inc Yahoo Broadcom Google Vmware Microsoft Cisco	Qualcomm Apple Palm Inc Samsung Seiko Epson Google Entit Software Blackberry NEC Applied Materials	Aruba Networks* Nimble Storage* Cisco Leia Inc* Google Entit Software Intel SanDisk TSMC Applied Materials
IBM	Hitachi Yahoo SanDisk Oracle Hewlett-Packard eBay Google Intel Applied Materials Western Digital	GlobalFoundries A*STAR Singapore Stanford Univ Google Lenovo* Yahoo NetApp US Nat'l Secur Agency Nuance Comm AMD	GlobalFoundries A*STAR Singapore STMicroelectronics Lenovo* CEA France Renesas Intel Facebook Google Applied Materials
Intel	Ovonyx ArrayComm Hewlett-Packard Oracle NVIDIA ThinkOptics Samsung Broadcom Cisco Google	Samsung Microsoft Micron Technology Google Cisco Blackberry Apple Applied Materials NVIDIA Oracle	Blackberry Micron Nokia Apple IBM SanDisk GlobalFoundries Google AT&T McAfee
NVIDIA	Microsoft Google Nishan Systems QST Holding Brocade Comm Catch-A-Wave Portalplayer Alvand Tech Nokia Magnachip	Google Apple Rambus MIT Intel LSI Corporation Oracle Stanford Univ SandForce Xilinx	MIT Stanford Univ Apple Intel Google Rambus Facebook Western Digital SunPower US Dept of Energy
Oracle	IBM Intel Sun Microsystems Palm Inc Yahoo Cisco Habanero Holdings Extreme Networks	Sun Microsystems Google Qualcomm Hewlett-Packard Intel PARC Salesforce IBM	Google Ericsson Samsung PureStorage Groupon Xilinx Ambarella Qualcomm

	Finisar Symantec	Broadcom Cisco	IBM Broadcom
Stanford	Honda Kosan Biosciences Bosch Intel General Electric MIT Google* Univ of California Hewlett-Packard* Medtronic	Honda IBM Rambus Univ of California Google* Caltech General Electric Samsung SRI International Lytro	OptiMedica Samsung Univ of California NVIDIA Caltech VIB Belgium VU Brussel US Dept Vet Affairs Lytro Univ of Wisconsin
Sun Microsystems**	Oracle Intel Broadcom SanDisk Cisco Red Hat Symantec NVIDIA Hewlett-Packard Apple	Oracle Google Broadcom NVIDIA Altera Apple Intersil Qualcomm Immersion Corp AMD	-
Univ of California	Lawrence Livermore PolyPlus Battery* Caltech Scripps Res Inst Synopsys Atrionix Fluidigm Adara Networks Plexxikon* Univ of Chicago	Stanford Univ Ekso Bionics* Sangamo Bioscience PolyPlus Battery* Lawrence Livermore Chevron Caltech ViOptics Toyota Qualcomm	Chevron Lawrence Livermore Stanford Univ Caribou Biosciences* Applied Materials British Petroleum (BP) Univ of Vienna Sandia US Dept Vet Affairs Rohm and Haas

* indicates that the companies were established as spin-offs of the linked organizations (whether originating from universities or other corporations)

** Sun Microsystems was acquired by Oracle in January 2010. The remainder of the company has been integrated into Oracle's core businesses

Box 1. Patterns of inter-organizational collaboration in scientific research: evidence from joint industry co-publications

Table 4-110. Joint publication matrices between selected dyads of Silicon Valley-based organizations

	Google	Apple	Cisco	Intel	Oracle	Hewlett-Packard	Applied Materials	Broadcom	Yahoo	AMD	NVIDIA	Western Digital	IBM	*Stanford*	*UC Berkeley*	*UCSF*	Genentech
Google	14,929	41	24	86	17	61	1	3	150	6	53	2	289	*758*	*635*	*46*	3
Apple	41	2,189	5	26	4	11	1	8	2	4	6	1	32	*86*	*18*	*6*	0
Cisco	24	5	3,919	59	36	28	0	21	4	3	1	0	71	*76*	*28*	*2*	0
Intel	86	26	59	25,012	41	133	30	37	23	99	91	7	426	*409*	*518*	*0*	0
Oracle	17	4	36	41	2,927	30	0	2	7	8	6	0	94	*31*	*21*	*2*	0
Hewlett-Packard	61	11	28	133	30	14,722	5	2	12	20	5	2	226	*496*	*209*	*7*	2
Applied Materials	1	1	0	30	0	5	2,965	1	3	25	1	1	64	*57*	*36*	*3*	1
Broadcom	3	8	21	37	2	2	1	1,576	1	3	6	1	22	*7*	*17*	*0*	0
Yahoo	150	2	4	23	7	12	3	1	26,580	0	1	0	139	*114*	*81*	*17*	2
AMD	6	4	3	99	8	20	25	3	0	3,418	39	1	185	*64*	*73*	*0*	0
NVIDIA	53	6	1	91	6	5	1	6	1	39	2,680	1	49	*118*	*91*	*0*	0
Western Digital	2	1	0	7	0	2	1	1	0	1	1	1,031	17	*17*	*24*	*0*	1
IBM	289	32	71	426	94	226	64	22	139	185	49	17	99,857	*1,224*	*813*	*89*	11
Stanford	*758*	*86*	*76*	*409*	*31*	*496*	*57*	*7*	*114*	*64*	*118*	*17*	*1,224*	*320,756*	*7,364*	*8,611*	629
UC Berkeley	*635*	*18*	*28*	*518*	*21*	*209*	*36*	*17*	*81*	*73*	*91*	*24*	*813*	*7,364*	*258,295*	*6,748*	141
UCSF	*46*	*6*	*2*	*0*	*2*	*7*	*3*	*0*	*17*	*0*	*0*	*0*	*89*	*8,611*	*6,748*	*199,156*	892
Genentech	3	0	0	0	0	2	1	0	2	0	0	1	11	*629*	*141*	*892*	16,125

Note: publication data were collected from Lens.org on December 3, 2021. We included publications affiliated with these organizations irrespective of time period (in other words, we took into consideration the entire set of publications affiliated with them throughout their existence). We also did not limit our definition of 'publications', with respect to the table above, for journal articles alone, but also included conference proceedings, book chapters, books, pre-prints, reports, clinical trials, datasets, and industry-funded dissertations. Figures in cells highlighted in orange refer to the entire number of publications affiliated with the organization of interest. Italicized figures indicate joint university-industry (U-I), or research institute-industry, co-publications. For dyads of co-publications with the total number of observations below 20, we indicate the table cells in white. For those with observation size between 20 and 50, the table cells are highlighted in light blue; for those with observation size between 51 and 100, the cells are highlighted in slightly darker blue. In the case of over 100+ repeat collaboration instances between organizational dyads, we indicate the table cells in dark purple-blue.

Dense inter-organizational linkages, it turns out, are not just limited to exchanges of technological knowledge, as already shown from the analysis of patent data above; in terms of scientific research collaboration (which we proxy with the presence of publications involving researchers from two or more organizations), there also occur rich networks of inter-organizational relationships, whether in the presence of formal agreements or solely informal exchange involving individual researchers across different companies (**Almeida et al., 2011**). Many of the most active patenters in the Silicon Valley region happen to be highly prolific producers of scientific knowledge as well, as demonstrated by Google (having almost 15,000 publications in aggregate since its inception), Intel (with 25,000 academic works), etc. While IBM is headquartered in Armonk, NY, the company also operates several major R&D centers in the region, the most notable example by which is IBM Almaden R&D Center.

One interesting insight we gleaned from the table above was the very high degree of exchange in scientific knowledge among researchers of these Silicon Valley-based organizations, even when most of them engage in intense competition in certain technology areas (e.g. joint scientific studies by researchers from Google and Yahoo, despite their competition in search engine market). This finding partly reflected the fieldwork by **Saxenian (1994)** and inter-organizational network analysis by **Almeida and Kogut (1999)**; in both respects, the region appeared as an outlier due to the presence of large, and highly global, ICT-related companies. The synergistic complementarities between competition and cooperation – also known as co-opetition (**Gnyawali and Park, 2011**) – has also been a significant driving force of innovation dynamics in Silicon Valley. Some instances of collaboration between these oftentimes-competing organizations (whether existing or ongoing) are shown in the bullet points below:

- Collaboration between Hewlett-Packard (HP), Intel, and Yahoo to develop cloud-computing technologies in the mid-2000s in a cross-country research consortium that involves Infocomm Development Authority of Singapore, University of Illinois at Urbana-Champaign (UIUC), and Karlsruhe Institute of Technology of Germany (link: https://www.hp.com/hpinfo/newsroom/press/2008/080729xa.html)
- Despite frequent rivalries between Intel and Advanced Micro Devices (AMD) as chipmakers, the two companies have – at times – collaborated together in next-generation chip development. For example, in 2018, the two companies collaborate together[262] in developing Intel 8th Generation Core chips in combination with AMD's Radeon RX Vega M graphics that enable accelerated CPU and GPU performance (link: https://www.forbes.com/sites/moorinsights/2018/01/07/intel-and-amd-partner-on-new-8th-gen-chip/?sh=1fb0ddfc186f)
- In 2015, Google and Yahoo – both of which are competitors in search engine market – decided to collaborate on search advertisements, or simply known as 'search ads'. In this collaboration agreement, Google agreed to provide search ads in any search results taking place in Yahoo, and in turn the latter will receive undisclosed advertising revenues from the former (link: https://www.businessinsider.com/yahoo-just-signed-a-deal-with-google-to-provide-search-ads-2015-10)
- Intel and NVIDIA, also fellow competitors in chipmaking, announce their collaboration in joint development of mobile PC gaming technologies, with the latter company unveiling their GTX 1600 graphics processing unit (GPU) that will make use of the latest CPUs by Intel (link: https://seekingalpha.com/article/4257349-intel-and-nvidia-partner-to-drive-mobile-pc-gaming)

UNIVERSITY-INDUSTRY COLLABORATION IN SCIENCE: EVIDENCE FROM ANALYSIS OF JOINT PUBLICATIONS

Afterwards, we study the patterns of university-industry collaboration in scientific research by taking into account publication data (specifically articles published in academic journals), which we obtained from Lens.org. Given our focus on publicly-funded research universities, our attention was primarily on the University of California – Berkeley (UC Berkeley), which we have also profiled in the previous Task 2 report. Throughout the 2009-2018 period, we identified a total of 56,979 journal articles involving UC Berkeley-based researchers, with and without collaboration with external organizations. Of these observations, approximately 6.3% (3,597 journal articles in total) are co-publications involving industry actors. This figure placed the university on par with the 6-7% global average estimated by **Tijssen et al. (2009)** in their analysis of 350 leading research universities worldwide. When we further break down the types of collaboration based on the geographical location of these firms (local, domestic non-local, and foreign),[263] we did not observe a noticeable divergence in the collaboration patterns; the number and proportion of joint publications with locally-based and domestic non-local enterprises have remained largely steady throughout the 10-year period. There has been a slight increase in the number and proportion of journal articles in collaboration with foreign firms, but such activities have yet to replace their persistent tendency of engaging in joint research primarily with American firms.

Table 4-111 in the following page lists out the top-10 collaborating local, domestic non-local, and foreign companies with UC Berkeley-based researchers in terms of co-authoring journal articles. The top-10 lists are not overwhelmingly dominated by large firms from a single sector (say, in ICT or in pharmaceuticals) alone; these industry collaborators represent a wide range of sectors, e.g. ICT (as represented by Google, Microsoft, Yahoo, IBM, Samsung), biotechnology/life sciences/pharmaceuticals (proxied by Genentech, Eli Lilly, Merck, Pfizer, Novartis), semiconductor (shown by Intel, GlobalFoundries, Agilent Technologies, Carl Zeiss), automobiles (General Motors, Toyota, Subaru), agriculture (EMBRAPA), etc. Box 2 in the next page provides illustration of UC Berkeley's rich collaboration with some of these leading enterprises.

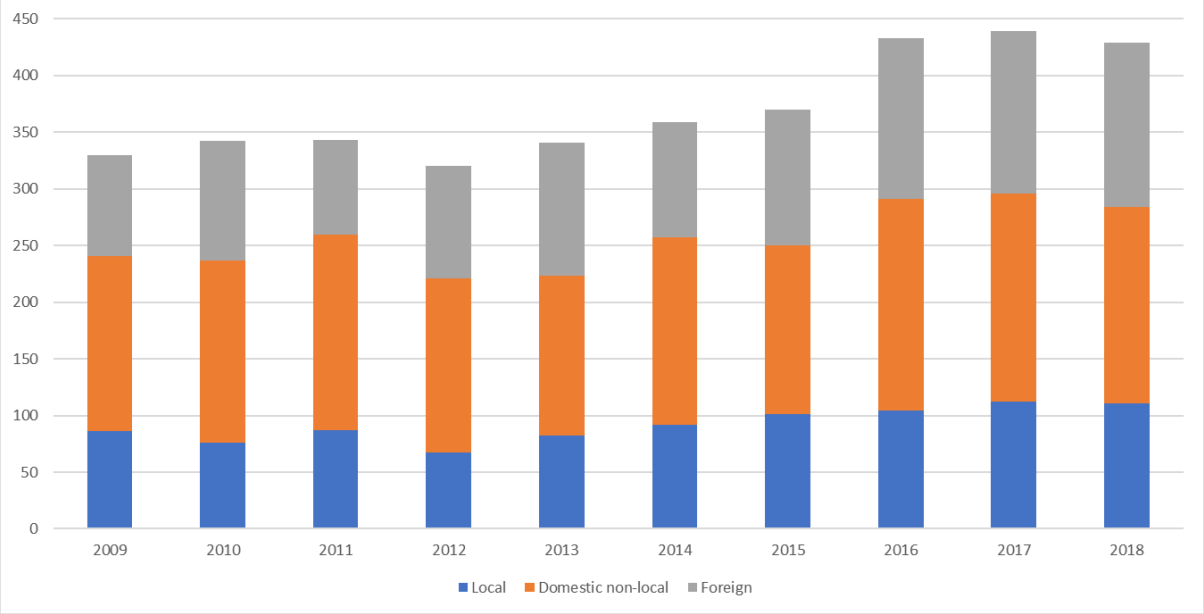


Figure 4-34. Types of U-I co-publications involving UC Berkeley (2009-2018) based on the geographical origins of collaborating firms

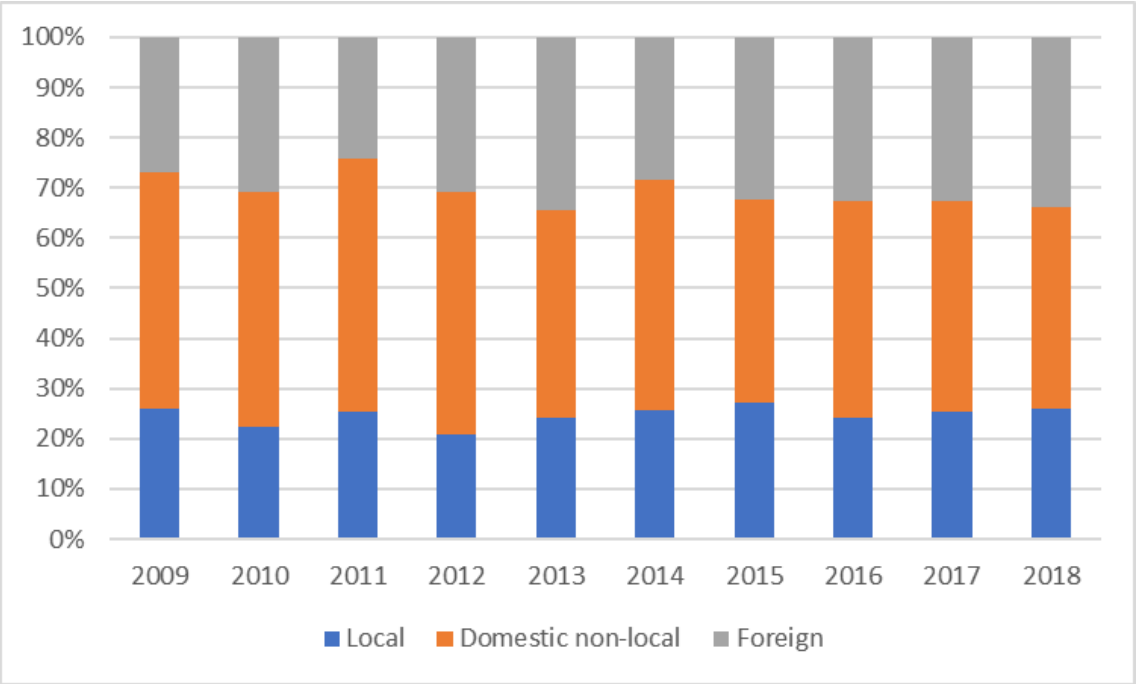


Table 4-111. Top 10 collaborating firms with University of California-Berkeley (UC Berkeley) in U-I co-publications (2009-2018 period, number of co-publications indicated in brackets)

Local firms (N = 989)	Domestic non-local firms (N = 1,854)	Foreign firms (N = 1,282)
Google (64)	Microsoft (126)	Hoffmann-La Roche (56)
Intel (54)	IBM (65)	Samsung (28)
Genentech (31)	Vision-Sciences Inc (37)	Carl Zeiss (20)
Hewlett-Packard (20)	Carnegie Learning (35)	Novartis (16)
Adobe Systems (15)	General Motors (26)	Toyota (14)
Pacific Gas & Electric (13)	Eli Lilly (24)	EMBRAPA (12)
Exponent (12)	Qualcomm (20)	GlaxoSmithKline (11)
GlobalFoundries (10)	Merck (19)	Philips (11)
Yahoo (8)	Pfizer (19)	Bristol-Myers Squibb (10)
Agilent Technologies (7)	General Electric (15)	Subaru (10)

Box 2. UC Berkeley's rich collaboration with local, domestic non-local, and foreign firms

Existing academic literature has demonstrated the not-insignificant role of UC Berkeley in pioneering academic entrepreneurship and university-industry collaboration, whether in ICT area by EECS faculty members (**Kenney and Goe, 2004**) or in life sciences (**Jong, 2014**). In recent years, there have been a growing number of initiatives, joint laboratories, as well as research consortia involving the university and major multinational corporations, some

names by which appeared in the top scientific collaborator lists. Some case illustrations are shown in the following bullet points:

- Berkeley Artificial Intelligence Research (BAIR) alliance, a joint initiative by UC Berkeley and 7 of the world's largest ICT firms (Amazon, Samsung, Microsoft, Alibaba, Facebook, Google, and more recently Panasonic): in this consortium, corporate/industrial researchers from these companies may engage in research collaboration with faculty members, students, or any other research staff from UC Berkeley in topics centered on artificial intelligence (AI). Some notable projects they are working on range from automated vehicles, building large-scale datasets for 3D object machine learning, mimicking animal movements, distributed learning, computational linguistics, etc. BAIR is currently led by Pieter Abbeel, a professor of computer science, and also a serial entrepreneur (Abbeel was a co-founder of Gradescope, a UC Berkeley exam-grading software spin-off).
- UC Berkeley-Intel collaboration: the two organizations have also been engaged in multiple collaboration efforts, primarily in the development of secure computing methods and discovery of new quantum materials that can potentially upend transistor and semiconductor technologies. Regarding the former, Intel established their "Science and Technology Center for Secure Computing" at the UC Berkeley campus. Members of the research consortium include Carnegie Mellon, Cornell, Drexel, Duke, UC Davis, UIUC, and the University of Georgia. Also known as SCRUB (Secure Computing Research for Users' Benefit), the center is jointly headed by UC Berkeley and Intel researchers.[264] With regard to the latter, the researchers are developing new materials that will be potentially 10-100x more efficient than the existing microprocessor technologies used in our computers.[265]
- Joint research consortium involving UC Berkeley, UCSF, Genentech, and Roche (Genentech's parent company, based in Switzerland): in February 2021, the four organizations established a US$53 million research consortium that will be dedicated towards advanced research in neurodegenerative disorders, e.g. Parkinson's, Alzheimer's, amyotrophic lateral sclerosis (ALS), and to accelerate the development of therapeutic treatments addressing these diseases. The collaboration is planned to last for up to 10 years.[266]

Moreover, we also focus our attention on a UC Berkeley's scientific collaboration with their own spin-offs. With our attention towards locally-based spin-offs, we identified 75 such companies producing a total of 214 journal articles with their counterparts at the university. As we have stated in the previous hub cases, we advise one major caveat with our finding, as not all of the spin-offs in Table 4-113 below are affiliated with Intellectual Property and Industry Research Alliances (IPIRA), the official technology transfer office for UC Berkeley. Overall, biotechnology/life science-related firms comprise the largest proportion (approximately 19%) of all identified UC Berkeley-affiliated spin-offs. In comparison to what we have observed from other universities covered in Task 2, the industry sectors represented by the university's spin-offs are also very diverse; other major sectors in addition to biotechnology include: software/big data/enterprise solutions, material sciences, social enterprises, AI/ML (artificial intelligence/machine learning), environmental conservation, etc. Table 4-113 below provides further illustrations on notable spin-offs either generated from research at UC Berkeley or founded by professors/graduates/alumni/researchers from the university.

Table 4-112. Specialization of UC Berkeley spin-offs identified from U-I co-publications (2009-2018)

Sector	Number (N = 75)
Biotechnology/pharmaceuticals	14
Software/big data/enterprise solutions	7
Material science	5
Social enterpreneurship	5
Artificial intelligence/machine learning	4
Environmental conservation	4
Electronics	4
Research contract/services	4
Architecture and design planning	3
Information and communication technologies	3
Semiconductor and related components	3
Business and management consulting	2
Diagnostics and testing-related equipment	2
Fintech (financial technology)	2
Mobile applications	2
Renewable energy-related technologies	2
Scientific and research instruments	2
Camera technology development	1
Carbon capture and storage	1
Intellectual property management	1
Internet of Things (IoT)	1
Laser-related technologies	1
Medical devices	1
Academic publishing	1

Table 4-113. Notable UC Berkeley spin-offs identified from U-I co-publications

Name	University	Profile
Acepodia	UC Berkeley	Acepodia (formerly Adheren) is pioneering next-generation technologies to better fight cancers. The company is currently in the process of developing cell therapies with significantly improved potency, better safety, as well as enhanced applicability across various tumor cancers. Acepodia was established in 2010 originally as Adheren, and acquired its current name in 2017. The founders were Dr. Patrick Y. Yang, a serial business executive who was executive vice president of Juno Therapeutics, Roche and Genentech; Dr. Sonny Hsiao, cell biologist with PhD from UC Berkeley and inventor of Acepodia's core technology, and; Matthew B. Francis, professor of cell biology at UC Berkeley.
Ayar Labs	MIT UC Berkeley UC Boulder	Ayar Labs aims to build a solution that overcomes the power and performance-scaling limitations of semiconductors and the interconnect bandwidth bottleneck

		between those devices. The technology is developed with the consideration of volume-based manufacturing in mind, leveraging high-volume semiconductor and packaging partners. The company was established by a group of academics and scientists from MIT, UC Berkeley, and University of Colorado - Boulder (UC Boulder): Mark Wade, Chen Sun, and Vladimir Stojanovic. Mark obtained his PhD at UC Boulder. Chen obtained his PhD from MIT. Vladimir is a professor of electrical engineering and computer science at UC Berkeley. The company leverages on their 10-year collaboration across 3 different universities, largely enabled by DARPA funding support.
Bandwidth10	UC Berkeley	Bandwidth10 aims to promote the commercialization of Vertical Cavity Surface Emitting Laser (VCSEL) technology, delivering cost-effective tunable solutions and advances in optoelectronics that are out of reach with conventional technologies. The company's technology is potentially applicable for many purposes, e.g. data communications, LIDAR (especially for automated vehicles), swept sources, etc. Bandwidth 10 was founded in February 2011 by a research team at UC Berkeley and industry veterans. Founders were Phil Worland, Chris Chase, and Mike Huang. Chris and Mike were PhD graduates from UC Berkeley.
Berkeley Research Group	UC Berkeley	Berkeley Research Group LLC is an international consulting firm that assists companies and various organizations on dispute resolutions, industry-related investigations, corporate finance and operation-related strategies. Berkeley Research Group was founded in 2010 by David Teece, professor of business at UC Berkeley Haas School of Business.
Caribou Biosciences	UC Berkeley	Caribou Biosciences is a clinical-stage genome-editing biotechnology company founded by pioneers of CRISPR biology and located in Berkeley, CA. The company is currently in the stage of developing an internal pipeline of off-the-shelf, genome-edited CAR-T for therapeutic applications. Caribou Biosciences was established in 2011, and is currently led, by Rachel Haurwitz (now the company's CEO), Jennifer Doudna, and Martin Jinek. Doudna was a 2020 Nobel Prize laureate in Chemistry (with her collaborator, Emmanuelle Charpentier), and is a full-time professor at UC Berkeley. Haurwitz was her PhD student, and Jinek – currently professor at the University of Zurich (Switzerland) – was her postdoc.
Databricks	UC Berkeley	Databricks is a software company founded by the creators of Apache Spark, an open-source distributed computing

		framework that utilizes Scala, a general-purpose programming language. Databricks develops a web-based platform for working with Apache Spark, as well as provides automated cluster management and IPython-style notebooks. The company actively organizes seminars and conferences about the use of Spark. Databricks' origin could be traced to a computer science research laboratory (AMPLab project) at UC Berkeley.
DataVisor	UC Berkeley Microsoft	DataVisor is a fraud-detection company that relies on artificial intelligence (AI) technologies to maximize their fraud detection performance. The company relies on unsupervised machine learning methods, with a focus on detecting potential frauds and crimes in the financial service sector. DataVisor collaborates with the leading banks, companies, and organizations globally to provide protection services from potential fraud attacks such as account takeovers, fake account creation, money laundering, fake transactions, etc. The company was founded in 2013, and is currently led, by Fang Yu and Yinglian Xie. Fang is the company's CTO, and was a PhD graduate from electronic engineering and computer science (EECS) program at UC Berkeley. Yinglian is the company's CEO and was a former research scientist at Microsoft. She received her PhD from Carnegie Mellon University.
GenEdit	UC Berkeley	GenEdit is a next-generation genome editing company. The company is currently focusing on non-viral delivery technologies for the CRISPR/Cas9 gene editing system that can safely correct gene mutations in patients, as well as to address concerns over virus-induced toxicity in the existing virus-based CRISPR delivery methods. The company aims to develop their gene-editing technologies into a major platform that can be used to provide therapeutic treatments against a broad range of genetically-induced diseases. It was established in 2016, and is currently led, by Hyo-Min Park and Kunwoo Lee, based on their bioengineering PhD research at UC Berkeley with professors Niren Murthy and Jennifer Doudna (a pioneer of CRISPR/Cas9 genome editing).
Gradescope	UC Berkeley	Gradescope allows teachers and lecturers elsewhere to mark online assignments in half the time needed. Their product has, at present, been used to grade over 3 million pages of work belonging to over 30,000 students at over 100 schools. Gradescope was founded in 2014, and is currently led, by Arjun Singh, Ibrahim Awwal, Pieter Abbeel, and Sergey Karayev. The company was established based on their research at University of

		California - Berkeley (UC Berkeley), with Arjun and Sergey as PhD students, Pieter as a computer science professor and their supervisor, and Ibrahim as a researcher there. Gradescope was acquired by Turnitin, one of the world's largest plagiarism detection software companies, in 2018.
Kiverdi	UC Berkeley LBNL	Kiverdi is a green-technology company that seeks to capture and transform carbon into products that can address a wide range of challenges relating to the ocean's plastic problem and sustainable agriculture. Inspired from research involving NASA technologies, Kiverdi seeks to convert carbon dioxide into people and planet-friendly bio-based products. The solutions include: 1) Reverse Plastics – transforming discarded plastics into biodegradable goods; 2) Revive Soil – increasing crop yield with CO2-based soil nutrients; 3) CO2 Aquafeed – feeding fish with CO2-based ingredients, and finally; 4) Custom Cycle – leveraging circular economy technology to create closed loop supply chains. It was founded in 2008, and is currently led, by Lisa Dyson, an African-American scientist-entrepreneur with PhD from MIT, based on her postdoctoral research at UC Berkeley and Lawrence Berkeley National Laboratory (LBNL).
Nanosys	Harvard UC Berkeley	Nanosys is one of the pioneers of quantum dot technology for display-related products. The company has been leading partnerships with multiple leading display makers (e.g. Samsung, BOE, Hitachi Chemical, LG) in creating energy-efficient world-class tablets, TVs and monitors that are brighter and more colorful than before. The company offers a quantum dot technology platform for all displays, ranging from LCDs to OLEDs and microLEDs, etc. We've partnered with some of the biggest names in tablets and televisions to bring our technology to everyday consumers including 3M, Samsung, BOE, Hitachi Chemical, and LG. Working closely with these leading companies has given us insight into the tough engineering problems they face. Nanosys also operates one of the world's largest quantum-dot manufacturing facilities. It was founded in 2001 by Larry Bock, one of the world's most influential venture capitalists, together with Charles Lieber (former professor at Harvard University), and Paul Alivisatos, when he was a professor at UC Berkeley. Alivisatos is currently the President of the University of Chicago.
Voleon	Stanford UC Berkeley	Voleon combines an academic approach to research with an emphasis on scalability and risk management to deliver cutting-edge technology at the forefront of the finance industry. Here, the company applies machine learning in

		investment management, in which flexible statistical models are applied to the problem of financial prediction. Instead of having humans look at individual events within the marketplace, machine learning employs statistical algorithms capable of detecting persistent effects across large datasets. Voleon was founded in 2007, and is currently led, by Michael Kharitonov and Jon McAuliffe. Michael is a serial entrepreneur with PhD from Stanford. Jon is currently a professor of statistics at UC Berkeley, where he also earned his PhD.

FINANCING SUPPORT FOR LOCAL TECHNOLOGY COMPANIES: EVIDENCE FROM CRUNCHBASE DATA

In this last section, we examine the financing activities by Silicon Valley-based investment funds, with a particular interest in investigating the extent to which these capital resources have been channeled towards local technology firms. Existing studies have previously shown Silicon Valley to be an 'outlier' in terms of the close co-location between technology firms and venture capital (VC) funds, as well as the high density of these VC offices, especially in municipalities such as Palo Alto, Mountain View, San Mateo, San Jose, etc.; numerous regional policymakers across the globe have aspired to replicate this 'model' into their respective localities (**Saxenian, 1994; Sorenson and Stuart, 2001; Klinger-Vidra, 2018**). Once again, historical contexts matter; the region was among the first in the United States – and indeed, the world – in which venture capital financing model was pioneered, with the founding of Fairchild Semiconductor being a major catalyst (**Adams, 2020**).

To better understand the dynamics of relationships between local investment funds and their proximate technology companies, we downloaded a comprehensive list of investors from Crunchbase. In total, we obtained a list of 14,307 investors based in the San Francisco Bay Area, approximately 7% of all organizational and individual investors listed in the database. In comparison to the other nine hubs we have covered, Silicon Valley has the highest number of VCs, private-equity firms, and angel investors combined. Over 47% of them (N = 6,798) have had no detailed information about their past and/or existing investment portfolio, whereas another 21% (N = 3,004) are single-portfolio investors only. One interesting insight we obtained was the comparatively high proportion of investors with over 50 cumulative investment activities, which we estimated to cover almost 3.5% of our dataset (N = 486). The proportion is, by and large, close to double the average rate (1.5-2.0%) we have observed in the other nine hubs. Furthermore, 13 of these investors have each accumulated a portfolio of at least 1,000 investment activities; this figure translates to a proportion of over 55% of such very-large-scale investors identified worldwide (N = 23).

Table 4-114. Information about investors in Silicon Valley (source: Crunchbase)

Size of investment activities	Number of investors
No information about investments	6,798
1 investment only	3,004
2-9 cumulative investments	2,850
10-25 cumulative investments	782
26-50 cumulative investments	381
51-99 cumulative investments	238
100-999 cumulative investments	235
1,000 or more cumulative investments	13
TOTAL	14,307

Cumulatively, slightly over 7,500 investors based in Silicon Valley account for 138,345 investment deals across 90,675 organizations worldwide. The top 1,000 investors, meanwhile, are responsible for 115,071 financing activities (over 5/6 of all recorded investments originating from the region) in a cumulative portfolio of 79,009 enterprises, or equivalent to 87% of entities collectively invested by all Silicon Valley-based inventors. In accordance with the approach we have replicated across the other nine case studies, we further restricted our attention to the 25 most-active investors based in the Bay Area. In aggregate, these 25 investors have been involved in 31,677 investment activities across 20,360 technology firms globally (equivalent to 23% of all recorded deals and 22.5% of total portfolio organizations originating from the region).

Quite interestingly, almost half (46%) of the financing activities by these top-25 investors ended up going to geographically proximate, co-located technology firms; such figure is the highest in comparison to what we have found for the other nine innovation hubs. This finding confirms the long-standing observation by **Almeida and Kogut (1999)** and **Sorenson and Stuart (2001)** about the persistence of very dense inter-organizational linkages within Silicon Valley, particularly in co-investment ties between local investors and the nearby technology companies. Such observation is not limited to notable major VC funds such as Y Combinator, 500 Startups, Sequoia Capital, Kleiner Perkins, Andreessen Horowitz, Khosla Ventures, etc.; all the remaining investors in the top-25 list are highly engaged in financially supporting technology companies emerging from the region. Box 3 below illustrates some of the world's most influential firms for which their early-stage inception was enabled by financial support by these leading VC firms.

Box 3. Notable VC funds in Silicon Valley and their major success stories

As we have explained early in the chapter, a multitude of interrelated factors contributed to the ascendance of Silicon Valley as the world's leading innovation hub (ranging from excellent universities and research centers, intensive inter-firm collaboration and competition, federal government support, spin-offs from Fairchild, technological revolution, a failure-embracing culture, among many others). Another no less important contributor is the high density of financial-support instruments, as well as the high proportion of such capital invested towards promising technology companies locally. Some of the leading investment funds (notably Sequoia Capital and Kleiner Perkins) that 'sow the seeds' for such enterprises have their origins traced back to Fairchild Semiconductor, in itself a technology company supported by financiers with a strong conviction on the promises of semiconductor brought forward by Fairchild.

These invested companies would include Apple, Google, Facebook, Zoom, Uber, Airbnb, NVIDIA (one of the world's largest and most advanced chipmakers), Reddit (one of the world's largest Internet forums), Twitch (a globally-leading game-streaming platform), Coinbase (one of the world's largest cryptocurrency exchange platforms), Impossible Foods (a major pioneer of animal-free meat), OpenAI (an artificial intelligence R&D company co-founded by Elon Musk), Udacity (an online-learning coding platform), Stripe (one of the world's most valuable fintech companies focused on payment-processing for businesses), etc.

Table 4-115. Notable, successful Silicon Valley-based companies funded by co-located VCs

Name	Major successes
Y Combinator	• Twitch • Reddit • Coinbase • GitLab • Substack • Airbnb
500 Startups	• Reddit • GitLab • Udemy • AngelList
Sequoia Capital	• NVIDIA • Apple • Reddit • WhatsApp • Facebook

	• Uber • Zoom • 23andMe • Google • Airbnb
Kleiner Perkins	• Stripe • Uber • DoorDash • Google • Airbnb • Twitter
Andreessen Horowitz	• Pinterest • Reddit • Stripe • Coinbase • Facebook
Khosla Ventures	• Stripe • GitLab • DoorDash • Instacart • OpenAI • Impossible Foods
Google Ventures (GV)	• Uber • GitLab • Medium • 23andMe • Udacity • Impossible Foods • Slack

Top 25 investment funds in Silicon Valley (source: Crunchbase)

Name	Summary	No. of investments	Investments in Silicon Valley	No. of portfolio organizations	Portfolio organizations in Silicon Valley
Y Combinator	The world's largest VC fund (in terms of number of investment deals)	4,100	2,090 (50.9%)	3,306	1,664 (50.3%)
500 Startups	The world's 2nd largest VC fund (in terms of number of investment deals)	2,675	870 (32.5%)	2,085	682 (32.7%)
New Enterprise Associates	A VC fund investing in emerging-technology and healthcare companies; one of the world's oldest and earliest VC funds	1,977	854 (43.2%)	1,060	450 (42.5%)
Accel	An early-stage and growth-stage VC fund focused on emerging-technology firms globally	1,700	719 (42.3%)	824	332 (40.3%)
Sequoia Capital	One of the world's oldest VC funds, with focus on energy, Internet, healthcare, financial, software firms, etc	1,588	872 (54.9%)	847	403 (47.6%)
Intel Capital	A corporate VC arm of Intel, one of the world's largest semiconductor and ICT firms	1,479	504 (34.1%)	993	317 (31.9%)
SV Angel	A network of angel investors based in Silicon Valley that provides	1,327	831 (62.6%)	1,060	665 (62.7%)

	investments, networking, and firm development advising services				
Kleiner Perkins	One of the world's oldest – and largest – VC funds, established by Eugene Kleiner, co-founder of Fairchild Semiconductor	1,298	761 (58.6%)	662	352 (53.2%)
Plug and Play Tech Center	An organization that serves simultaneously as a VC fund, accelerator, and platform for corporate innovation	1,260	537 (42.6%)	1,023	416 (33.0%)
Right Side Capital	An investment fund focused almost exclusively on pre-seed stage investments	1,230	194 (15.8%)	1,167	183 (15.7%)
Bessemer Venture Partners	A VC fund focused on consumer, enterprise, and healthcare start-ups	1,180	337 (28.6%)	607	175 (28.7%)
Andreessen Horowitz	A stage-agnostic fund of funds focused on investments in various technology firms	1,077	733 (68.0%)	600	392 (65.3%)
Lightspeed Venture Partners	A VC fund focused on consumer, enterprise, healthcare, and clean-tech start-ups	1,029	578 (56.2%)	560	288 (51.4%)
Index Ventures	A specialized VC fund to assist technology start-ups in global business expansion efforts	984	346 (35.2%)	536	183 (34.1%)

Khosla Ventures	A VC fund by Vinod Khosla, the founder of Sun Microsystems	952	632 (66.4%)	498	317 (63.7%)
Google Ventures (GV)	A corporate VC arm of Google, one of the world's largest search-engine companies	901	491 (54.5%)	552	290 (52.5%)
Threshold	A VC fund that provides early-stage investments in companies focused on consumers, enterprise solutions, and healthcare	869	437 (50.3%)	431	213 (49.4%)
First Round Capital	VC investment firm that provides early-stage funding support for technology companies	816	416 (51.0%)	430	217 (50.5%)
Norwest Venture Partners	An investment firm that offers VC and equity growth financing for technology firms globally	793	445 (56.1%)	392	209 (53.3%)
Greylock	A VC fund that focuses on consumer and enterprise solutions firms	771	497 (64.5%)	432	261 (60.4%)
Venrock	A VC fund that invests in technology companies, mainly in healthcare	764	334 (43.7%)	408	165 (40.4%)
GGV Capital	A VC firm pooling funds worldwide to be invested in Silicon Valley firms	761	210 (27.6%)	442	111 (25.1%)
Silicon Valley Bank	Specialized high-tech commercial bank that offers VC and private	731	193 (26.4%)	631	164 (26.0%)

	equity support for technology firms, esp in life sciences & clean-tech				
Founders Fund	VC fund that invests in deep-tech firms building revolutionary technology	714	372 (52.1%)	452	222 (49.2%)
Canaan Partners	Early-stage VC firm that supports visionary start-up founders with ambitious ideas	701	286 (40.8%)	362	140 (38.7%)
TOTAL (for top 25 funds)		31,677	14,539 (45.9%)	20,360	8,811 (43.3%)

4.4.11.2. Discussions and conclusions

Through three distinctive analyses, we have identified and learned [n] important insights from Silicon Valley. First, universities play a significant and necessary role in contributing to regional development (**Etzkowitz, 2012**), but relying on them as a major regional driver is highly insufficient. This is evident from our patent-based analysis of inter-organizational linkages; Stanford, UC Berkeley, and UCSF, respectively, have consistently generated the highest betweenness centrality scores (until Google and Apple surpassed them in the 2013-2018 period), but in comparison to other leading firms within the ecosystem, the universities did not generate a considerable number of patents. This insight is not unexpected, given that universities are organizationally distinctive from corporations, as their core missions are centered on scientific publications and teaching. Such observation notwithstanding, the fact that these universities rank very highly in betweenness centrality aspect demonstrates their outsized significance in bridging and facilitating knowledge flows and exchange across numerous organizations within Silicon Valley's innovation networks and beyond, whether through generating university graduates, career mobility of researchers, spin-off formation, researchers patenting on behalf of industry partnets, etc. (**Laforgia and Lissoni, 2009**).

Second, inter-firm linkages represent a substantial factor in driving the innovation dynamics in Silicon Valley (**Saxenian, 1994; Almeida and Kogut, 1999**). Beyond hosting excellent research universities, San Francisco Bay Area is also home to many of the world's most influential technology companies, and the linkages among these enterprises have been consistently dense and numerous. Over two dozens of technology firms have degree centrality scores above 100, an indication that these firms have built direct ties with more than 100 industry counterparts within the region, whether as collaborators or competitors (**Gnyawali and Park, 2011**). IBM, in particular, has been described as one of the major catalysts due to their postdoctoral research program that attracted PhD graduates from Stanford, UC Berkeley, and beyond, the experience by which has

continued to result in strong bonding among these researchers long after their postdoctoral 'graduation' and their switches across different workplaces (**Fleming and Frenken, 2007**). The non-enforcement of non-compete agreements, which often prevent employees from switching careers to different firms or establishing start-ups within the same industry, also largely explains the unique appeal of Silicon Valley (**Marx, 2011**). The regional culture that 'celebrates' failure – instead of condemning it as a taboo – also allows talents and founders to quickly move on from one company to another in case their business fails, thus ensuring a constant, cross-organizational knowledge circulation (**Saxenian, 1994**).

This unique regional feature subsequently brings us to the third insight: the habit of spinning off technological innovations. Whether in the form of university spin-offs (e.g. the 'birth' of Hewlett-Packard and Google from Stanford University) or corporate spin-offs (e.g. the 'children' of Fairchild Semiconductor), spin-offs have been a large part and parcel of Silicon Valley innovation ecosystem. The latter category, in particular, plays an outsized, unique role in that regard (**Adams, 2020**); Fairchid's 'open' culture of encouraging their employees to form companies to exploit their own inventions not necessarily relevant for the firm's business objective has been a major contributing factor (**Endeavor Insight, 2014**). Even more interestingly, some of the co-founders of Fairchild would often mentor these spin-off founders, a seemingly 'hereditary' trait that has been inherited by generations of firms (and VC funds) whose origins could be traced back to Fairchild.

Fourth, such mentoring support – coupled with the fact that Fairchild itself was funded by venture capital – helps explain the abundance and high density of VC funds within the Silicon Valley region. Moreover, there is a high degree of investments committed by these investors towards co-located technology companies, in large part enabled by informal networks and geographical proximity (**Sorenson and Stuart, 2001**). Indeed, some of Fairchild's co-founders and former employees would end up establishing their own technology companies, and subsequently with their success, VC funds that provide financial support for other promising firms, e.g. Sequoia Capital and Kleiner Perkins.

Fifth, and last but not least, historical serendipities matter. ICT-enabled technological revolution, e.g. semiconductor, personal computers (PCs), Internet, social media, fintech, etc., would have been impossible without the initial, historical role of federal government funding for research on these progenitor technologies (**Block, 2008; Mazzucato, 2011**), as well as their widespread use throughout numerous historical events, from World War II to Cold War (**Adams, 2020**). While other regions in the U.S. have received similarly large amounts of funding grants from the government, e.g. Boston, Silicon Valley stood out due to the combination of four factors above. The subsequent proliferation of ICT technologies on a worldwide scale – coupled with economic globalization – further catapults the region's global influence (**Dunning, 1998**). Regulations, in particular, form another impetus explaining the region's success, as notably illustrated by the impact of Bayh-Dole Act (and legal precedents set by the U.S. Supreme Court) in catalyzing the emergence of biotechnology industry clusters in Silicon Valley and other places (**Powell et al., 2012**).[267]

Nonetheless, having these five driving forces alone is insufficient to drive innovation dynamics in a region; a constant co-interaction, as well as co-adaptation, among these factors is no less vital (**Sotarauta and Srinivas, 2005**). Knowledge flows and circulation are often complex, non-linear, and responsive towards constant changes and disruptions (**Carayannis and**

Campbell, 2011); here, rather than treating every actor as an agent with a singular rationale, we need to view them as autonomous agents with capabilities to consistently adapt and evolve, whether with each other or in response to shocks. Policy intervention (e.g. federal government support, court rulings setting a new precedent, etc.) only explain a part and parcel of how Silicon Valley came to be; patterns of interaction among local actors in response to regulation, government policies, emerging technologies, and the common societal and community values (**Marquis and Battilana, 2009**) binding them together also matter. In summary, there is no 'grand design' that accounts for the success of Silicon Valley.

Numerous policymakers across the globe, in envy of Silicon Valley, have paid numerous tributes to the region, and aspired to create their own 'Valleys' through top-down government plans; thus their efforts to build science/technology parks, or S&T-driven new cities, all the while closely mimicking the model cluster (**Castells, 1994**). We advise caution against such 'copy-it-and-they-will-come' policy approaches. First, Silicon Valley's emergence was inevitably, in large part, enabled by historical serendipities (being at the right place at the right time), the events by which will be nearly impossible to replicate in different contexts and circumstances. Second, majority of localities across the world that replicated Silicon Valley model – from Russia to Malaysia to Japan to South Korea, and even many science parks within the United States – struggle to achieve their objectives as leading innovation hubs; qualitative and quantitative studies have shown either limited successes or outright failures of these ventures (**Castells, 1994; Etzkowitz, 2012; Wallsten, 2004**). Third, many of such policy actions overlook these localities' own unique advantages while replicating Silicon Valley model (**Boschma, 2015**).

These limitations notwithstanding, there are two major lessons from this region that policymakers across the globe – and particularly in Hong Kong – can learn. First, strengthening universities' research capabilities and encouraging open exchange of knowledge with local non-academic actors, particularly industries, is vital. A study by **Azagra-Caro et al. (2017)** on the dissemination of micro-electromechanical systems (MEMS) technology within Silicon Valley represented an interesting case, with the scholars demonstrating that successful development of innovation ecosystems require an equivalent use of both formal (e.g. patents, publications, licenses, spin-offs, etc) and informal (networking, open knowledge spaces, regular conversation at casual setting) knowledge transfer channels. Second, governments and universities can do better in terms of building linkages with local industries. As we have demonstrated in the Hong Kong case study, the city is increasingly building collaborative ties with non-local actors, whereas linkages with local industries have remained low and sparse. Relatedly, the city can explore potential areas of competitive advantages.

4.5 Conclusions and policy recommendations

4.5.1. Conclusions

In this task, we have examined multiple types of policies and practices supporting different missions of universities as well as a variety of contextual conditions that may lead to the expansion and success of a regional innovation system. Within a knowledge-based economy, governments began to reform their industrial policies, from encouraging industrial upgrading, promoting university-industry collaboration, to the adoption of rules encouraging the formation of technology start-ups and commercialization of scientific research. Although heterogeneous in themselves, some common elements lying behind the formation of "these best practices" include the presence of flexible financial resource allocation, availability of talents, professional and visionary leadership, close collaboration between industry and universities, as well as the quality and quantity of research institutes. An indication is that operational strategies need to be designed in adaption to the local needs, rather than just any transfer of the best practices from the leading innovation and technology hub.

The core mission of universities, as we go through various reports released from both the government and university side, is always linked with the generation and improvement of knowledge and talents through educating students, training, and basic research. Meanwhile, the policy context in our selected hubs increasingly emphasizes the importance of strengthening the role of universities to boost innovation and economic development, with a gradual shift in government policy from single focused upon teaching and research, to a mixed one targeting third mission function of public universities with wider societal roles. The exploitation and valorisation of university research has been stressed across the policy documents, and universities are no longer considered just producers or creators of knowledge but hub of entrepreneurship forming new entrepreneurial ecosystems. A cluster of leading universities with high research and knowledge transfer capabilities could be of fundamentally significance for the development of the local competitiveness, as reflected in the case studies of Tokyo, London, Beijing, Singapore, and Silicon Valley. This also echoed the insights provided by Mok (2022) on the potential opportunities to reimagine the urban development and university relationship. Basic research capabilities were also highlighted in a number of strategic plans by the local governments, stressing the need to invest in blue-sky research that may benefit the society. Robust sources of R&D funds for both basic research and applied research are provided in some east Asian cities. The research intensity of Beijing, for example, rises to 6.5% in 2021, Moreover, governments increasingly support the joint creation of knowledge in the forms of joint research laboratories and joint infrastructures, and established intermediary organizations enhancing the connections between firms and universities.

It should be noted that governments' involvement in placing different policies varied across the hubs, and in cases such as Silicon Valley and London, some policies were initially piloted by universities in advance of their adoption by governments. Indeed, the balance between laissez-faire and state-led attitudes should be carefully designed when devising the policy frameworks to strengthen university innovation and regional development. In hubs located in East Asia, for example, Beijing, Shanghai, Shenzhen, and Singapore, have issued a series of

plans to prioritize development of certain emerging industries and/or technologies and actively been involved in construction of science parks, incubators, R&D research centres, and proof-of-concept centres. Short-term and long-term development plans have been set by some governments, indicating the areas they would like to involve spanning different time periods. City or regional-level knowledge transfer offices have been established to fulfill some governments' ambitions to harness public research, aiming to create a broad service platform. Standards and rules supporting the mobility of skilled personnel between university and industry were also established by governments in Beijing and Shanghai to facilitate knowledge sharing. Authorities sometimes also serve as a facilitator of venture capital industry, as in the case of Singapore, which significantly differed from the predominantly private sector-driven VC model in Silicon Valley.

In this task, universities' pathways in engagement in knowledge/technology transfer are manifest in a wide variety of channels, depending on the institutional settings where these higher-education institutions are located (Gardner et al., 2010). Universities' linkages to their respective innovation systems – especially in KT/TT activities – are both complex as well as multifaceted. For example, in Tsinghua's technology transfer ecosystem, different organizations exist in the highly interactive system: technology transfer offices; university-owned enterprises (which are separate from research spin-offs); university science parks (operated by TusPark); national engineering research centers; joint research institutes between Tsinghua and local governments, and; university-industry joint research centers. Such institutional configuration, in turn, may shape Tsinghua's attitude on collaboration with other academic and non-academic actors, particularly in scientific research. Outcomes associated with the technology transfer could also be different across universities and industry fields. Some universities may be more likely to establish spin-offs to transfer the research results, while some may prefer patenting or licensing activities with industry. A trend is that universities increasingly create their own ventures and act as angels funding the early-stages of firm-formation. Biotechnology and information and communication technologies are often among the fields in which university engagement could be able to generate higher market value

Our survey for industry indicates that a wide variety of linkages between academia and industry serve to promote innovation, productivity improvement, and new product development. These channels include human resource exchange and training, consultancies and contract research. For many firms, the most important and recognized function of leading universities is to supply excellent human resources, in particular to support research and development efforts. Often the graduates recruited keep in touch with their alma mater and thus their firms are able to keep abreast of state-of-the-art research. Several motivations for industry to collaborate with universities include: to create innovative products, technologies, and markets and to strengthen the companies' R&D capabilities by learning new research techniques from university researchers.

Several issues were also brought up in the surveys regarding the barriers and incentives for industry to collaborate with universities. Different perceptions regarding the project timeline and expectations were considered as an important barrier to university-industry interactions. Inflexible rules and potential conflicts of interest also act as a barrier to the participation of

industry in knowledge transfer, which has also been mentioned in our survey with academia in Task 2.

While universities are necessary in contributing towards the development of innovative hubs and catalyze economic growth (Etzkowitz, 2012; Valero and Van Reenen, 2019), the cases that we have studied suggested that sometimes the local innovation system have been-by and large-driven by other organizational bodies including MNCs, SMEs, or other public or private research institutes. The Seoul case has shown the roles of chaebol groups in producing deep technologies, and also the case of Tokyo in which universities are often engaged with large, incumbent (and mostly Japanese) corporations. In Singapore, the presence (and combination) of multinational corporations (MNCs) and excellent research-oriented universities has particularly been shown to be important 'conduits' for local regions to be better connected to the global knowledge flows. In Shenzhen, the innovation ecosystem has been historically driven by enterprises, and it remains to be seen the extent to which Shenzhen's education and research infrastructure will further propel the city's innovation ecosystem in the future. Universities in Shenzhen are thus far from sufficient from being the primary actors expected to perform such roles in building a thriving innovation ecosystem (Chatterton and Goddard, 2000; Rosli and Rossi, 2016; Uyarra, 2010).

The platform/network development role of university as 'anchor tenants' potentially catalyze the growth of local communities of practice in a regional innovation system as shown by analysis of evolution of biotech hubs in the US (Powell et al., 2012). The university platform is based on the connections with students through education, dissemination of research output by scholars in related fields through academic activities, provision of manpower and exchange of technologies and scientific insights with industry actors, and the provision of advice for government agencies and other public institutions. We also identified a trend of innovation and entrepreneurial networks that are becoming more and more interdisciplinary and collaborative in the selected hubs, with universities forming more relationships with different stakeholders both domestically and internationally. Different collaboration channels were developed with MNCs, interdisciplinary collaboration in developing future technologies. The push for universities to take on greater social responsibility can also be seen in the growing number of research centres or interdisciplinary programs.

4.5.2. Policy implications

Key message 1: Government and universities should review and design strategies targeting at emerging industries/technologies that have been listed by the Chinese central government as the upcoming 'priority areas.'

Government may consider supporting sectors and technological development that are commensurate with the Chinese government's SEIs and other priority industries, especially in emerging sectors such as AI, biotechnology, life sciences, quantum computing, semiconductor, etc. This would be pivotal for Hong Kong, given that their competitive advantages in the service sector (the largest driver of Hong Kong's economy, accounting for more than 90% of

their annual GDP) have been slipping rapidly in the face of rising competition from other major mainland Chinese cities (Fuller, 2010). Hong Kong universities, already pioneering some of the most groundbreaking research in these areas, would be particularly well-positioned to grab such opportunities, and to possibly transform the resulting outputs for further economic development, as already demonstrated by the cases of DJI and SenseTime.

Key message 2: Hong Kong government needs to more proactively reach out to major foreign VC funds and other global investors to establish offices, as well as support the city's aspiring technology start-ups.

As we have shown from the case analysis of Shanghai, nearly one-quarter of Shanghai's largest investors are affiliated with foreign investment funds, and these financiers – by and large – have enabled the proliferation of unicorn start-up companies within the city. It is not that Hong Kong lacks foreign-based VC funds; indeed, from our in-depth study of the city, a significant proportion of the largest investors are actually non-local entities, but almost none of these investments end up allocated for local technology companies. Given the significant presence of such funds, and the success already demonstrated by home-grown 'champions' such as SenseTime, it would be good for the Hong Kong government to proactively liaise with existing and/or prospective investors and connect them with some of the city's emerging technology start-ups.

Key message 3: Government and universities should further promote their funding support at all stages of R&D development, as well as guidelines and support for knowledge transfer offices.

Translating university science and technology results is essentially a risk-elimination mechanism. What may capture the potential of these technologies is to identify those projects with commercialisation and socialisation prospects from among the many outstanding basic research results in the pre-transformation phase of science and technology results. This may be achieved through government and universities' effort in technology readiness evaluation, prototyping activities, and other measures to support the pilot testing of high-risk projects. Hong Kong government should develop more funds and mechanisms for early-stage funding and attract greater private investment in developing early-stage funding. Moreover, government should review and develop funding and incentive programmes to encourage collaboration between industry and universities at different stages of R&D.

Key message 4: Government and universities should promote platforms and networking events for both local, regional, and international, research facilities, infrastructures.

Governments and universities can serve as a platform of regional network to horizontally integrate key players with the existing technologies, industries, and socio-economic activities for solving regional problems and a vision for regional economic development. Both

government and universities should develop a holistic roadmap and picture for building interactions among key actors through various channels and platforms (technology transfer offices, incubators, science parks, and investment funds; collaborative research centers; the establishment of branch campus) and consider how they might build long-term partnership with mainland cities or other global hubs for achieving higher innovation and technology outputs.

Key message 5: Government should train a practitioner-oriented workforce tailored to industry. Governments and universities should also strengthen policies to attract and retain global talent and build a sustainable local talent pipeline.

As we have mentioned in Task 2, skilled professionals in technology transfer that is both good at business and science would be important to provide support for developing capacity building programs. A vibrant innovation hub requires an array of talents, including world-class researchers, highly qualified technology transfer managers, start-up entrepreneurs, and investors. It is therefore necessary for governments and universities to strive for ways to attract and position these talents, as well as provide follow-up support to facilitate the sustainable development of a local talent pool.

Key message 6: Government and universities should seek more diverse channels with industry.

We also argue that governments should look beyond the mere economic outputs generated from patenting or licensing. In other words, we encourage the government to raise more inclusive objectives and spear the entrepreneurial spirit. Government and universities need to look at other kinds of channels apart from indicators such as conferences and scientific publications. The degree of knowledge exchange between researchers at the city's leading universities and their counterparts at PROs such as Applied Science and Technology Research Institute (ASTRI), or Nano and Advanced Materials Institute (NAMI), has been characterized as limited, weak, and more competitive than collaborative (Fuller, 2010). Such competitive tendency, in particular, is oftentimes attributed to the fact that these institutions are vying to attract the same funding/grant resources provided by the Hong Kong government. The government may consider, in consultation with scientific communities in both the universities and research institutes, ways to promote closer two-way collaboration and research synergies.

5 Task 4 - Policy Analysis for Developing the Strategic Roadmaps

We have examined systematically, in the previous three tasks, the practices of universities and hubs in accelerating innovation and technology development. In this task, we will review the policies and individual types of measures that have been adopted by governments and universities in generating innovative hubs and creating strong university-industry linkages. We also present a set of policy options for promoting innovation as references for Hong Kong, providing potential pathways for universities to fully develop the necessary functions to play a significant role in innovation. At the end of this task, systematic policy recommendations are presented for enhancing the roles of universities in innovation-centric entrepreneurship.

5.1 Policy options

This section presents a set of policy options based on the key messages identified in previous three reports. We will mainly focus on five aspects: (a) government practices and university policies for facilitating knowledge transfer; (b) measures to attract and retain talent for university innovation and regional development; (c) measures to increase universities' role in societal development; (d) Entrepreneurship/entrepreneurial-oriented policies; (e) policy coordination mechanisms across disparate areas with a view to enhance the role of public research universities in the development of technology and innovation hub. The options listed here are based on the two surveys we previously conducted and several interviews with different stakeholders.

Measures to facilitate knowledge transfer

Many governments have expressed their concerns about how to promote the university knowledge transfer in order to harness the greatest potential of basic research. Some typical measures include funds supporting all stages of R&D development, research collaboration, university-industry collaboration, and establishment of intermediary organizations for linking diverse actors. In the following subsections, we will present a set of policy options frequently used by governments to facilitate university technology transfer.

- **Management of intellectual property rights**

Since the late 1970s, we have overseen an increasing proliferation of efforts to institutionalize universities' roles in catalyzing knowledge and/or technology transfer, as well as science commercialization activities (Etzkowitz, 2012). Various policy approaches have been implemented to harness the full potentials of public universities, and the transformation of research public universities into more entrepreneurial is taking place through the creation of new incentives and collaboration mechanisms for knowledge transfer.

Intellectual property rights have been widely used as a tool to provide incentives for university-

industry collaboration. The enactment of laws of the Bayh-Dole Act 1980 in the US, for instance, legitimized the technology transfer activities that some universities had already been actively engaged in and facilitated and encouraged knowledge transfer collaboration with industry in many other universities (Kenney and Goe, 2004). Prior to Bayh-Dole Act, the government retained ownership of inventions that resulted from federally funded research, which accounted for a large majority of research funding in universities. The policy was based on the principle that no single institution should enjoy exclusively the benefits derived from publicly funded research, and therefore only nonexclusive licenses to patents were granted. The Act allowed universities, small businesses, and federal laboratories to retain ownership of IP emerging from the government-funded research, thereby providing not only the incentives for the firms to participate in the commercialization of fundamental research, but catalysts for the creation of university startups (Audretsch, 2021). Bayh-Dole-type legislation have also been implemented in countries outside the United States such as China, Singapore, Japan, South Korea since the early 1990s. The passage of the law was also followed by a wave of universities establishing their own local knowledge transfer offices. Although we could not say that causal relationships exist in the proliferation of university outputs, a considerable growth in patenting and licensing activities by universities in these regions have been observed. This institutional reform also spurred the universities to establish and design their regulations or technology transfer offices supporting the translation of university technology, as shown by the number of growths in technology licensing offices. Complementary policies to grant universities to profit from IP licensing, contract agreement, and other knowledge exchange activities have been passed in some of the selected cases. For example, in Chinese hubs such as Beijing, Shenzhen, and Shanghai, universities have been given greater freedom to collaborate with industry, in the forms of industry-university research projects, centres, and contracts.

Policy intervention in the form of laws similar to Bayh-Dole Act may not always be the proper one-size-fits-all approach in maximizing the flows of university knowledge and technologies into industry (Geuna and Muscio, 2009), due to the presence of various barriers, such as tensions between promoting basic science versus applied R&D, socio-cultural gaps between academic and industry actors, as well as the variation in universities' capacities to maximize patenting outputs and licensing income. Norm & value discrepancies between academia and industry, in particular, can be a major challenge for the universities' aspiration in contributing to further regional development. While recent studies have shown that academia-industry boundaries are more blurred than previously assumed due to a significant variation in the behavior of actors across both domains (c.f. Lam, 2010; Owen-Smith and Powell, 2001; Sauermann and Stephan, 2013; Vallas and Kleinman, 2008), these do not indicate that boundaries no longer exist. Tensions may still occur, especially when industry actors unscrupulously exploit academics' research works for their own agenda (Perkmann et al., 2019).

A crucial aspect of intellectual property creation is the provision of financial benefits for academic researchers. As we have identified in the university survey, policy on the sharing of royalty income and engage in knowledge transfer related work could be not that satisfied among the respondents. Additionally, there are also big concern towards invention disclosure

because faculty members think their efforts are not rewarded and other people may steal their ideas. To build the trust of potential licensees, an example would be CoMotion that has standardized the terms of the licensing agreements. They avoid anyone feeling discriminated against because he/she is not a good negotiator, by building a process where the terms that are used in licenses are formulated in a very structured way. For example, in the case of royalty rates, CoMotion uses a database with a VC firm which works with all the major universities here in and outside the US, providing statistics for royalty rates per industry and per level of development of technology. CoMotion takes the median number in that database as the royalty rates in negotiations with firms. In this way, they are seen as fair and not greedy and not optimizing every single deal.

Universities in the selected mainland cities have offered relatively high royalty rates to empower faculty in participation in technology transfer. The commercialization efforts of researchers could be rewarded with generous royalties and equity terms, as encouraged by governments at both national and local level. In 2015, the central government has issued the Law of the People's Republic of China on Promoting the Transformation of Scientific and Technological, which regulated that "those who have made major contributions in research and development and transformation of scientific and technological achievements shall receive no less than 50% of the total reward." In the case of Tsinghua, the royalty distribution for patents and license is: 70% to research team; 15% to University; 15% to college/department. Specific to the royalty distribution rule related to some research directions, like Automotive and Electronics, 5-10% goes to technology transfer intermediaries with the goal to motivate technology transfer office. While this type of reward measure could incentivize researchers to engage in more knowledge transfer activities, what the researchers really care, as indicated by one of our interviewees,

> "They may care more about their promotion or career paths, rather than cash or royalty rewards. Setting such high rewards may also distract the researchers from their basic duties, as the main tasks of universities should be teaching, education, and research." (Anonymous, an interview with a TTO expert, 2022)

Debackere and Veugelers (2005) remark that studies show that universities with higher inventor royalty shares, have higher licensing incomes. Thus, reconsideration may be needed regarding the policy on royalty shares with those of the selected top global entrepreneurial universities, while also taking into account the individual characteristics of universities. Just to provide an initial example of comparison, though with respect to a private university, Stanford University's royalty income sharing is as follows – first, 15% of the gross royalty income is deducted for administrative expenses; second, other direct expenses (typically patent costs) are deducted; finally, net royalties are divided one-third to the inventor(s), one-third to the department, and one-third to the school.

- **Gap-funding instrument**

Proof of Concept scheme

Universities play an important role in advancing the frontier of science. One of the easily encountered problems in the knowledge transfer process is that most university-generated knowledge is likely to remain in a laboratory setting due to insufficient platforms, technologies, talents, and investments for pilot maturation. A "valley of death" is often seen at the earliest stages of technology development and there is a lack of private funding sources, oftentimes requiring more adequate support to securely translate the basic research into the market space. As one of our interviewees stated,

> "Governments may provide large amount of funding for basic research or innovation subsidies to the innovative startups and firms. Meanwhile, private sector tends to focus on projects with a clear business model and profit model. The validation and initial valorization of the early-stage knowledge generated from the universities and laboratories, oftentimes, are wasted due to the high risk accompanied with their projects." (anonymous, an interview with a TTO expert in Shanghai, 2022)

Governments and universities seek to address these gaps using different support mechanisms, including university incubators and university-managed seed funds. Investments in early-stage technology have increased and to de-risk the embryonic technologies and attract more capitals, instruments such as "proof of concept" have frequently been endorsed in public policies in recent years, for example, the Ideation (Tnufa) Incentive Program in Israel, Fintech Proof of Concept (POC) scheme in Singapore, and Blockchain Technology Verification Support program in Korea. Hong Kong also has a Fintech Proof-of-Concept Subsidy Scheme for the pre-commercialization of leading-edge financial technologies. Mainland cities such as Beijing, Shanghai, and Shenzhen start to provide a variety of support for the establishment of proof of concepts centers by universities, enterprises, or medical institutions. The main objectives of these POC programs include: the evaluation of industrial applicability and commercial potential of early university ideas, entrepreneurial support for researchers who want to translate their research. More recently, governments in mainland cities have called for the creation of POC center to enhance the innovation capacity of SMEs. For example, in Beijing, SMEs are given priority to adopt the first-use, then-pay method to undertake scientific and technological achievements licensed by universities and scientific research institutions.

- **Measures supporting collaborative research**

Universities have partnered with industry, government, and world-leading institutions to develop collaborative research centers supporting their strategic interests and missions. An array of Centers of Excellence or joint research laboratories have been established to engage in applied research for interdisciplinary research which is needed to solve societal problems. Some of the world's leading corporations have also established either joint research centers or

joint postgraduate programs – as demonstrated by the case of Siemens – with their counterparts in Tsinghua.

Common approaches used by government to facilitate the university-industry collaboration include: 1) R&D grants (e.g., matching grant) on condition that recipients from a consortium of industry and universities; 2) providing tax incentives to companies that contract R&D expenditure at research organizations. An example of the first type of funding is the knowledge transfer partnership (KTP) in UK. KTP supports businesses and companies to achieve technological innovation or change to a more entrepreneurial style of management. This programme is especially beneficial for SMEs as they have high priority when applying for management KTPs and they are granted with higher portion of funding (up to 67%) regarding eligible costs compared with large companies (up to 50%) (gov.uk, 2022). Universities could also provide cash-matching commitment. For example, with a matching fund of US$ 4 million from the National Institutes of Health, UW established the Washington Entrepreneurial Research Evaluation and Commercialization Hub (WE-REACH), to support scientists involved in research projects in the life sciences to commercialize their innovations.

Box 5-1. Case study: University of Washington's long-standing partnership with local industries: the cases of Microsoft and Boeing

As we have highlighted in the beginning of this section, Seattle's innovation ecosystem has been – by and large – driven by four 'core' organizational actors: UW, Microsoft, Boeing, and Amazon. While we have yet to identify instances of formal collaboration at the organizational level between UW and Amazon through our desktop research, we have identified a noticeable number of formal research efforts involving UW scientists and their counterparts in Microsoft and Boeing.

With specific regard to Microsoft, their collaboration with researchers has spanned various disciplinary fields and technology applications, some illustrations by which were displayed in the bullet points below:

- In 2016, both organizations announced that their researchers have successfully set a new record in DNA data storage, in which they encoded – and subsequently decoded – a music video, a UN declaration translated into 100 languages, 100 most-read books from Gutenberg Project, and a crop seed database – into strands of DNA molecules.[268] Their invention paved the future potential application of DNA as not only carriers of genetic information, but also media for storing large-scale data. The research was carried out in UW's Molecular Information Systems Lab (by computer science professors Georg Seelig and Luis Ceze), in collaboration with Microsoft researcher Karin Strauss, and their counterparts in Twist Bioscience, a biotechnology company specialized in manufacturing synthetic DNA
- In 2020, UW launched the latest Center for Research and Education on Accessible Technology and Experiences (CREATE), with an initial US$2.5 million funding support by Microsoft. The center is focused on promoting technological innovation in terms of automated, personalized mobility, accessibility, and wearable technologies for communities living with disabilities.[269] The center includes faculty members with interdisciplinary backgrounds, namely School of Computer Science

and Engineering, The Information School, School of Medicine, Department of Mechanical Engineering, Human-Centered Design and Engineering, as well as Disability Studies Program.

- More recently, in early 2021, Microsoft awarded a grant worth US$5 million to researchers at UW's Institute for Protein Design.[270] This grant will be utilized to further their studies that seek to utilize artificial intelligence (AI) approaches to accelerate the identification and design of proteins that will be subsequently useful for the development of drugs and therapeutics in anticipation of future pandemics and other emerging diseases. One current related research work that the institute is conducting relates to the application of artificial proteins for creating more potent vaccine candidates against new variants of coronaviruses.

In the case of Boeing, the company has established – and jointly operated – a research center within the UW campus since 2014.[271] Known as Boeing Advanced Research Center (BARC), the center is primarily responsible for industrial application-oriented research projects on topics linked to aircraft manufacturing and assembly. Nevertheless, in recent years, BARC has also been implementing research projects related to machine learning, 3D printing, as well as robotics, all of which are aimed to make aircraft production more efficient and safer. Members of the research center include students and faculty members from the departments of aerospace, material science and engineering, mechanical engineering, industrial and systems engineering, as well as environmental and occupational health sciences. Through BARC, UW researchers and students have the opportunities to conduct research side-by-side with their counterparts from Boeing.

Beyond research, BARC also runs education-related programs, through seminars, continuing education programs, as well as Boeing Technical Fellowship program.[272] Seminars organized by BARC entail two-way knowledge exchange, with UW researchers presenting their latest research at Boeing facilities, and Boeing researchers and engineers sharing their works in the UW campus. Furthermore, BARC offers certification- and degree-bearing programs for Boeing's current employees by taking courses at UW, in fields ranging from aircraft composite materials, structural design and analysis, to project management. Most importantly, Boeing also offers their Technical Fellowship program, in which PhD graduates (from any university) compete to obtain postdoctoral research positions in the company.

Governments can also promote university-industry collaboration through performance-based funding. A typical example of it is the introduction of Knowledge Exchange Framework (KEF) and Research Excellence Framework (REF) in UK. The former takes a more holistic view of benchmarking how universities will be delivering their third mission goal and consider contract and collaborative research as important as other channels such as intellectual property and spin-offs. These frameworks, with an inclusion of a third mission engagement, could orient the universities to adopt a more strategic approach to planning for their third mission activities.

Collaborative research activities between SMEs and universities would benefit the growth of local businesses. Though, compared to large companies, SMEs may have limited channels knowing about the research and innovation opportunities, relatively weak networks and connections, and inadequate financial pools for them to collaborate with universities. SMEs appear to be far away from the intense collaboration with universities if no government support

would be provided. Government agencies provide innovation vouchers to SMEs to purchase services from universities, which are usually fast and light, easy to administer, and responsive. This is also a fast-track solution to tackle some industry-wide challenges at local level. Although as one interviewee mentioned,

> "People in SMEs may find it difficult to fill the file for the application, and sometimes the paperwork might be too difficult and lengthy for them as they may not have relevant skills and knowledge to prepare the paperwork "

Governments have also provided other support for SMEs to participate in university innovation project. For example, in Singapore, the government established Centres of Innovation (COIs) to assist in SMEs in upgrading their skills. Resources are provided including laboratory facilities, consulting, and testing services in specific industries.

- **Venture capital (VC) funding pools/ diversification and asset allocation**

While there is a growing trend among universities to foster economic development and innovation within their local community, the traditional research and teaching are not only not diminished, but universities seek more funding to support efforts to upgrade the quality of these conventional functions (Youtie and Shapira, 2008). Universities are actively seeking interaction with the private sector and a trend is that universities increasingly create their own ventures and act as angels funding the early-stages of firm-formation. Universities with high innovation and technological performance, for example, the University of Washington, have developed a very innovative and very developed ecosystem involving venture capitalists, entrepreneurs looking for projects, as well as various public and private organizations - which has contributed to establishing its solid record of technology transfer. As what we have mapped out in Task 2, some of the key external organization supporting the research and technology transfer of this university include a state-funded Technology Center, a private not-for-profit foundation that has built venture Center where office space or business facilities are made available for early-stage startups. As for the presence of VCs in Seattle, below is a comment made by our interviewee, which indicates that access to VCs is no bottleneck.

> "Just to give you like a very tiny example, if you think about, Global Health, Seattle has several significant organizations in this field, for example, the Gates Foundation. And so it would be more difficult, I would guess, to push forward projects in global health in other locations. Here, you know, we just need to pick up the phone and we talked to the Gates Foundation… We know them they know us." (Anonymous. 2021. Interview with a knowledge transfer official. August 27.)

The more research-intensive universities have set up wholly (or partly) owned subsidiary technology transfer businesses and investment funds which can include university funding in conjunction with funds from business angels and Venture Capital firms. Those that had not been able to set up these funds, either with their own resources or in partnership with local investors, frequently suggested that Universities could be supported by government to help set

up their own funds, which could stimulate potential co-investment subject to agreed criteria on how the funds could be allocated.

A typical example would be Japanese government's ambitious moves to rejuvenate the country's innovation ecosystem. Much of this corresponds to a recurrent issue within Japan's economy, by which an overwhelmingly large size of their venture capital (VC) funding pools contrast sharply with diminishing tendencies to invest and support in domestic technology start-ups (Hemmert et al., 2019). It is not that the government's efforts were left wanting in the past; various scholars have demonstrated Japan's past efforts to nurture academic entrepreneurship, such as incentives to increase R&D investment to JPY24 trillion (US$210 billion approximately) in their 2001-2005 Science and Technology Plan (Harada and Mitsuhashi, 2011). Nevertheless, the country's entrepreneurial dynamics – while not stagnant – have certainly been more lackluster in comparison to those of other countries, e.g. UK or US (Suzuki et al., 2002; Whittaker et al., 2009). This was attested by the persistently small number of unicorn start-up companies, which we have demonstrated in the previous paragraph.

One of the Japanese government's latest plans is to introduce a JPY10 trillion (equivalent to US$88 billion) innovation fund, which will invest in basic research and start-ups seeking to exploit the potential of next-generation emerging technologies resulting from these basic science activities (Takeo and Ito, 2022). A major feature that differentiates this fund with the government's prior efforts is that the innovation fund will be directly led by seasoned venture capitalists with decades of experience in managing investment funds, particularly in high-risk investments. The fund aims to generate annual returns of close to 4.4% in order to support their ambition of funding frontier research – and in turn start-ups seeking to commercialize their results – worth at least JPY300 billion (US$2.7 billion) every year (Takeo and Ito, 2022). This innovation fund will be formally launched in March 2022.

Almost simultaneously, Japan's most prestigious universities have also commenced efforts to embed themselves more closely in the country's VC investment ecosystem. The most notable example is illustrated by the University of Tokyo (Todai), for which their VC investment arm, University of Tokyo Edge Capital (UTEC), is the pioneer – and the largest – of such funds in the country. UTEC was co-founded, and is currently led, by Tomotaka Goji, himself a data-science PhD graduate of Todai, an MBA alumnus of Stanford, and a former government official who co-sponsored Japan's first legislation on reforming the country's VC industry. As of December 2021, based on the data we collected from Crunchbase, UTEC – since its establishment in 2004 – has been involved in 135 financing deals in Todai-based technology start-ups (with the number rising to 140 as of February 2022), with 17 of these companies subsequently listed in stock exchanges and another 13 either acquired by or merged with other incumbent corporations (University of Tokyo Edge Capital, 2022). Some notable spin-offs originating from the university include UTEC-supported companies, such as Advanced Softmaterials (ASM), Autonomous Control Systems Laboratory (ACSL), and Exergy Power Systems. More recently, as of September 2021, the university's leadership has launched another fund worth JPY60 billion (approximately US$540 million) to further support another 300 Todai-based start-up companies (Hata and Suzuki, 2021).

Beyond Todai, other universities have also followed suit in establishing university-run VC

funds. Our additional desktop research, and investigation on Crunchbase, identifies at least 6 other universities that have established and are operating their own VC funds. While majority of these funds are initiated by Tokyo-based universities, a minority of them originate from universities outside the capital, e.g. Osaka, Kyoto, and Tohoku (Sendai).

The best illustration is demonstrated by the case of University of Tokyo Edge Capital (UTEC), which has provided venture capital support (not only seed and/or angel investments) for over 100+ Todai-based spin-offs since its establishment. Beyond Todai, a growing number of universities – mostly within Tokyo metropolitan region, but increasingly across the country – are establishing their dedicated VC funds, replicating UTEC's organizational structure and approaches. The creation of such funds parallels with the Japanese government's simultaneous efforts in setting up special 'innovation funds' specially tailored towards high-technology firms commercializing the latest scientific breakthroughs. In the case of Hong Kong, thus far we could only identify one such instance (HKUST Entrepreneurship Fund / "E-Fund"), but we believe more such university VC funds will emerge in the future.

While spinoff-based commercialization strategies ought to be supported, we advise caution in terms of prudently managing such ventures, and in particular its potential repercussions when such strategies are not properly regulated (Fini et al., 2018). Once again, the case of Tsinghua Tongfang demonstrates the limits of such practice. With specific regard to Hong Kong universities – and in which we have covered extensively in the Task 1 report, the Tsinghua Tongfang controversy also reminds us of the preceding polemic surrounding PolyU's spin-offs before 2010, and the subsequent reform efforts that the university leadership has embarked on to better enhance their spin-off management processes.

Box 5-2. Governments' role in stimulating VC industry: the curious case of Shenzhen Capital Group

Established in 1999 by the Shenzhen municipal government, Shenzhen Capital Group (better abbreviated as 'SCG') is one of the earliest, and also among the biggest, VC funds in China; the government set up such fund as a participatory 'experiment' in the country's then-nascent VC industry. This was demonstrated from the creation of Red Earth Innovation Fund Management, the first private equity-controlled public management fund in China. Furthermore, according to the company's website (**Shenzhen Capital Group, 2022**), SCG has expanded into a major business group with VC activities as its core, with a registered capital of RMB10 billion (equivalent to US$1.6 billion), and total assets under management of approximately RMB426.6 billion (close to nearly US$66 billion). At present, SCG manages a total of 150 private equity funds, 13 fund-of-funds, and 19 special funds (including real estate funds, fixed growth funds, etc).

Furthermore, as of early 2022, SCG has been consistently placed as one of China's most active investors; their website, corroborated by external reports, showed that a total of 1,420

investment deals involving SCG (across over 1,200 companies) have been recorded, with a cumulative financing amount worth 81.9 billion yuan (equivalent to US$12.6 billion); among these deals, 209 invested enterprises have ended up with public listing in 17 stock exchanges and other capital markets across the world, and 403 other firms in the process of exiting, either through merger and acquisition (M&A) or IPO (**Greater Bay Finance, 2022; Shenzhen Capital Group, 2022**). These figures also happen to be considerably larger than those reported in the Crunchbase data. Moreover, as of March 2021, SCG ranked second domestically after Sequoia Capital, followed by IDG Capital, as one of mainland China's most active technology investors (**Jiemian News, 2022**).

Within Shenzhen specifically, SCG has also played a strategic role in expanding the city's investment ecosystem and innovation networks. Many of the city's major investors and founders of local VC funds had their career histories in SCG (**Canzhaoxi, 2022**). Some of SCG's major successes within the city include technology giants such as Tencent Music, Mindray, Contemporary Amperex Technology (CATL), Chipscreen Biosciences, Royole, etc (**Shenzhen Capital Group, 2022**). Nevertheless, the state-owned VC fund is not free of its existing limitations too. Until recent years, a large proportion of their investments have been primarily allocated towards lifestyle-related technology sectors, most notably e-commerce, social media, and Internet-related industries. In addition, of more than 200 SCG-invested firms that have subsequently been publicly listed, only 49 (slightly below 25%) of them happen to be Shenzhen-based enterprises. The company also has yet to succeed with their internationalization efforts, in which their dual-currency and US dollar-denominated investment funds were not commensurate with Shenzhen's status as China's third largest VC/PE investment market (**Canzhaoxi, 2022**).

In the last 4-5 years, however, SCG has increasingly directed their investment efforts to support companies specialized in the development of technologies currently prioritized by the Chinese government, especially the strategic emerging industries (SEI) program. Moreover, the VC fund is devoting large-scale financial capital into 'government-guided fund-of-funds', an amalgamation of state-supported funds (often in partnership with private-sector enterprises) to support companies focused on the government's priority sectors of interest. Most importantly, SCG has been considerably expanding their research team, which consists of postdoctoral fellows, experienced analysts, industry experts, as well as academic scholars. As of 2021, more than 40 full-time researchers were being employed by the company in conducting in-depth industry research. It remains to be seen the extent to which their transformation efforts will generate payoffs in the long run.

Funding of infrastructures and intermediaries related to knowledge transfer

Various measures are used by governments to support the university boundary-spanning organizations between academic environment of the university and the commercial

environment of the market. These organizations include science parks, technology transfer offices, incubators, investment funds, and branch campus.

Science parks

Many governments have taken an interest in building up science and technology parks that locate on or near the universities to manage the knowledge and technology flow among universities, industry, and public research organisations. Well-trained graduates in the universities could serve as a valuable workforce for the technology companies to the region, as seen in the case of Silicon Valley and Beijing. In hubs such as Beijing, Shanghai, Seoul, and Singapore, high-technology zones have been formed around the niche sectors of the economy, oftentimes taking advantages of the proximity to the universities and the research strengths of the universities. Some known examples include Zhongguancun Science park around Tsinghua university and Peking University in Beijing, Zhangjiang Science City (formerly Zhangjiang hi-tech Park) in Shanghai, and Singapore Science Park around National University of Singapore (see Box below for detailed illustration). These university science parks usually bring together national laboratories engaged in sector-specific R&D activities, centres of excellence of universities, global firms with established R&D units.

In the case of Zhongguancun, a variety of preferential policies introduced by the local or national governments include the rights to dispose of, as well as profit from, government-designated 'scientific and technological achievements' (e.g., patents, high-impact publications, etc), equity incentives, favorable tax incentives, management of scientific research funds, identification and support of high-technology enterprises, etc. Zhongguancun's success as a driving 'core' of Beijing innovation hub could also be attributed, to a certain degree, by government policies. Moreover, it is worth noting that the cluster is the first 'independent innovation demonstration zone' in China; such zones refer to areas where the Chinese central government introduced and implemented a variety of preferential policies, and given the successes achieved in Zhongguancun, were subsequently replicated in similar zones established in various Chinese cities, e.g. Zhangjiang (Shanghai), Hangzhou, Wuhan, etc.

Box 5-3. Build it and they will come? A*STAR and the case of Singapore Science Park

In the previous paragraphs, we have repeatedly mentioned about the outsized importance of A*STAR as one of Singapore's most active patenting actors. The agency's success has inspired policymakers globally to replicate their approaches within their domestic settings. Nevertheless, there have also been case studies about innovation agencies that started from peripheral position (overlooked by most other government agencies, with initially limited resources, and little public exposure), but would nevertheless transform their territories into some of the world's most promising innovation hubs, e.g. Office of the Chief Scientist (OCS) in Israel. The central dilemma becomes: should innovation agencies 'go big', or 'start small'? The answer is: it depends, as every option has its own advantages and limitations, and is contextually contingent on the circumstances surrounding the country of interest. This dilemma was vividly illustrated by **Breznitz et al. (2018)** and **Breznitz (2021)** as they created a typology of various innovation agencies across the globe.

A*STAR's case represents a particular type of its own, with **Breznitz et al. (2018)** describing them as a 'directed-upgrader' innovation agency. Unlike its Israeli counterpart in OCS, A*STAR does not focus on promoting radical innovation, but rather on existing technologies that are of strategic value for Singaporean government and industries. Moreover, the agency had a contrasting 'beginning' in comparison to OCS, with A*STAR established in 2001 with considerable fanfare and supporting resources; in this regard, it was designated as a core agency of the Singaporean government. As readers may recall, we have discussed in the previous pages about A*STAR's steering role in implementing the development of strategic technologies and industries based on the city-state's five-year science and technology (S&T) plans, e.g. microelectronics, new materials, renewable energy, water, environment, ICT, etc. Nevertheless, the agency's central position – and constant public monitoring – also 'ensured' that A*STAR be relatively conservative in terms of researching new-to-the-world technologies, given the high risks of failure with such ventures, and public scrutiny that may follow (**Breznitz et al., 2018**). Moreover, the agency is more frequently involved in research and industrial collaboration with foreign multinational enterprises than with local Singaporean companies (**Breznitz, 2021**). A*STAR's popularity, in turn, manifests itself into its own limitations, which in turn leads to another disadvantage: the agency's lack of ability in generating successful indigenous-led industries (**Breznitz, 2021**).

Given A*STAR's location in Singapore Science Park, we shall also briefly highlight about the locality surrounding this agency, which amalgamates 12 research institutes and support centers across the city-state, mostly within the science park.[273] Also known as SSP, the science park was established by the government as a series of upgrades to the existing local infrastructure to entice foreign MNCs to expand their business operations in Singapore (**Koh et al., 2005**). Over time, however, SSP was increasingly 're-modeled' to both incorporate and emulate the existing innovation cluster models in Silicon Valley (US), Cambridge (UK), as well as Hsinchu (Taiwan) (**Cho and Valler, 2017; Koh et al., 2005**). Nevertheless, based on the authors' fieldwork, they found that the inception of science park has yet to incentivize further inter-firm linkages, especially the broader, Triple Helix-driven inter-organizational relationships (**Cho and Valler, 2017**).[274] Foreign firms, in particular, were fairly restrictive in terms of safeguarding their proprietary knowledge, which limited knowledge spillover and dissemination within the cluster (**Koh et al., 2005**). This was further reinforced by the tendency for A*STAR to prioritize collaboration with incumbent foreign multinationals, particularly in pharmaceutical and life science industries (**Breznitz et al., 2018; Breznitz, 2021**).

The Singaporean government was keenly aware about these ongoing limitations, and in recent years, especially since 2015, has embarked on efforts to transform the surrounding SSP into a cluster more open for innovation and start-up entrepreneurship. As an example, the government dedicated S$200 million for the development of new buildings and facilities, as well as cultural amenities and green spaces, supporting the science park (**Cho and Valler, 2017**). From additional fieldwork and interviews with start-up entrepreneurs and researchers, however, the responses were largely mixed.[275] Entrepreneurs, in general, were more appreciative of the more 'open' landscape resulting from such refurbishment, whereas researchers – especially those working in A*STAR and universities – remain more concerned with the persistent lack of incentives for inter-organizational collaboration, especially due to the existing evaluation mechanism and key performance indicators (KPI) that continue to prioritize absolute numbers of publication outputs over research

collaboration.[276] Moreover, the authors noted that among majority of Singaporeans, in particular, there remains a persistent cultural attitude on 'fear of failure', a limitation that policy intervention alone cannot – in and of itself – fully address.

Incubators

Incubators provide support for early-stage companies to grow and survive and can be either freestanding or linked to universities or research institutes. Governments provided funding, space, and networking resources for the construction of business technology incubator as a vehicle for linking startups. For example, in Israel, one of the representative government programs is the Technology Incubator Program (TIP) initiated by the office of the Chief Scientist in the 1991. The initial objective of the incubator program was to leverage the strengths of immigrants from former USSR, many of whom are scientists, engineers, technicians, and physicians.

Universities could enhance their role through an effective and well-integrated incubation system to support a win-win interrelation between universities and industry. University incubators usually provide workspace, equipment, prototyping facilities, mentoring, and a small amount of financial support. They may be more appropriate as a supporting tool for leadership and reinforcing entrepreneurial culture.

Some universities have created space for entrepreneurs in their in-house incubators. Indeed, universities are expected to provide a way that entrepreneurs could work on campus in partnership with researchers, as one of our interviewees shared his experiences in Israel with us,

> "When we are in Israeli universities, it is always interesting to see that there is not that clear physical boundary between researchers, students, or entrepreneurs. Entrepreneurs could easily access the university space and they even could have their own tables and space in the university." (Anonymous, an interview with a founder, 2022)

Recently, virtual incubator services have been practiced as one of the incubator models. Digital technology has created an opportunity for entrepreneurs to create a virtual incubator service model that connects them to ecosystem.

Technology transfer offices

Universities often seek to further their knowledge transfer capabilities through the creation of Technology Transfer Office (TTOs) and the organization and business model of technology transfer offices varies. Many universities have an internal technology transfer office, usually an integrated and dependent office that could be divided into several sub-offices responsible for duties including intellectual property management, corporate relations, technology

licensing office, or liaison offices. Some universities have set up international technology transfer office to process international affairs. As part of their efforts to translate their research, some universities partner with other research institutes or local governments to establish regional technology transfer centers. Such examples could be found in mainland cities such as Guangzhou, Shanghai, or Shenzhen. In China, universities are given rights to set up national demonstration centers, with policies and priorities given to these organizations.

Imperial Innovations achieved a breakthrough that no other university TTOs had done: public listing at a stock exchange. At one point raising capital worth £300 million, Imperial Innovations had – nevertheless – ended up delisted from the stock exchange due to uncertain financial returns from commercializing novel technologies originating from university research, as well as to provide more personalized services for university researchers. Eventually, ICL administrators had to reduce, and eventually remove, the remaining shares at Imperial Innovations in order to improve their financial situation. By 2018, the university decided to wholly revamp their technology transfer organizational structure by forming a new TTO under the new name of Imperial Enterprise, and this time in the form of a university administrative unit, rather than an independent company.

TTO staffing is one of the organizational factors that can crucially contribute to the university's performance in TT (Siegel et al., 2003). To be effective at managing knowledge transfer staffs, highly skilled professionals are required. Universities need to pay attention to the recruitment process and the continuous specialized training of staff, so as to maintain their high capacity to promote entrepreneurship in the university. An example would be Ramot in Tel Aviv University, compared to other technology transfer offices we are studying, its distinctiveness in knowledge transfer results relates to the dominance of TTO professionals that are seasoned serial entrepreneurs, venture capitalists (VCs), as well as those with decades of industry experience in multiple high-technology companies.

Macho-Stadler et al. (2007) point out that setting up a TTO alone does not necessarily secure a positive net income from IP, but rather other TTO-related matters such as the size of the TTO also need to be taken into account. For example, Nosella and Grimaldi (2009) argue that larger the TTO staff, the more spin-offs are generated. Comacchio et al. (2012) also suggest that the TTO size positively influences the university's boundary-spanning capacity.

Perhaps on a more basic level, the presence of a KT representative in each college or school and proactively approaching faculty and researchers may have been a way for the TTO to address the lack of awareness on the part of the university community of the existence of TTO. For example, Huyghe et al. (2016) found that less experienced researchers or entrepreneurs or those from specific academic departments tend to be unaware of the existence of the TTO within their own universities. They argue that this was the reason why many researchers bypass the TTOs and take their inventions directly to the market. It can also be argued that while researchers are aware of TTO's existence, they have little information or direct experience of the extent to which TTO can assist them in their KT activities. In addition, according to Macho-Stadler et al. (2007), TTO also has the role of pooling innovation across research units within the university.

- **Assessment for KT**

Concerning the indicators utilized in the assessment of universities' KT/TT performance, there has been considerable scrutiny by various scholars. One common theme discussed in this regard relates to the tendency for university administrators, policymakers, and academic scholars in management research, innovation studies, and/or economics to pay overwhelming attention on income-generating indicators (c.f. Hughes and Kitson, 2012; Lambert Report, 2003; Middlehurst, 2004; Rossi and Rosli, 2016). The current isomorphic pressure for more and more universities to be involved in a narrow set of straightforwardly benchmarkable indicators (primarily on patenting, licensing, and spin-off formation alone) has – more often than not – caused universities to overlook the broader picture of the 'third mission' and innovation ecosystem-building imperative itself (Rosli and Rossi, 2016). Furthermore, given the substantial variation in the organizational capabilities of universities themselves (as well as the degree of resource endowments bestowed to these KTO/TTOs), it would be unrealistic to expect all of these institutions to generate substantial financial returns through these oftentimes narrowly-defined KT/TT categories (Lambert Report, 2003). Indeed, even at renown, world-class research universities with longstanding KT/TT experience, categories such as patenting and licensing have been shown not to be as perceived vital as innovation scholars tend to assume, as demonstrated by Agrawal and Henderson (2002) in their survey of MIT academics and D'Este and Patel (2007) in their analysis of faculty members at major research universities in the UK.

In Hong Kong, the recurrent granting to universities, as documented in UGC's Notes on Procedures, involves issuing policy letters, submitting and discussing academic development proposals, assessing recurrent grants by UGC and recommending them to the Legislative Council[277]. As part of the discussion and evaluation of Planning Exercise Proposals (PEPs) submitted by universities, the UAA sets up performance indicators to measure the performance of the university in five domains, including knowledge transfer. Sector-wide performance indicators include (1) total income from knowledge transfer via provision of research and business services; (2) income generating from IP; (3) expenditure on public engagement activities; and (4) student engagement in start-ups and entrepreneurship.

Meanwhile, UGC allows universities to establish their own institution-specific KPIs across five domains according to their circumstances. A summary of knowledge transfer KPIs for individual universities and their performance is presented in Table 5-1, and further discussion will be provided in later sections. According to UGC, the establishment and disclosure of UAA documents may provide public information. As a result, it enhances the reputation and public profile of universities for their efforts in quality enhancement and efficient governance. There is, however, limited information regarding the situation when universities fail to meet their goals. Thus, the current UGC documents, including UAAs, do not establish a direct link between universities'performance (including knowledge transfer) and their recurrent funding. As a result, it is unclear how effective UAA and its KPIs are in motivating universities to

improve, particularly in knowledge transfer.

Table 5-1 Key Performance Indicators (KPI) on knowledge transfer under UAA

	CityU	CUHK	PolyU	HKUST	HKU
2019-22 Triennium	• Activity level per staff in KT activities • Number of companies, NGOs and government organization with which CityU staff partner • Number of issued US patents • Invention commercialization rate	• Participation in KT activities by academic staff members • Patent applications filed and licenses granted • Students' participation in entreneurship and innovation activities • Contract research/consultancies undertaken and the income so generated	• KT impact cases with economic and/or social impact • Cumulative number of start-up ventures created by students, graduates or staff with support from the University's seed funding and entrepreneureship programs in the last three years • Survival rate of start-up ventures • Number of partnerships for KT and entrepreneurship activities	• KT and commercialization by number of patents filed, granted and used • Entrepreneurship – number of start-up and spin-off companies funded or incubated by HKUST programs on entrepreneurship and number of entries in HKUST-supported competitions • Other societal contribution: number, participant size and diversity of community engagement projects, social service events, art related functions	• Research collaborations, and public-public and public-private, partnership projects • Patents filed and grants, know-hows and licenses • Innovation and entrepreneurial activities • (External) advisory and editorial membership
2022-	• Activity	• Participation	• Rolling 3-	• KT and	• Research

	CityU	CUHK	PolyU	HKUST	HKU
25 Triennium	level per staff in KT activities • Number of companies, NGOs and government organization with which CityU staff partner • Number of issued US patents • Invention commercialization rate	in KT activities by academic staff members • Invention disclosure, patent applications filed and licenses granted • Contract research/consultancies undertaken and the income so generated • PPP undertaken	year average number of patents licensed • The ratio of the amount of follow-on external investment and funding support secured by PolyU-supported start-up companies to the funding support provided by the University • Number of jobs maintained and created through PolyU supported start-up companies in the financial year concerned • Number of strategic partnerships for KT, entrepreneureship, social innovations and wider engagemen	commercialization by number of patents filed, granted and used • Entrepreneurship – number of start-up and spin-off companies funded or incubated by HKUST programs on entrepreneurship and number of entries in HKUST-supported competitions • Other societal contribution: number, participant size and diversity of community engagement projects, social service events, art related functions	collaborations, and public-public and public-private, partnership projects • Patents filed and grants, know-hows and licenses • Innovation and entrepreneurial activities • (External) advisory and editorial membership

	CityU	CUHK	PolyU	HKUST	HKU
			t activities		

A criticism of the current university KT assessment is that the indicators are not sufficient in Hong Kong compared to other advanced societies (OHKF, 2020). In UK, for example, the Knowledge Exchange Framework (KEF) was launched in March 2021, covering 7 perspectives with 19 metrics[278]. By contrast, Hong Kong does not introduce any assessment framework specified for universities' KT performance. The sector-wide performance measurement for 2022-25 includes a new indicator (student participation), but it is still not sufficient to accurately reflect KT performance and support university-to-university comparisons. Similar problem can be observed in the institution-specific KPI sets. Moreover, since universities adopt different KT development models, their targets may differ, making comparisons difficult.

- **Provision of information to businesses**

One of the most frequently perceived obstacles to engagement activities such as commercialization and consulting is the difficulty in finding the right partner. Governments usually set up a one-stop service and platforms bridging the information gap between industry, especially SMEs, and universities. Universities also disclose some of their achievements, patents, and scholarly publications on their website, providing accessible information for those who might be interested in the application research and further collaboration. A range of competitions, roadshows, training sessions and networking events are also provided by governments or universities itself, forming both formal and informal networks. In general, information should be accessible and available to the potential entrepreneurs so that they could find high-quality advice and mentoring.

- **Awareness raising**

The regional culture that 'celebrates' failure – instead of condemning it as a taboo –also allows talents and founders to quickly move on from one company to another in case their business fails, thus ensuring a constant, cross-organizational knowledge circulation (Saxenian, 1994). It is also critical to reframe the public's thinking so that they view entrepreneurship as a desirable career choice. The culture of accepting failure and culture perceptions towards career development differ across the hubs. For example, within Japan, there has been a general tendency for a large proportion of the workforce to prefer seeking stable jobs to establishing risky ventures (Witt, 2014). By contrast, Silicon Valley's innovation dynamics have been attributed to the pervasive culture of 'job-hopping', which facilitated significant knowledge spillover and dissemination between firms and organizations (Saxenian, 1994; Almeida and Kogut, 1999; Fleming and Frenken, 2007). In recent decade, Japan's job culture is gradually changing into one more amenable towards job-hopping, albeit in a different context from that in Silicon Valley. Whereas job mobility in Silicon Valley is largely the domain of inventors

and innovators (often in search of better workplaces or to establish their own start-ups), job mobility in Tokyo – and Japan more broadly – is primarily among temporary contract workers, many of whom are in low-paying jobs, whereas permanent employees are more likely to stay with their workplaces for a longer period of time, a reflection of the two-tiered nature of Japan's existing job market (Witt, 2014). While professionals are increasingly open-minded on the notion of career mobility (Whittaker et al., 2009), such dynamics are not as widespread as those in Silicon Valley, or other innovation hubs.

- **Incentives for faculty**

Universities may favor the academics' research performance compared to other criteria and sometimes hardly takes into consideration faculty members' achievements in knowledge/technology transfer (e.g., patenting and licensing) and entrepreneurial (e.g. spin-off formation) activities. Faculty evaluation systems in many of our selected universities continue to place significant weightings primarily on research – in particular publications in high-impact academic journals, teaching, and service to a lesser extent, which strongly accounts for tensions within university bodies on whether to prioritize outstanding research (in other words, scientific breakthroughs with no immediate use-based application) versus useful research (findings with immediate relevance for application that are not necessarily groundbreaking) (D'Este et al., 2018).

There is a need to promote flexibility in the current academic system, such as increasing additional positions on research-only tenure-track academic position (e.g. research professor position), as well as revising the existing faculty evaluation policies that reflect academic staff's contribution to research that is funded by sources beyond UGC's existing schemes.

- **Policies to increase talent availability**

The attraction and retainment of high-skilled individuals have always been one of the central foci in the local policy initiatives, especially in places with relatively small geographical areas and scarce resources. For example, Singapore has endeavored to open markets to global high-skilled workforce and operates a very selective immigration policy. In terms of the population diversity with tertiary education, we observed that hubs such as London, Seattle, and Silicon Valley have formed a talent pool with cultural diversity. In hubs such as Tokyo, Seoul, or Shenzhen, although there may be available skilled employees, the limited pool with global interdisciplinary background might limit their potentials as a global knowledge hub. Table 5-2 lists more talent-related indicators for the comparison of the existing human resources and university talents in the selected 11 hubs.

Table 5-2 A comparison of the existing human resources and university talents in the selected 11 hubs

PILLAR	VARIABLE	San Francisco	Singapore	Seattle	London	Hong Kong	Tokyo	Seoul	Tel Aviv	Beijing	Shanghai	Shenzhen
	Overall GTIC	1	7	8	9	20	46	54	55	64	77	82
Enable	1.1 GDP per capita, PPP (current international $)	2	7	8	27	45	47	78	64	90	97	64
	1.2 Internet speed (average megabits per second, Mbps)	2	1	5	79	2	43	71	97	140	140	140
	1.3 Ease of doing business	6	2	6	19	3	73	6	83	56	74	58
Attract	2.1 Presence of Forbes Global 2000 companies (HQ presence, % of population)	5	36	31	9	7	18	39	27	23	48	47
	2.2 Foreign-born population (% of total)	16	11	37	18	10	83	87	21	92	88	92
Grow	3.1 Major universities (average score of top universities—up to three universities)	1	12	13	6	21	19	25	53	11	29	61
	3.2 Tertiary enrolment (%)	44	90	32	n.a.	85	74	84	81	n.a.	89	100
Retain	4.1 Environmental quality (annual mean of PM10 concentrations)	15	76	2	49	81	86	109	116	131	113	99
	4.2 Happiness	44	64	44	50	110	93	95	5	123	96	128
Global Knowledge Skills	5.1 Population with tertiary education (%)	7	32	18	13	76	n.a.	n.a.	60	89	77	81
	5.2 Patent applications (% of population)	3	26	10	45	31	7	13	27	20	37	2

For PhD and postdocs

Doctoral and postdoc students could be highly important in university-industry collaboration.

Postdocs are expected to be one important actor in transferring the university-generated knowledge. They are usually equipped with adequate academic skills, understanding of the academic funding system, and in connection with their previous research team. They could also be employed in a short period and gained some industry experience. Some governments and universities (e.g., UC Berkeley) have developed entrepreneurial postdoctoral programs which allow the postdocs to collaborate with local business leaders to foster the cross-disciplinary knowledge exchange. Also, as one of our interviewees mentioned,

> "Postdocs or Phd graduates could be employed in TTO, or they could serve as gateways for their labs or Professors. "

An example: Commercialization Fellow Program in University of Washington

The Commercialization Fellow Program is a one-year highly competitive Fellows program. Through this program, graduate students or postdocs work closely with both their faculty

advisor and the CoMotion project team in exploring the commercialization potential of the innovation they helped to develop. During the fellowship program, they can focus on the commercialization journey, and not have worry about the obligation of seeking academic grants or jobs after graduation. Fellows participating in the program receive assistance in various areas such as assessing marketing opportunities, pursuing business development funds, and filing patents. They can obtain advice from mentors who have experience in building their business, obtaining funding from investors, and product development.

An increasing number of doctoral students have started to collaborate with industries, but they might have little industrial experiences. As one of our interviewees stated,

> "Although Hong Kong government has provided Ph.D. scheme matching support for some of the small and medium business groups, the PhDs they have hired usually are not equipped with necessary business skills or industrial experiences, which does not really help them a lot in leading or delivering the projects"

More ways to enhance the industrial career of the PhDs and more collaboration model should be rethink and design, for example, think about the real ways that they really could contribute to the industry experiences.

Some of our interviewees have also suggested 'entrepreneur-in-residence' programs (allowing serial entrepreneurs to work with the universities for a fixed period of time to collaborate with university scientists to establish companies and 'exit' the universities), as exemplified by the PolyU illustration. One of our interviewees has, indeed, suggested to the Hong Kong government about the need for support schemes to enable serial entrepreneurs assisting early-stage academic entrepreneurs.

Recruitment of overseas returnees

A large proportion of overseas returnees are often found in the author list of scientific publications and founder names of the university spin-off, especially in cities such as Beijing and Shanghai. One of the examples would be the returnee-founded enterprises, which have frequently engaged in such linkages with those in Tsinghua; much of this reflects the fact that some of these returnees happened to be alumni from the university. Chinese municipalities, and in particular those with considerable capital reserves such as Shenzhen and Shanghai, have introduced schemes that offer prospective returnees a substantial amount of monetary support, ranging from start-up incubation fund to free housing, all-expense-paid packages for returnees' family members, etc. (Zweig et al., 2008).

In Israel, overseas diaspora has often been touted as strategic intermediaries in connecting their home countries with the global innovation ecosystem (Kenney et al., 2013; Lorenzen and Mudambi, 2013; Saxenian, 2006; Welch and Hao, 2016). Oftentimes, attracting overseas returnees necessitates concerted efforts by dedicated, multi-stakeholder 'coalitions of the willing', one example by which has been demonstrated in our case study of TAU in Task 2

report regarding university-industry-government tripartite efforts to invite Israeli scholars in the United States and beyond to return to the country. Such tripartite efforts that are specifically tailored for Hong Kong's areas of innovation priorities are worth considering for replication.

"Techscientist"

Governments and universities have provided training courses or networking channels to help scientist gain more views in terms of the business management and market regulations. For example, in the case of Singapore, Singapore's aspiration of knowledge-based economic development was fundamentally premised on privileging 'the technoscientist' and the 'academic entrepreneur', based on an in-depth investigation of policy documents and ministerial speeches by Tan (2008).

For talents with STEM skills/interdisciplinary background

In the global waves of technological innovations, talents with STEM skills could be of highly important as great contributors to the local development. In hubs such as Seattle and Silicon Valley, we found a great proportion of talents with engineering skills. Israelis, students' preferences at universities, computer science was the most popular course among undergraduate students in Israel, with a distribution of more than 70%

During some of our interviews with the local companies, they claimed that they often find it difficult to hire graduates with STEM skills. From the perspective of the graduates, however, they often claim that they could not find enough opportunities in the labour market. Tsui et al. (2017) echoes these challenges about hiring STEM talents in Hong Kong organizations in general. The authors asserted that one major reason for such difficulties in attracting STEM students can be attributed to the limited career prospects for the graduates from these university programs. Furthermore, many of the graduates from these degrees – given few career opportunities in Hong Kong – end up working in business- and finance-related sectors. The purpose of pointing out the observation made by Tsui et al. (2017) is not to suggest that STEM graduates necessarily prioritize TT in their job search, but rather the career of a KT professional can be made more attractive, for example, in terms of making the remuneration package comparable to those of the finance-related jobs. While STEM innovation is critical, other opportunities should not be overlooked. Talents with interdisciplinary backgrounds need to be trained, which could be found in the case of UK.

Professional for innovation manager/TTO

Universities often carries such objectives to discover new and novel things and to create inventions, oftentimes without a clear goal towards a clear thought of commercial products or markets they want. This is also something always debated regarding the "ivory tower" form with an abstraction from the real-world problems, which is also among the barriers when taking out the university-industry collaboration observed from both our surveys and interviews. Our

previous findings have also indicated the role of innovation managers with the relevant expertise to match the area of research. Or in some cases, the alternative label for innovation managers is the technology transfer manager, which refer to the talents with both business skills, science understanding, and technology transfer skills. We have discussed some of the incentives provided by governments to motivate these group of people in searching, matching and negotiating with external partners. Apart from those cash or equity rewards, governments in Shanghai, Beijing, and Shenzhen have started to accredit the technology transfer manager and establish evaluation classification system. Different promotion rules are offered by the local government, coupled with the training courses by technology transfer academy.

- **Entrepreneurship education and program**

Governments and universities are implementing strategies to embed a mindset and culture in entrepreneurship in the educational curricular, with the intention to equip people with skills and knowledge essential for carrying out entrepreneurial activities.

To foster a long-term knowledge transfer partnership, Governments expected that higher education institutions not only nurture a research-intensive culture, produce high-quality undergraduate programs, and build domestic research capacities, but also imprint an entrepreneurial culture and mindset among the university communities – particularly in commercializing the results of scientific research. It is also critical to reframe the public's thinking so that they view entrepreneurship as a desirable career choice. For example, unicorns or startups that thrive can serve as inspiring success stories for younger generations. More effort could be made to increase students' exposure to entrepreneurship, such as by introducing entrepreneurship as a viable path in career education, matching students with mentors or providing internships at startups.

Some examples include the NUS's practice on building an entrepreneurial university. For example, one of the popular NUS Overseas Colleges (NOC) programme, which combines overseas start-up internships with entrepreneurial coursework at leading partner universities, equips our students with valuable hands-on experience in dynamic innovation hubs. Students get to spend up to a year at an entrepreneurial hotspot overseas. Students have opportunity to be an intern at a start-up and have access to mentors and coaches in the local ecosystems. While taking classes at a prestigious partner university. In last two decades, more than 3,400 students graduated from NOC programme. More than 1,000 companies have been formed by these graduates, and two of them are unicorns (PatSnap and Carousell). More importantly, the success of the NOC programme lies in that it not only produced many start-ups at much higher rate than normal university graduates do, but it also contributed to creating many graduates who choose to work in the ecosystem. (government agencies, incubators, venture capitalists). The programme's alumni are almost 10 times more likely to become entrepreneurs than other NUS graduates. Of startups that have raised more than US$10 million in external funding, almost 5 per cent are NOC alumni.

One programme that training students to become deep-tech start-up founders is the Master of

Science in Venture Creation (MScVC). Launched in AY2020/21, the one-year MScVC is an immersive programme combining experiential learning with academic studies, targeted at aspiring entrepreneurs who hope to launch new ventures. Designed to accelerate the translation of ideas into solutions, the programme offers mentorship in business development, access to NUS technologies and opportunities to network for market access.

Another programme is the NUS Venture Building Programme. As part of Enterprise Singapore's enhanced Startup SG Founder Programme, the three-month NUS Venture Building experiential programme was launched in October 2020. It provides mentorship and access to NUS technologies, and teaches participants how to analyse market opportunities, develop business models and make professional pitches. Of the more than 100 participants in the three cohorts to date, several graduating teams have received recommendations for the enhanced Startup SG Founder Grant.

- **Practices to serve as platform**

The development of ICT has undergone tremendous changes as it affects all areas of the conventional functions such as teaching, research, and service, as well as management, administration, finance, infrastructure, organizational culture, leadership, and decision-making processes of university organizations (Marginson and Sawir, 2006; Yuen et al., 2003). The environmental changes that make it easy for anyone to access and learn knowledge and information anytime, anywhere by overcoming the constraints of time and space, require a new vision and appropriate response strategies after the COVID-19 pandemic (Bylieva et al., 2020). The representative of this trend is the Massive Open Online Course (MOOC) which launched in 2011 with three courses at Stanford University (Alhazzani, 2020). The MOOC has completely changed the paradigm of education amid the COVID-19 pandemic. In this context, the platformization of the university has expanded to not only provide the roles of education and research, but also to utilize the human, material, institutional, and financial educational resources of the local community for improving the quality of education and catalyzing further regional innovation (Mishra et al., 2020).

Related to the societal role of universities, universities are expected to provide diversified courses, degrees and expertise responding to some of the emerging issues. Universities also support continuing education and lifelong learning and invite expertise from different fields, or sometimes the university's alumni back to actively engage in education programs.

5.2 Interviews and dissemination

A list of interviewees was identified from the individuals who indicated an interest and left their emails for a follow-up interview in the industry survey. Other targeted respondents include technology/knowledge transfer officers, managers of business incubators, intellectual property lawyers, government officials and academics. Interviewees are from different places, with most of them from mainland cities (e.g., Shanghai, Shenzhen, and Guangzhou). We talked to some local businesses in sectors such as biomedicine and information technology as well as

some university startups in order to understand their perspectives and concerns regarding the existing innovation and technology environment in Hong Kong. We have also visited some science parks and incubators in Hong Kong to understand how university-based knowledge could be utilized and valorized. A snowball technique was used during the process of interviews with the respondents to identify potential stakeholders for compiling further opinions and recommendations. Pilot interviews were conducted to tailor our interview questions to different groups of respondents with various organization affiliations.

A total number of 16 in-depth interviews were conducted between March 2022 and September 2022 and the interviews normally lasted for 45-75 minutes. Some generic questions we asked during the interviews are:

- What are the roles and contribution of the university in the development of local regional innovation and technology competitiveness?
- What policies and actions Hong Kong government and universities could introduce/improve to enhance the roles of universities in accelerating regional development?

Other interview questions were asked depending on the specificities of the organizations and groups and centered around topics such as: support for social entrepreneurship and alleviating social challenges, joint university-industry interactions and activities, challenges and catalysts of such joint UI operations, and motivations for addressing UI relationships with social goals.

Table 5-3 List of interviewee participants

Interviewee	Position	Organization type
1	CEO	Startup
2	CEO	Startup
3	Manager	Incubator
4	Lawyer	Intellectual property office
5	Technology Transfer Officer	Technology transfer office
6	Technology Transfer Officer	Technology transfer office
7	CEO	Startup
8	Founder	Startup
9	CTO	Enterprise
10	Manager	Incubator
11	Faculty	University
12	Faculty	University
13	Manager	Enterprise
14	Analyst	Think tank
15	CEO	Startup
16	CEO	Startup

Dissemination

The research team planned to organize two seminars centered around “Accelerating the Development of a Global Innovation and Technology Hub in the Guangdong-Hong Kong-Macau Bay Area: The Roles of Public Research Universities in Hong Kong” in mid-November. Different experts and scholars in the field of higher education and innovation technology

development will be invited to share their ideas and experiences. The seminars will be co-organized with the Institute for Public Policy of the Hong Kong University of Science and Technology (HKUST). The main findings of this project will be summarized and disseminated at the seminars.

The main findings of this study will also be published through digital platforms and social media to enhance the impacts of this study. These channels include the facebook and wechat official accounts focusing on regional innovation studies, and the videos of the events will be posted on relevant YouTube channels. We will also share the main results from our case studies and surveys with those respondents who agreed to participate in our surveys and expressed an interest in learning more about the university-industry collaboration, including both the university and industry perspectives.

5.3 Recommendations

Based on the policy implications obtained from previous 3 tasks and interviews with relevant stakeholders, we summarized our policy recommendation around five main themes.

Theme 1: Government and universities in Hong Kong should review how to further strengthen collaboration in building a vibrant innovation ecosystem

Recommendation 1a: Hong Kong universities and governments should continue to seek opportunities to develop blue sky technologies by establishing strategic R&D centers and laboratories. Universities may do well to strengthen and institutionalize their linkages with various enterprises – whether local, mainland Chinese, or foreign – through variegated measures. These can be demonstrated by establishing joint R&D centers (which have been implemented by some universities, e.g. HKUST-Huawei Research Center), two-way short-term exchange of research personnel (with university scientists participating in research internships in major firms for a limited period of time), joint postgraduate/doctoral programs with major corporations, as well as the establishment of research consortia centered on emerging technologies that involve universities, industries, as well as government research institutes. Hong Kong universities may also leverage their position in the development of emerging technologies by establishing strategic R&D centers in the upcoming Lok Ma Chau Loop, a joint technology park between Hong Kong and Shenzhen; such moves may, hopefully, better integrate the universities' knowledge ecosystems with those of industries.

Recommendation 1b: Hong Kong government and universities need to build stronger connection with overseas Hong Kong and Chinese diaspora, and in particular those with science, technology, and engineering-related expertise who are currently based in major innovation hubs overseas (e.g. Silicon Valley). Tel Aviv – and Israel more broadly, by extension – has been able to thrive thanks to their success in building strong ties with Israeli and Jewish communities in Silicon Valley and New York City.

Recommendation 1c: Hong Kong government may further expand their bilateral collaboration with more countries globally – in particular countries that are leading innovation hubs – in terms of STI-related collaboration, with a structure akin to US-Israel Bi-national Industrial Research and Development (BIRD) model. Thus far, UGC has several joint schemes in place (primarily with mainland China, European Union, Germany, and France), but these schemes are largely limited to scientific research and travel grants for visiting scientists. The authorities can also conduct more public outreach efforts to leading universities and/or PROs globally to establish either branch campuses or research institutes, in partnership with Hong Kong's leading universities, as an avenue to strengthen cross-country collaboration in knowledge production.

Recommendation 1d: Both Hong Kong and Shenzhen will generate additional benefits through proactive, two-way collaboration within the STI scope. Despite substantial differences in their scientific and technological knowledge bases, on top of their highly distinctive innovation policy frameworks, there have been several areas where the two cities can enhance their complementarities, namely: 1) recruitment of STI-related talents; 2) joint R&D initiatives; 3) initiatives to improve enterprise competitiveness, and; 4) cross-border start-up incubation. Lok

Ma Chau Loop, which is currently under construction and will be officially ready by 2026 or 2027, will be pivotal – and highly symbolic – in terms of the degree to which Hong Kong and Shenzhen will enhance their two-way linkages, especially in the post-COVID era.

Theme 2: Hong Kong government and universities should consider formulating new schemes to attract various sources to facilitate university knowledge transfer.

Recommendation 2a: The Hong Kong government – in close consultation with academia, industries, and other relevant stakeholders – may consider formulating new schemes and/or incentives to encourage a wide variety of enterprises, whether local Hong Kong firms, mainland Chinese-based companies, or foreign MNCs to establish either joint R&D centers, or joint postgraduate programs, with the city's leading research universities. Recently formulated schemes, such as 'InnoHK' – which encourages scientific collaboration with major research universities across the globe, can be modified to replicate such approaches, but in the context of U-I collaboration. Such policy schemes may provide further opportunities for the city's university graduates – especially those in science and engineering-related fields – to acquire relevant, real world-based learning experience by working closely with enterprises.

Recommendation 2b: Universities may be encouraged to establish their own VC funds to support the booming spin-offs. Thus far, university spin-offs primarily receive their early-stage funding from the Hong Kong government under Technology Start-up Support Scheme for Universities (TSSSU). Universities should also diversify their funding to include more private or philanthropic sources.

Theme 3: Hong Kong government and universities should further promote the engagement of various innovation actors in knowledge transfer - universities' success in promoting innovation and entrepreneurship with holistic inclusion of stakeholders.

Recommendation 3a: Universities should revisit the faculty evaluation and tenure policies and increase flexibility in existing academic scheme. There is a need to promote flexibility in the current academic system, such as increasing additional positions on research-only tenure-track academic position (e.g. research professor position), as well as revising the existing faculty evaluation policies that reflect academic staff's contribution to research that is funded by sources beyond UGC's existing schemes. In response to the prevailing value gap between further promotion of KT and incentive structures that lean towards research and teaching, university administrators may possibly consider a shift to more quality-oriented indicators in assessing faculty members' KT performance. The current appraisal system that follows UGC's direction of category-based targets may be complemented with better combination of quantitative and qualitative assessment methods.

Recommendation 3b: Beyond the traditional roles such as teaching and education, Hong Kong should consider introducing institutional experiments in terms of the appointment policies of faculties. The basic role of faculties is to contribute to the development of regions and countries by producing knowledge and nurturing talented students. Despite the changes of the times, the

unique role of universities continued to give an emphasis on teaching and research. However, the rapid development of science and technology, changes in the industrial system, and convergence of disciplines across academic boundaries require more changes in the employment systems of faculties. Firstly, one of the universities we studied (i.e., Seoul National University) introduced a system of appointment to faculty positions that focus on the university-industry cooperation. Since candidates for this position are required to have more than 10 years of industry experience, we can interpret that the university has the intention to utilize their personal networks and connections in promoting university and industry cooperation. In addition, despite their positions as professors, they do not have any teaching and/or research obligations, which allows them only to focus on the university-industry cooperation. Secondly, an institutional experiment to break away from the traditional 'one day per week' policy can be introduced.

Recommendation 3c: Existing KTOs/TTOs in Hong Kong's universities need to engage more professionals with business-relevant backgrounds, particularly those with experiences as serial entrepreneurs, venture capitalists, and/or academic entrepreneurs. An association or regional knowledge transfer platform may be helpful in facilitating the exchange of information regarding the translational university sources within the Greater Bay Area.

Recommendation 3d: Hong Kong universities should venture beyond patenting and licensing for avenues of commercialization. At present, most universities in Hong Kong continue to prioritize patenting and licensing as the major avenues for commercialization. Nevertheless, their subsequent performance in licensing remains to be desired. It is important for the universities, especially the KTOs, to consider strategies beyond patenting and licensing for commercializing university inventions. One suggested possibility is for the KTOs to place equal importance on both formal and informal means of commercializing university technologies through strategies such as expanding platforms for networking with industry actors, as well as establishment of open laboratories for other university stakeholders and prospective industry players in further refining and developing faculty members' university inventions.

Theme 4: Hong Kong should continue to develop innovation funding programs, particularly in deep tech areas with high potentials.

Recommendation 4a: Hong Kong government should develop more funds and mechanisms for early-stage funding and attract greater private investment in developing early-stage funding. Specifically, Hong Kong government need to expedite its mechanism to de-risk given the embryonic nature of university-generated basic research. Government may consider set up a Proof-of-concept center providing overall technical feasibility evaluation and commercialization support specifically targeting the strategic industries.

Theme 5: Hong Kong government should invest more efforts in talent attraction and retainment

Recommendation 5a: Governments could develop schemes that offer prospective returnees a

substantial amount of monetary support, ranging from start-up incubation fund to free housing, all-expense-paid packages for returnees' family members. Potential housing provision could be situated in LOOP, coupled with other supporting infrastructure.

Recommendation 5b: Hong Kong government may consider developing a university-centered research park in Loop to attract and retain science and technology companies and talent. Establishment of regional research platforms/centers would be a choice for placing talents and addressing the local and regional needs of technology development, in lieu of merely financial or accommodation support. Large-scale, multi-sector, and interdisciplinary research programs could be launched in response to the emerging social demands to achieve the continuity of research and teaching of Hong Kong universities. More university-based incubators could also be moved to Loop, offering opportunities for young researchers, entrepreneurs, and opening more opportunities for collaboration.

Recommendation 5c: Governments could also provide more postdoc positions targeting interdisciplinary programs and enhance industry career prospects of PhD candidates. Governments and universities need to develop entrepreneurial postdoctoral programs which allow the postdocs to collaborate with local business leaders to foster the cross-disciplinary knowledge exchange.

Theme 6: Entrepreneurship, culture, and mindset

Transforming Hong Kong's innovation ecosystem cannot be solely implemented through policy changes alone; a shift in mindset hindering richer linkages among local innovation actors are also needed. Many local people could be risk-averse, and they constantly pursue higher education with the expectation of gaining stable employment in large corporations in the long run.

Recommendation 6a: Universities need to provide interdisciplinary education and training that will prepare future scientists and engineers. Universities have increasingly developed new departments or future institutes concentrating on emerging disciplines and interdisciplinary disciplines such as new generation of information technology, energy conservation and environmental protection, biotechnology and biomedicine. A portfolio of degree programs have also been offered integrating innovation education, interdisciplinary technology development and entrepreneurial practice. Also, we would suggest an entrepreneurial ecosystem development strategy that more explicitly incorporates a multi-stakeholder perspective, for example, by developing stronger relations with alumni and promoting interdisciplinary teamwork.

Recommendation 6b: Universities might also consider the inclusion of societal contribution and sustainable development goals aligned with their overall development strategy. In light of the rising prominence of the 'entrepreneurial university' concept, Hong Kong universities have been increasingly paying attention, and also investing in resources, to support innovation and entrepreneurship development. Meanwhile, universities could broaden their regional impacts through provision of continuing education.

6 Conclusions

Public research universities in Hong Kong are among its most important strategic assets from the perspective of innovation and technology not only because of their global standing and network, but also due to the fact that these universities undertake over 50% of all R&D activities in Hong Kong based on R&D expenditure. To understand the extent to which these activities have originated from universities and how they can be fully exploited for improving the capacity of local innovation and technology (I&T), this project examined the roles of public research universities in fostering Hong Kong's I&T development and policies to enhance such roles. We have collected and identified regional and global good practices, policies, and measures that can enhance the roles of public universities in the development of innovation and technology hubs, offering a reference for universities to fully develop the necessary functions to play a significant role in innovation.

From the cases selected in this project, it is visible that universities have increasingly been expected to play a more proactive role to support socio-economic development in the process of forming a modern industrial region, in addition to their traditional core functions of nurturing human resources and producing knowledge. A third mission has increasingly been included as a central tenant of universities' strategic orientation, often with an aggressive pursuit of academic entrepreneurship, commercialization of university technology transfer, and societal engagement strategies with local communities. All the selected universities in our study, to varying degrees, have developed incubators, science parks, venture funds, gap fund programs, universities spin-offs and entrepreneurship programs that promote innovation and entrepreneurship development. Many of the selected universities have also developed innovation arms such as technology transfer offices to enhance the information transfer activities and manage knowledge exchange. Furthermore, universities have sought to collaborate with regional partners and global networks through a variety of means, not only through licensing and collaborative research, but also through industry affiliate programs and through its organized research units, namely, research institutes and centers.

Drawing on the experiences of other universities' practices, Hong Kong universities should continuously review and evaluate their strategic visions and culture, investment portfolios in research and development, the institutional environment, and organization settings to support entrepreneurship and knowledge transfer, as well as the overall regional impacts and innovation performance of universities. It is crucial for Hong Kong universities to strike a balance between local needs, national development priorities, and global trends while reflecting the peculiarities and strengths of themselves. To meet the real local needs, close dialogues between various stakeholders (e.g., universities, industry, and government) would be beneficial. Another aspect universities need to pay attention to relates to accelerating the R&D and knowledge transfer capabilities of Hong Kong universities. We noticed that, as part of the universities' innovation and technology strategies, a number of interdisciplinary programs or joint R&D research centers have been developed to promote research and education activities. Whether and how these initiatives could lead to inventions and commercialization require careful monitoring, to prevent fragmentation of university resources and conflicts that increase competition rather than collaboration.

In the Chief Executive's 2022 Policy Address, Hong Kong government has introduced a number of new measures for enhancing universities' roles in regional development, including

a new funding scheme “Research, Academic and Industry Sectors One-plus Scheme” (RAISe+ Scheme) of $10 billion, expanded subsidies and relaxed immigration restrictions to attract talents, encouraging STEAM schemes (Science, Technology, Engineering, the Arts, Mathematics) and promoting mainland and international exchanges. In terms of the talent policies, universities and government in Hong Kong should consider creating more positions for individuals or research team with interdisciplinary background or STEAM skills to participate in local projects. Moreover, in view of Hong Kong’s high living costs, additional resources including accommodation are needed, not just monetary assistance. Lok Ma Chau Loop in San Tin Technopole could be used to provide accommodation facilities. Hong Kong universities may also leverage their position in the development of emerging technologies by establishing strategic R&D centers and cross-border start-up incubation in the upcoming Lok Ma Chau Loop.

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7 APPENDICES

7.1 Appendix 1. Survey questionnaire for academia

BASIC INFORMATION: FACULTY

Q1.1 Which university do you work at?

Q1.2 What is your academic field?

- Science
- Engineering
- Medicine
- Social Science
- Business
- Economics
- Law
- Others (please specify below)

_____

Q1.3 What is your academic title?

- Chair Professor / Professor / Reader
- Associate Professor
- Assistant Professor
- Senior Lecturer
- Lecturer
- Others (please specify below)

_____

Q1.4 Do you have teaching obligations?

- Yes
- No

Q1.5 Do you hold any administrative position(s) at your university?

- Yes
- No

Skip To: Q1.7 If Do you hold any administrative position(s) at your university? = No

Q1.6 If you hold an administrative position(s) in your university, please click below (multiple choices all that apply)

University level

Faculty/School/College level

Department/Division level

Research Institute

Others (please specify below) _____

Q1.7 Your gender

- Male
- Female
- Prefer not to say

Q1.8 Kindly select the Survey that is relevant to your academic field.

- Survey 1 (Science, Engineering, Mathematics, etc.)
- Survey 2 (Social Science, Business, Humanities, etc.)

End of Block: BASIC INFORMATION: FACULTY

Start of Block: FUNDING (SURVEY 1)

Q2.1 Have you received research funding from the following sources in the last two years?

	Yes	No	Not Applicable
Domestic government funding sources			
Industry funding sources (companies)			
Other private sources (e.g., NGOs, charities, etc.)			
International sources			

Q2.2 In your opinion, is the funding from the following sources adequate for your research?

	Yes	No
Domestic government funding sources		
Industry funding sources (companies)		
Other private sources (e.g., NGOs, charities, etc.)		
International sources		

End of Block: FUNDING (SURVEY 1)

Start of Block: INVOLVEMENT IN KNOWLEDGE TRANSFER (SURVEY 1)

Q3.1 Now we would like to ask you some questions about your involvement in knowledge transfer activities, which are defined as *engagements with the system and processes by which knowledge and discoveries, including technology, know-how, expertise, and skills, are*

transferred from higher education institutions to society/industry for economic and societal benefit.

Do you agree with the following statements?

	Yes	No
I contribute to the industry by sitting in the board of firms		
I seek funding from industries for my/our research group activities		
I contribute to the community by sitting in public advisory boards of government agencies, commissions, departments, etc.		
I seek funding from the government research funding agencies (local or international)		
I cooperate with government entities regarding providing consultancy services		
I engage in activities with any charitable or voluntary organisations		
I am involved in activities with social enterprises		
I participate in professional non-academic events (e.g., conference, symposia and workshop)		
I seek research opportunities outside the traditional university environment		
I seek significant funding from sources other than the academia		
When I come upon an unconventional new idea, I let someone from my research team try it and see what happens		

End of Block: INVOLVEMENT IN KNOWLEDGE TRANSFER (SURVEY 1)

Start of Block: MOTIVATIONS/PERCEPTIONS (SURVEY 1)

Q4.1 Now we would like to ask you about your opinion with regard to the potential contribution in collaboration with industry. To what extent do you agree with the following statements?

	Strongly disagree	Some what disagr ee	Neither agree nor disagree	Somewhat agree	Stron gly agree
Collaboration with industry provides better opportunities to seek new intellectual property rights					
Collaboration is a useful channel to get the latest insights from industry					
Collaboration increases the applicability of university research in industry					
Through collaboration with industry, I become part of a broader network of professionals relevant for my research					
It is important to interact with industry for access to materials or data necessary for research and/or state-of-the art equipment and facilities					
My research work is highly regarded by industry					
I am recognized by industry for my flexibility and innovativeness					
Cooperation with organizations outside the university significantly improves my research activities					
My university appreciates my collaborating with non-academic professionals					
I am often the first to try new ideas, rather than let someone else try it and wait to see what happens					

Q4.2 Now we would like to ask you about your opinion with regard to the potential contribution of informal networks. To what extent do you agree with the following statements?

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Some what agree	Stron gly agree
Informal networks (e.g., alumni network and association) play a role to create collaboration opportunities with industry					
Cooperation in research via joint activities and initiatives (e.g., research centers, labs, cluster programs & platforms) is important					

End of Block: MOTIVATIONS/PERCEPTIONS (SURVEY 1)

Start of Block: BARRIERS/INCENTIVES (SURVEY 1)

Q5.1 In your opinion, is the following factor a barrier for engagement with industry?

	Not a barrier	Small barrier	Big barrier
Differences in objectives between industry and academia			
Work needed by industry not interesting			
Difficulties of getting in touch with relevant industrial organizations			
Insufficient equipment and facilities			
Engagement with industry has limited impact on academic performance and promotion assessment			
Delay in publication			
Intellectual property rights issues			
Industries surrounding our university do not have the capacity to use research effectively			
Other reason (please specify)			

Q5.2 Policies with regard to inventions vary across universities - some universities are strict, while others are not. In some circumstances, some faculty members may have reasons not to

disclose their inventions. To what extent do you agree the following are the reasons for faculty members not to disclose their inventions?

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
University does not require invention disclosure					
Faculty members do not trust the evaluation by the transfer office					
Faculty members' concerns on inventions being evaluated as having low value					
Faculty members' efforts are not rewarded					
Other people may steal their ideas					
Faculty members have their own contact; no need for bureaucracy					
Other reason					

Q5.3 Are you satisfied with the following policy at the university level?

	No such policy	Extremely satisfied	Somewhat satisfied	Neither satisfied nor dissatisfied	Somewhat dissatisfied	Extremely dissatisfied
The inclusion of knowledge transfer into the faculty assessment policy for promotion						
The intellectual property ownership policy						
The policy on the sharing of royalty income (i.e., distribution of licensing fee among inventor, university, and host department)						
The policy on outside practice to engage in knowledge transfer-related work (e.g., one-day-per week policy, leave of absence, etc.)						

Q5.4 Have you had any interaction with the technology transfer office of your university?

- Yes
- No

Skip To: End of Block If Have you had any interaction with the technology transfer office of your university? = No

Q5.5 Are you satisfied with the support from the university's technology transfer office?

	Extremely dissatisfied	Somewhat dissatisfied	Neither satisfied nor dissatisfied	Somewhat satisfied	Extremely satisfied
Administrative support provided by the technology transfer office (e.g. patents filing)					
Marketing support provided by the technology transfer office (e.g. promoting your inventions, networking activities)					

End of Block: BARRIERS/INCENTIVES (SURVEY 1)

Start of Block: ADDITIONAL COMMENTS/INFORMATION

Q6.1 If you have any additional comments on your university's knowledge transfer practices that we did not cover in our questionnaire, please write them below. (optional)

_____

End of Block: ADDITIONAL COMMENTS/INFORMATION

Start of Block: FUNDING (SURVEY 2)

Q7.1 Have you received research funding from the following sources?

	Yes	No	Not applicable
Domestic government funding sources			
Industry funding sources (companies)			
Other private sources (e.g., NGOs, charities, etc.)			
International sources			

Q7.2 In your opinion, is the funding from the following sources adequate for your research?

	Yes	No
Domestic government funding sources		
Industry funding sources (companies)		
Other private sources (e.g., NGOs, charities, etc.)		
International sources		

End of Block: FUNDING (SURVEY 2)

Start of Block: COLLABORATION IN KNOWLEDGE TRANSFER (SURVEY 2)

Q8.1 Now we would like to ask you some questions about your involvement in knowledge transfer activities, which are defined as *engagements with the system and processes by which knowledge and discoveries, including technology, know-how, expertise, and skills, are*

transferred from higher education institutions to society/industry for economic and societal benefit. Do you agree with the following statements?

	Yes	No
I contribute to the industry/private organisations by sitting in the board of firms		
I seek funding from industries/private organisations for my/our research group activities		
I contribute to the community by sitting in public advisory boards of government agencies, commissions, departments, etc.		
I seek funding from the government research funding agencies (local or international)		
I cooperate with government entities regarding providing consultancy services		
I engage in activities with any charitable or voluntary organisations		
I am involved in activities with social enterprises		
I participate in professional non-academic events (e.g., conference, symposia and workshop)		
I seek research opportunities outside the traditional university environment		
I seek significant funding from sources other than the academia		
When I come upon an unconventional new idea, I let someone from my research team try it and see what happens		

End of Block: COLLABORATION IN KNOWLEDGE TRANSFER (SURVEY 2)

Start of Block: MOTIVATIONS/PERCEPTIONS (SURVEY 2)

Q9.1 Now we would like to ask you about your opinion with regard to the potential contribution of informal networks. To what extent do you agree with the following statements?

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
Informal networks (e.g., alumni network and association) play a role to create collaboration opportunities with industry					
It is important to consider societal needs when developing research and new ideas					
I am good at identifying new research opportunities potentially applicable for the society					
My university appreciates my collaborating with non-academic professionals					
Cooperation with organizations outside the university significantly improves my research activities					

End of Block: MOTIVATIONS/PERCEPTIONS (SURVEY 2)

Start of Block: BARRIERS/INCENTIVES (SURVEY 2)

Q10.1 Are you satisfied with the following policy at the university level?

	No such policy	Extremely dissatisfied	Somewhat dissatisfied	Neither satisfied nor dissatisfied	Somewhat satisfied	Extremely satisfied
The inclusion of knowledge transfer into the faculty assessment policy for promotion						
The policy on outside practice to engage in knowledge transfer-related work (e.g., one-day-per week policy, leave of absence, etc.)						

End of Block: BARRIERS/INCENTIVES

7.2 Appendix 2. Survey instrument for industry

Start of Block: INTRODUCTION

INTRODUCTION
The purpose of this questionnaire is to collect information about your perspectives towards universities–industry collaboration. We would be grateful if you could spare 5 minutes to complete the survey.

All information will be kept confidential and anonymous, and will be used only for academic research and policy advice.

Thank you very much for your time.

End of Block: INTRODUCTION

Start of Block: SECTION A. General Information

Q1
This section includes demographic questions about your organization and your background.

Q2 In which city or region is the head office of your company located?

- ○ London
- ○ Seattle
- ○ Seoul
- ○ Silicon Valley
- ○ Singapore
- ○ Tel Aviv
- ○ Tokyo
- ○ Beijing
- ○ Hong Kong
- ○ Shanghai
- ○ Shenzhen
- ○ Others: (please specify) _____

Q3 In which year was your company established?

_____

Q4 Is your company a start-up from a university?

- ○ Yes (1)
- ○ No (2)

Q5 Which best describes your company's primary sector?

- ○ Manufacturing (1)
- ○ Information technology (2)
- ○ Finance and insurance (3)
- ○ Comprehensive industry (4)
- ○ Bio-medical Technology (5)
- ○ ICT (6)
- ○ Green Technology (7)
- ○ Material and precision engineering (8)
- ○ Electronics (9)
- ○ Others: (please specify) (10) _____

Q6 What is the current total number of employees of your entire enterprise?

- ○ 0-100 (1)
- ○ 101-250 (2)
- ○ 251-500 (3)
- ○ 501-1000 (4)
- ○ >1000 (5)

Q7 Which of the following best describes your role in your company?

- ○ Executive (CEO/COO/CFO) (1)
- ○ Manager (2)
- ○ Engineer/specialist (3)
- ○ Staff (4)
- ○ Others (5)

End of Block: SECTION A. General Information

Start of Block: SECTION B. Experiences on Collaboration with Universities

Q8
In this section, we would like to know about your experiences on collaboration with universities.

Q9 Has your company had any experience in collaborating with universities?

- ○ Yes (1)
- ○ No (2)

Skip To: End of Block If Has your company had any experience in collaborating with universities? = No

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Q10 Where is/are locations of the university(ies) with which your company collaborates? (Could choose more than one)

- ○ The same city as the company (1)
- ○ Located in other city (please specified): (2) _____

Q11 How many projects has your company engaged in collaboration with universities in the last 5 years?

- ○ 1 (1)
- ○ 2 (2)
- ○ 3 (3)
- ○ 4 (4)
- ○ 5 and above (5)

Q12 Which channels have your company used to identify academic partners in university-industry collaboration (Could choose more than one)

University's website (1)

Online platform (2)

Conferences (3)

Informal interaction (4)

Professional associations or industry associations (5)

Journal articles or books (6)

Trade fairs, exhibitions (7)

Other: (please specified) (8) _____

Q13 At which stage would your company seek research collaboration partners from the university?

	Yes (1)	No (2)
Basic research (academic research) (1)	○	○
Applied research (2)	○	○
Technology development (3)	○	○
Production (4)	○	○
Marketing (5)	○	○

Q14 Are the following outputs generated from the collaboration with university in your company?

	Yes (4)	No (5)
1. Research papers published in academic journals as a direct result of your firm's relationship with the university (1)	○	○
2. Research papers presented at professional conferences as a direct result of your firm's relationship with the university (2)	○	○
3. Patents, patent applications, licenses resulting directly from your firm's relationship with the university (3)	○	○
4. Products and/or processes resulting directly from your firm's relationship with the university (4)	○	○

Q15 Is the university-industry collaboration satisfactory to your company?

○ Yes (1)

○ No (2)

End of Block: SECTION B. Experiences on Collaboration with Universities

Start of Block: SECTION C. Motivation to Collaborate with Universities

Q13

In this section, we would like to understand the motivation of your company to engage in collaboration with universities

Q16 In your opinion, do the following statements capture the reasons why your company would collaborate with universities?

	Yes (1)	No (2)
1. To create innovative products, technologies, markets (1)	○	○
2. To access faculty who created the cutting-edge knowledge and technology central to university research (2)	○	○
3. To enhance your company's reputation through joint publications with university partners in the same city (3)	○	○
4. To gain access to exclusive licensing for patents developed by university researchers (4)	○	○
5. To strengthen companies' R&D capabilities by learning new research techniques from university researchers (5)	○	○
6. To attract researchers and absorb knowledge from universities (6)	○	○
7. To gain access to local government/public funding (7)	○	○

8. To access the state-of-the-art research facilities located in the universities (8)	○	○
9. To explore close distance and convenient access between company and collaborating university (9)	○	○
10. To take advantage of university's reputation (10)	○	○

End of Block: SECTION C. Motivation to Collaborate with Universities

Start of Block: SECTION D. Incentives and Barriers in Collaboration with Universities

Q16
In this section, we would like to understand your perceptions of the incentives and barriers in collaboration with universities.

Q17 In your opinion, how important are the following factors in increasing your company's incentive to collaborate with a specific university?

	Not at all important (1)	Slightly important (2)	Moderately important (3)	Very important (4)	Extremely important (5)
1. The university has outstanding researchers, high ranking and is scientifically leading in their field (1)	○	○	○	○	○
2. The university has comprehensive research facilities and establishment of joint industry-university research labs (2)	○	○	○	○	○
3. The university is active in commercialising its research and its previous achievements on commercialising their research (3)	○	○	○	○	○
4. The university has IP policies that are clear and flexible/equitable in revenue and royalty sharing (4)	○	○	○	○	○

Q18 To what extent do you think the following factor(s) are barriers for your company to collaborate with universities?

	No obstacle (1)	Minor obstacle (2)	Major obstacle (3)
1. Different perceptions of time horizon on research project (long-term research view by academia, short-term research view by industries) (1)	○	○	○
2. Lack of understanding of expectations and working practices mutually (2)	○	○	○
3. Potential conflicts with the university regarding royalty payments from patents or other intellectual property rights and concerns about confidentiality (3)	○	○	○
4. My company lacks the financial resources to collaborate with universities to explore new knowledge (4)	○	○	○
5. My company does not have an R&D employee capable of accessing universities for new knowledge (5)	○	○	○

6. Lack of proper intermediary organizations to bridge university-industry collaboration (6)	○	○	○
7. Universities would make unwarranted claims (7)	○	○	○

End of Block: SECTION D. Incentives and Barriers in Collaboration with Universities

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Start of Block: SECTION E. Your suggestions for improvement

Q19
Please indicate your suggestions for improving university-industry interactions in this section

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Q20 In your opinion, how important are the following measures to improve your company's relationship/collaboration with university

	Not at all important (1)	Slightly important (2)	Moderately important (3)	Very important (4)	Extremely important (5)
Enhance the access to laboratory facilities and other infrastructure at universities (1)	○	○	○	○	○
Improve the exchange of information between universities and industry (2)	○	○	○	○	○
Foster the university and industry collaboration via informal meetings, talks, communications (3)	○	○	○	○	○
Establish industry-sponsored degree programs (4)	○	○	○	○	○
Provide tax incentives for companies collaborating with universities (5)	○	○	○	○	○
Set up industrial/science parks closer to university campuses (6)	○	○	○	○	○

Encourage academic representation in industrial committees / chambers / boards (7)	○	○	○	○	○

Q21 Apart from the measures above, do you have other suggestions for improving university-industry interactions?

- ○ Yes, please specify (1) _____
- ○ No (2)

End of Block: SECTION E. Your suggestions for improvement

Start of Block: Section F Interview invitation

Q22 Are you willing to participate in an interview?

- ○ Yes (1)
- ○ No (2)

Skip To: End of Survey If Are you willing to participate in an interview? = No

Q25 Please enter your name and email address in the box below if you would like to participate in the interview

Your response will be completely anonymized, and your information will not be mentioned anywhere.

- ○ Name (1) _____
- ○ Email address (2) _____

End of Block: Section F Interview invitation

Notes

[1] One illustration to demonstrate the government's limited interest in developing the I&T sector was the fact that statistical information on R&D activities only began to be collected, and released, in the annual statistical yearbooks beginning from the mid-1990s onward.

[2] The source for OECD data was retrieved from OECD Social Policy Division on November 10, 2019: https://www.oecd.org/els/soc/PF1_2_Public_expenditure_education.pdf. The source for the Hong Kong data was Hong Kong Annual Digest of Statistics (2018 Edition), on p. 267 (Public expenditure by policy area group): https://www.statistics.gov.hk/pub/B10100032018AN18B0100.pdf.

[3] The Chinese University of Hong Kong. (2020). Mission & Vision, Motto & Emblem. Retrieved from https://www.cuhk.edu.hk/english/aboutus/mission.html

[4] University Grants Committee, *University Accountability Agreement (The Chinese University of Hong Kong)*, https://www.ugc.edu.hk/doc/eng/ugc/activity/uaa/CUHK_uaa.pdf.

[5] The Chinese University of Hong Kong (2021). *Invention disclosure form and invention assignment*. https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.orkts.cuhk.edu.hk%2Fimages%2Fcontent%2Fknowledge-transfer%2Fcuhk-technologies%2FForms_and_Guidelines%2F20211007_IDF_Oct2021ORKTS.doc&wdOrigin=BROWSELINK

[6] The Chinese University of Hong Kong (2017). Policy on Research, Intellectual Property and Knowledge Transfer. https://www.orkts.cuhk.edu.hk/images/Research_Funding/IP_Policy_2020.pdf.

[7] According to the General Panel Guidelines of UGC's RAE 2020, 'impact' refers to "the demonstrable contributions, beneficial effects, valuable changes or advantages that research qualitatively brings to the economy, society, culture, public policy or services, health, the environment or quality of life whether locally, regionally or internationally; and that are beyond academia" (**UGC, 2020**: no. 47a)

[8] SCMP Report. (August 14, 2010). PolyU told to rethink commercial activities. *South China Morning Post*, https://www.scmp.com/article/722096/polyu-told-rethink-commercial-activities.

[9] The independent review panel was established by PolyU to to review the operation of its own subsidiaries, associates and jointly controlled entities.

[10] PolyU was able to shut down eleven companies which had a poor performance, but difficulties were encountered in exiting from other JV agreements which did not have an explicit exit clause. The other shareholders were not willing to either buy out the university's share or terminate the JV. Another obstacle encountered was that the JV company failed to provide the updated financial accounts required by the Stamp Duty Office of the Inland Revenue Department for stamping the share transfer documents. Upon the advice of a reputable external law firm and after obtaining the approval of the University Management, PolyU used two offshore companies in British Virgin Island (BVI) to hold the shares of existing JV companies in which PolyU was no longer actively involved. According to PolyU, this was part of its exit strategy, since the regulations governing BVI companies were more flexible, that is to say, there is no stamping required for the transfer of the shares and that BVI companies can be dissolved when circumstances warrant such as failure to file the required documents. PolyU intended to dispose these companies eventually (cf. The Hong Kong Polytechnic University. (May 14, 2016). Report on the BVI-Company Arrangement. Retrieved from https://www.polyu.edu.hk/cpa/BVI_Report/BVI_Report_201605.pdf).

[11] Legislative Council (2012). The Bills Committee on the Hong Kong Polytechnic University (Amendment) Bill 2011 – Minutes of the Third Meeting held on Thursday, 2 February 2012. https://www.legco.gov.hk.

[12] Institute for Entrepreneurship. (2020). Entrepreneurs-in-Residence. Retrieved from https://www.polyu.edu.hk/ife/corp/en/entrepreneurship_dev/entrepreneurs_in_residence.php?refid=15542.

[13] Taking into account the differences between the targeted industries of the science/engineering disciplines and those of the humanities/social science disciplines, PolyU encouraged individual departments to come up with their own KT metrics so as to encourage all faculty to engage in entrepreneurial activities (cf. annual report 2014/15).

[14] 1) Student Entrepreneurial Proof-of-Concept Fund - introduced in 2017, to support student innovations at the pre-seeding stage for building and validating their business/technology prototypes; 2) Good Seed Programme - introduced in 2015 for social innovation programs, funded by the Social Innovation and Entrepreneurship Development Fund of the Hong Kong government; 3) Micro Fund Scheme - introduced in 2011/12, to provide seed funding and pre-incubation funding; 4) Hong Kong Science and Technology Park (HKSTP)-PolyU Tech Incubation Fund (TIF) - launched in 2014, supports early-stage technology start-ups by offering both seed funds (from PolyU) and incubation support (from HKSTP); and, 5) PolyU Tech Launchpad Fund (TLF) - offers "scaled-up" funding to accelerate the growth of qualified ventures by matching dollar-to-dollar investment made by investors up to $2 million

[15] To illustrate, PolyU has granted licenses on a gratis basis, i.e., a nominal fee of HK$1, in order to benefit and create a positive impact on society to two companies, namely, Construction Industry Council promoting the wide adoption of the anti-heat stress workwear, and marine equipment companies to encourage them to manufacture and sell the other one-size-fit-all life jackets for use in Hong Kong's waters. (Anonymous. 2020. Email response from a KT official. December 19.)

[16] Whether or not HKU's proactive emphasis on 'impact' since the start of KT reporting period has directly influenced UGC's decision to incorporate 'impact' as assessment components in the upcoming RAE 2020 exercise is something that cannot be solidly ascertained at this stage. However, certainly HKU has made efforts to recommend the Commission leadership this new measure. The impetus for HKU's engagement with UGC on the inclusion of impact could be traced back to 2014/15 reporting year, when Leeds-HKU Conference was organized in Hong Kong. Speakers invited by HKU were experts in KT who were instrumental in successfully persuading HEFCE (the higher education assessment body in the UK) to include 20% of assessment weightings from UK Research Excellence Framework (REF) – the equivalent of Hong Kong's RAE – from the assessment of KT impact. Having been motivated by the insight shared by these KT experts, the university leadership started to make more active follow-up, such as designating 'impact' as their strategic theme in 2016-2019 triennium, as well as regularly inviting these experts to share their experiences in HKU-organized impact workshops on an annual basis. It was also in this new triennium that the institution's senior management openly suggested to UGC, in the 2016/17 annual KT report, to incorporate 20% of assessment scores for RAE 2020 exercise for impact assessment.

[17] In the context of bureaucratic model, the emphasis is primarily on executing agreed-upon strategies within the limits set upon in the strategic plans. Faculty evaluation reviews illustrate the manifestation of this management model. By contrast, in entrepreneurial model, the senior management's focus is related to securing resources with new approaches. Strategies to promote and maximize KT participation are symbolic examples of this management model.

[18] **Mok (2013)** further added that the consequence of such changes is that research becomes overly valued (by both the universities' senior management and faculty members) at the expense of teaching. As governments and universities take rankings increasingly seriously, they also end up responsible for the proliferating 'publish-or-perish' culture. Furthermore, with performance assessment exercises tied to largely stagnant support resources, competition to obtain research funding is becoming more intense than before.

[19] In their in-depth case study of how an emerging technology (micro-electro-mechanical sensors/MEMS) contributes to economic development in San Francisco Bay Area, **Azagra-Caro et al. (2017)** identified that the actual emergence of the new technology sector commenced long after the expiry of the focal patent protecting this invention. This is largely attributed to an abundance of co-interactions – both formal and informal – among university inventors and industry players that either licensed or cited the focal patent. The inventors' proactive attitude has also been credited as another factor that catalyzed the growth: they set up open laboratories that allow the establishment of spin-offs utilizing the technology.

[20] The annual figure of 7% was obtained based on comprehensive analysis by **Tijssen et al. (2009)** on 350 major global research universities that are listed in CWTS Leiden Ranking.

[21] The Chinese University of Hong Kong (2018). Governance Framework for Subsidiaries and Spin-off Companies from The Chinese University of Hong Kong, Annex 1. http://www.orkts.cuhk.edu.hk/images/CUSSOC_gov_frame.pdf.

[22] The authors further showed that the probabilities of spin-off survival – proxied by their ability to receive external financing (e.g. from major investors and/or VCs) – are highly contingent on the quality of the related university TTOs. From their studies of university spin-offs established between 1997-2003 period, they found that spin-offs from highly-ranked institutions, e.g. Oxford and Cambridge, have a 95% chance of receiving external investments, whereas 1/3 of all surveyed UK universities produced spin-offs that receive no financing from external investors at all.

[23] As suggested by the scholars, there are at least four possible models to drive ecosystem development. The first, and most ideal, pathway is to allow faculty members and experienced entrepreneurs (surrogate entrepreneurs).
[24] "The World's Most Innovative Universities 2016 – University of Washington," Reuters, accessed June 29, 2021, https://www.reuters.com/most-innovative-universities-2016/profile?uid=5.

[25] CoMotion, "University of Washington a Top Performer in Ranking," Press Release, April 20, 2017, https://comotion.uw.edu/news/press-releases/.

[26] "The World's Most Innovative Universities 2016 – University of Washington."

[27] "The World's Most Innovative Universities 2019," Reuters, accessed June 29, 2021, https://www.reuters.com/innovative-universities-2019.

[28] Congressional Research Services, "Federal Research and Development Funding: FY2020," accessed July 17, 2021, https://fas.org/sgp/crs/misc/R45715.pdf.

[29] "About Us," Washington Technology Center, LinkedIn, accessed July 5, 2021, https://www.linkedin.com/company/washington-technology-center.

[30] "Startup Investments," Washington Research Foundation, accessed July 19, 2021, https://www.wrfseattle.org/startup-investments/.

[31] "About Us – History and Overview," Washington Research Foundation, accessed July 5, 2021, https://www.wrfseattle.org/about-us/.

[32] "Venture Center," Washington Research Foundation, accessed July 6, 2021, https://www.wrfseattle.org/about-us/venture-center/.
[33] "About Us," CoMotion, accessed June 30, 2021, https://comotion.uw.edu/about-us/comotion-mission/.

[34] "About Us," CoMotion.

[35] "The World's Most Innovative Universities 2016 – University of Washington."

[36] "CoMotion Innovation Gap Fund," Funding and Competitions, CoMotion, accessed June 30, 2021, https://comotion.uw.edu/funding-and-competitions/programs/comotion-innovation-gap-fund/.

[37] Series A funding is for companies which has achieved a track record such as established user base and stable revenue flow; Series B funding is aimed at taking a business firm to the next level beyond the development state; Series C funding is meant to help an already quite successful company to develop new products, expand to new markets, or acquire another company. (cf. See endnote 9)

[38] "Series A, B, C Funding: How it works," Investopedia, accessed June 30, 2021, https://www.investopedia.com/articles/personal-finance/102015/series-b-c-funding-what-it-all-means-and-how-it-works.asp.)

[39] "WE-REACH," Funding and Competitions, CoMotion, accessed June 30, 2021, https://www.washington.edu/we-reach/funding_resources/.

[40] CoMotion, "UW's new WE-REACH center to accelerate development of the 'most exciting' biomedical discoveries," *Press Release*, January 31, 2020, https://comotion.uw.edu/news/press-releases/.

[41] "Commercialization Fellows Program," Funding and Competitions, CoMotion, accessed June 30, 2021, https://comotion.uw.edu/funding-and-competitions/programs/commercialization-fellows-program/.

[42] "Public Funding for Innovation," What We Do, CoMotion, accessed June 30, 2021, https://comotion.uw.edu/funding-and-competitions/public-funding-for-innovations/.

[43] "About Us," CoMotion.

[44] "What We Do," CoMotion, accessed June 30, 2021, https://comotion.uw.edu/innovation-training/.

[45] "CoMotion Mentoring," What We Do, CoMotion, accessed June 30, 2021, https://uwcomotion.chronus.com/pages/programs.

[46] "CoMotion Labs," What We Do, CoMotion, accessed June 30, 2021, https://comotion.uw.edu/startups-incubation/comotion-labs/.

[47] CoMotion, "Innovation District Grows with Opening of New UW CoMotion Headquarters Building," *Press Release*, June 30, 2016, https://comotion.uw.edu/news/press-releases/.

[48] University of California, "Faculty Code and Governance," Appointment and Promotion of Faculty Members (Chapter 24), accessed August 31, 2021, https://www.washington.edu/admin/rules/policies/FCG/FCCH24.html.

[49] University of California, "Faculty Code and Governance."

[50] "Intellectual Property (IP) Guide," Intellectual Property, CoMotion, accessed June 30, 2021, https://comotion.uw.edu/intellectual-property/ip-guide/.

[51] "Student IP Ownership," Intellectual Property, CoMotion, accessed June 30, 2021, https://comotion.uw.edu/intellectual-property/ip-guide/student-ip-ownership/.

[52] UC Berkeley also have similar licensing agreements, namely, letter of intent and option agreement.

[53] "Option and Evaluation Licenses," Licensing, CoMotion, accessed June 30, 2021, https://comotion.uw.edu/licensing/option-evaluation-licenses/.

[54] "Material Transfer Agreements," What We Do, CoMotion, access July 2, 2021, https://comotion.uw.edu/licensing/material-transfer-agreements/.

[55] CoMotion, "University of Washington celebrates 40th anniversary landmark Bayh-Dole Act with the launch of Husky FAST Start Licensing," *Press Release*, December 9, 2020, https://comotion.uw.edu/news/press-releases/.

[56] "Express Digital Content," What We Do, CoMotion, accessed July 2, 2021, https://els2.comotion.uw.edu/.

[57] "Startup Portfolio," Innovation, University of Washington, accessed July 2, 2021, https://www.washington.edu/innovation/.

[58] "University of Washington," World's Most Innovative Universities 2016, Reuters, accessed September 3, 2021, https://www.reuters.com/most-innovative-universities-2016/profile?uid=5; "University of Washington," World's Most Innovative Universities 2017, Reuters, accessed September 3, 2021, https://www.reuters.com/innovative-universities-2017/profile?uid=7; "University of Washington," World's Most Innovative Universities 2018, Reuters, accessed September 3, 2021, https://www.reuters.com/innovative-universities-2018/profile?uid=5; "The

World's Most Innovative Universities 2019, accessed September 3, 2021, https://www.reuters.com/innovative-universities-2019.

[59] "Products," Express Digital Content, CoMotion, accessed July 6, 2021, https://els2.comotion.uw.edu/.

[60] "Start-up Portfolio," Innovation, University of Washington, accessed July 3, 2021, https://www.washington.edu/innovation/startups/.

[61] "Our Work," Washington Technology Alliance, accessed July 5, 2021, https://www.technology-alliance.com/our-work.

[62] University of London system, at present, comprises of 17 universities, colleges, specialized schools, and research institutes, namely Birkbeck University of London, City University of London, Courtauld Institute of Art, Goldsmiths University of London, Institute of Cancer Research, King's College London, London Business School, London School of Economics and Political Science, London School of Hygiene and Tropical Medicine, Queen Mary University of London, Royal Academy of Music, Royal Central School of Speech and Drama, Royal Holloway University of London, Royal Veterinary College, School of Oriental and African Studies, St George's University of London, and University College London.

[63] With regard to teaching, faculty assessment and promotion committees carefully consider these categories as follows: 1) Effectiveness and innovation in the delivery of course content; 2) Conferral of teaching awards in the past; 3) Participation in national and/or international education committees; 4) Involvement as a senior tutor at department level, and; 5) Supervision of research postgraduate students. In the case of research, the relevant categories taken into account are: 1) Quality and quantity of research output; 2) Consistent track record in receipt of funding grants; 3) Receipt of scientific prizes, medals, or awards; 4) Prestigious lectures; 5) Participation in editorial boards of scientific journals, and; 6) Membership in national and/or international science and research committees. Last but not least, in the leadership and management dimension, the committees examine these indicators as follows: 1) Design and leadership capabilities in research and/or teaching programs; 2) Staff management skills; 3) Proactive participation in staff development activities, and; 4) Positive reviews in terms of decision-making and problem-solving skills.

[64] There is some additional consideration with regard to leave policy. For faculty members who are also supervising postgraduate students, they must discuss arrangements on the students with either postgraduate tutor or director of postgraduate studies. In the case of academic staff with college duties (e.g. heads of a college committee), those wishing to apply for leave of absence must also discuss arrangements with their respective faculty deans. When the applicant is a head of department or division, he/she must also receive consent from the dean of the faculty the staff is currently in. Finally, for faculty members who also hold position as wardens of residence halls, they must receive approval from Vice Provost of Education with a full, written justification, and their leave of absence is limited to 10 days for each academic term (semester).

[65] The College also provides other types of leave (beyond leave of absence, sabbatical leave, and unpaid leave), namely compassionate leave, parental bereavement leave, domestic emergencies leave, family emergencies leave, parental leave, public duties leave, jury service leave, witness duty leave, volunteer reserve forces service leave (for those who are armed force reservists), and study leave.

[66] There are also several conditions by which College members need not register them as 'external interests', but nonetheless are still required to include them under the 'annual declaration' policy. These situations are namely: 1) when ICL staff perform academic duties at other universities / colleges / higher-education institutions in any form; 2) the editorship held by the individual in an academic journal, and; 3) the circumstance by which College staff also engage in any casual work within the College premises (such as retail, bar, etc).

[67] IP Group plc also invests in spin-offs originating from research at universities (primarily Oxford, Cambridge, ICL, and UCL, but currently also inclusive of spin-offs from other universities in the UK, and more recently, those in the US and Australia). At present, their portfolio includes stakes at 4 Imperial College spin-offs.

[68] As a matter of comparison, for Hong Kong universities, the latest RAE 2020 exercise, which has recently been concluded, assigned a weighting of 15% for research impact in the assessment of universities' research performance. **Hockaday (2020)** further added that in the latest REF 2021 exercise for UK universities, portions

of assessment attributed to impact has been raised from 20% to 25%. [Just a caveat, but you don't need to include in the write-up: RAE 2020 informs only about 12.5% of the Block Grant allocated by UGC to universities for research. That is why, if you recall, in the Task 1 interviews, some remarked that RAE 2020 did little to motivate faculty engage in knowledge transfer.]

[69] Imperial Innovations was publicly listed in London Stock Exchange in 2006, in effect becoming the first university technology transfer-oriented company to be traded on a stock exchange. However, below the surface, there appeared to be some issues with Imperial Innovations afterward. A 2017 article by Financial Times mentioned that the company's stock performance has been less than satisfactory, given the reason that IP commercialization companies often experience highly uncertain returns due to the speculatory nature of novel technologies introduced by university spin-offs. Furthermore, Imperial Innovations was perceived to have a hostile relationship with IP Group plc, which was founded originally as a technology transfer unit of the Department of Chemistry of the University of Oxford (**Hockaday, 2020**). In the same year that the article was released, Imperial Innovations changed their name into "Touchstone Innovations", which was eventually acquired by IP Group plc. In the aftermath of these events, ICL once again 're-launched' their technology transfer unit (also renamed Imperial Innovations), in what was essentially a 'start-from-scratch' moment.

[70] Currently, UC has ten campuses: UC Berkeley, UC San Davis, UC Irvine, UC Los Angeles, UC Merced, UC Riverside, UC Santa Barbara, UC San Diego, UC San Francisco, UC Santa Cruz. UC also manages three national labs for the U.S. Department of Energy, one of which is Lawrence Berkeley National Laboratory.

[71] It is the first foundation in the U.S.A. exclusively for the advancement of science. As a private foundation, it provides funding for basic research in the physical sciences at colleges and universities (https://rescorp.org/rcsa/about).

[72] Berkeley Computer Corporation was established in the late 1960s by Melvin W. Pirtle, Butler Lampson, Chuck Thacker, and L. Peter Deutsch, young technical leaders who had previously worked for Project Genie, a computer research project at UC Berkeley. The company went bankrupts after the 1969-70 recession.

[73] This office was also known, particularly between 2009 and 2015, as Innovation Alliances and Services (cf. UC's Technology Transfer/Commercialization Reports). Prior to being named Innovation Alliances and Services, it was called the Office of Technology Transfer (cf. UC's Technology Transfer Report 2009)

[74] "UC Discovery Grant," Research Initiatives, University of California, accessed May 17, 2021, https://www.ucop.edu/research-initiatives/programs/innovation-opportunities/discovery-grant.html,

[75] See also "Assembly Bill no. 2664, Chapter 862," California Legislative Information, accessed May 14, 2021, https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160AB2664.

[76] UC Office of the President, "UC Statement on Gov. Newsom's 2021-22 revised budget," *News*, May 14, 2021, https://www.universityofcalifornia.edu/press-room/uc-statement-governor-newsom-s-2021-22-revised-budget.

[77] "UC Investments," Overview, UC Office of the President, accessed May 13, 2021, https://www.ucop.edu/investment-office/.

[78] Bay Area Council Economic Institute, "Entrepreneurs, Startups, and Innovation at the University of California," August 2016, http://www.bayareaeconomy.org/report/entrepreneurs-startups-innovation-at-uc/.

[79] Bay Area Council Economic Institute, "Entrepreneurs, Startups, and Innovation," p. 11.

[80] "Research Policy Analysis and Coordination," Overview, UC Office of the President, accessed May 13, 2021, https://www.ucop.edu/research-policy-analysis-coordination/.

[81] "Our Commitment," Innovation and Entrepreneurship, University of California, accessed May 13, 2021, https://www.universityofcalifornia.edu/initiative/innovation-and-entrepreneurship-initiative/our-commitment.

[82] "UC Legal," Overview, UC Office of the President, accessed May 13, 2021, https://www.ucop.edu/uc-legal/.

[83] "Knowledge Transfer Office," Overview, UC Office of the President, accessed May 5, 2021, https://www.ucop.edu/knowledge-transfer-office/. The website provides, among others, information about UC technologies available for licensing.

[84] Bay Area Council Economic Institute, "Entrepreneurs, Startups, and Innovation at the University of California," August 2016, http://www.bayareaeconomy.org/report/entrepreneurs-startups-innovation-at-uc/.

[85] "About Us," UC Berkeley IPIRA, accessed May 5, 2021, https://ipira.berkeley.edu/about-us.

[86] Bay Area Council Economic Institute, "Entrepreneurs, Startups, and Innovation," p. 19.

[87] The other two initiatives are Calit2 (California Institute for Telecommunications and Information Technology) and CNSI (California NanoSystems Institute).

[88] "Knowledge Transfer Advisory Committee," Knowledge Transfer, UC Office of the President, accessed May 5, 2021, https://www.ucop.edu/knowledge-transfer-office/innovation/technology-transfer-advisory-committee.html.

[89] "Knowledge Transfer Advisory Committee," UC Office of the President, Knowledge Transfer Office, accessed May 15, 2021, https://www.ucop.edu/knowledge-transfer-office/innovation/technology-transfer-advisory-committee.html.

[90] "Innovation and Entrepreneurship," University of California, Office of the President, accessed May 15, 2021, https://www.universityofcalifornia.edu/entrepreneurs.

[91] University of California, "Compendium of Conflict of Interest and Integrity Policies – Guidance," Office of the President, effective May 22, 2018, https://policy.ucop.edu/doc/1200679/CompendiumCOIPoliciesGuidance.

[92] "1) Universities should reserve the right to practice licensed inventions and to allow other non-profit and governmental organizations to do so; 2) Exclusive licenses should be structured in a manner that encourages technology development and use; 3) Strive to minimize the licensing of future improvements; 4) Universities should anticipate and help to manage technology transfer related conflicts of interest; 5) Ensure broad access to research tools; 6) Enforcement action should be carefully considered; 7) Be mindful of export regulations; 8) Be mindful of the implications of working with patent aggregators; 9) Consider provisions that address unmet needs..." (Association of University Technology Managers, "Nine Points to Consider in Licensing University Technology," March 6, 2007, https://www.autm.net/AUTMMain/media/Advocacy/Documents/Points_to_Consider.pdf.)

[93] 'Patent troll' is a derogatory term for a type of patent aggregators who acquire patents that broadly cuts across one or more technological fields, but instead of developing these technologies, their intention is to stifle competition or to use patent infringement claims to win court judgements for profit. The other type of patent aggregators, i.e., the 'good' type, refers to patent licensees who assemble a portfolio of patents related to a particular technology to enable them to offer a complete package to a secondary licensee, in so doing contributes to the successful development of technologies.

[94] "1) The primary objective in developing a patenting and licensing strategy for an invention should be to support the education, research, and public benefit mission of the University; 2) University must meet existing third party obligations; 3) The selected licensee should be capable of bringing the invention to the marketplace; 4) The license agreement should include diligence terms that support the timely development, marketing, and deployment of the invention; 5) The University should receive fair consideration in exchange for the grant of commercial licensing rights; 6) The license should support the academic principles of the University; 7) Licensing activities should be carried out within delegated authority; 8) The license agreement should be approved as to legal integrity and consistency; 9) All decisions made about licensing University inventions should be based upon legitimate institutional academic and business considerations and not upon matters related to personal financial gain; 10) Making the distribution of innovation in technology as wide as possible" (University of California, "University Licensing Guidelines," revised January 2, 2012, https://www.ucop.edu/research-policy-analysis-coordination/_files/licensing_guidelines_2012.pdf.)

[95] University of California, "Patent Policy," Knowledge Transfer Office, issued January 10, 1997, https://policy.ucop.edu/doc/2500493/PatentPolicy.

[96] University of California, "Benefits and Privileges – Leaves of Absence/Other Leaves Without Pay (Academic Personnel Manual-759)," revised December 14, 2000, https://www.ucop.edu/academic-personnel-programs/_files/apm/apm-759.pdf.

[97] "EECS Faculty Leave Policy," Berkeley Electrical Engineering and Computer Sciences, last updated April 2015, https://eecs.berkeley.edu/resources/faculty-staff/academic-personnel/faculty-leave-policy.

[98] "EECS Faculty Leave Policy," Berkeley Electrical Engineering and Computer Sciences.

[99] Belgium is a federal state that primarily comprises of three first-level administrative divisions, also known as 'regions': Flemish Region (Dutch-speaking territory), Walloon Region (French-speaking territory), and Brussels-Capital Region (Brussels being the capital of the federal state). Each of the regions enjoys a high degree of autonomy, which explains the preponderance of funding and other support schemes at KU Leuven that are mainly from Flemish regional government.

[100] VLAIO also provides other options with which researchers from KU Leuven and other universities in the Flemish region can utilize, such as their 'Spearhead Clusters' (e.g. SIM, CATALISTI, Flanders' Food, VIL, Blauwe Cluster, FLUX 50, etc), SCK-CEN (research center focused on nuclear sciences), and international collaboration programs (ERANET, EUREKA, CORNET, AAL, ITEA, etc). Meanwhile, FWO's research is primarily centered on research infrastructure support services for academic researchers.

[101] Being a research professor does not exempt individuals holding this position from teaching obligation, however. As mandated by Belgian law, research professors are still required to perform teaching duties, but their amount of work is considerably more limited than that of their regular faculty-track counterparts. In this regard, research professors are only entitled to up to 4 hours of teaching per week in their 1st year, and at most 1 day a week in their 2nd year. Progressively, the number of teaching hours is increased up to a point where they reach parity with that of regular faculty members.

[102] In KAMEA program, TAU does not provide any financial support to the hired immigrant scientists. Instead, the program only facilitates external funding support by KAMEA's partners for these scientists.

[103] The 2009 Annual Report highlighted the intense negotiation processes between Israel's university presidents and the Ministry of Finance, which determines and administers the allocation of annual budget from the government. Since 2002, the Ministry has enacted a series of ongoing budget cuts on the country's annual education expenditure, with the report estimating the 2009 education budget has been 20% lower than the annual expenditure in the seven years prior. The Ministry of Finance insisted that they would not approve an increase in education budget unless the universities increased student tuition fees, which was a non-starter given that Israel was heavily impacted by the global financial crisis, economic slowdown, as well as 2009 war in Gaza Strip. It was only when the university presidents – in a collective show of force, including TAU's then-president – threatened to cancel the entire academic year (which, had it happened, could have meant neither research nor teaching activities for a whole year) that the Ministry made concessions to the academic sector. Furthermore, as TAU's philanthropic sources dried up due to the fallout from Bernie Madoff investment scandal that affected many of Israel's major financial trusts, the university's top leaders decided to take a 5% pay cut of their own salaries to partly offset financial difficulties that TAU was facing.

[104] With specific regard to the 20% weighting for funding performance, the interviewee explained that tenure committees distinguished the performance of newly-hired scientists and senior faculty members. The former tend to have higher success rates than the latter in obtaining funding grants due to the availability of special funding programs for early-stage faculty members, but a 'grace period' (normally lasting for 5 years) applies to these early-career academics. Beyond the grace period, these faculty members must have success records in applying for the second, and more competitive, round of funding. Their success in securing competitive grants in the second funding round is a major bonus for the 20% funding criteria assessed by the tenure committees.

[105] Faculty members who would like to apply for unpaid leave must submit their applications to the Rector 8 months in advance (before the commencement date of the proposed leave). The Rector has the final say over the

status of the applications. Unpaid leave is normally disbursed to TAU academics in batches of 6 months, for a period no longer than two consecutive years. In case the faculty members are taking up public office or government posts, the Rector allows the unpaid leave period to be doubled up to four consecutive years.

[106] According to the Invention, Patent, and Commerialization Regulation (Directive Number: 01-003(B), as of July 12, 2015), TAU defines an invention as "an invention or discovery, whether the invention or discovery is a product or a process, or whether it is novel use of an existing invention or discovery, or whether it is tangible research results, and including know-how; technology; a method; a development; an organism; transgenic animals; genetic material and other biological material; a composition of substances; a chemical compound; an apparatus; a machine; hardware; a chemical substance; an algorithm; software; an integrated circuit; mask works; a plant strain or species; and any other research result (including a result constituting an enhancement or improvement of an existing invention or discovery), but excluding a result constituting a work which is the subject of copyright protection, when in this regard an algorithm, software, integrated circuit, and mask works will not be regarded as works subject to copyright protection".

[107] The Regulation highlights two possible scenarios by which faculty members engaged in outside work with for-profit companies inappropriately disclose university IP or content of university research to their partners. First, this occurs when inventions based on the researchers' work in the companies are granted to other entities or organizations beyond TAU (Ramot) due to the companies' requirement. Second, there is the possibility of researchers signing agreements with the companies – unbeknownst to the university – which contain terms that allow the assignment of subsequent patents to their partners, not the university.

[108] Source: UTokyo Division of University Corporate Relations website, https://www.ducr.u-tokyo.ac.jp/en/organization/organization.html

[109] Resource from: https://www.ducr.u-tokyo.ac.jp/content/400059598.pdf

[110] Resource from: Homepage of IOI, Institute for Open Innovation: https://www.ioi.t.u-tokyo.ac.jp/en/

[111] Resource from: https://www.ducr.u-tokyo.ac.jp/en/organization/intellectual_property.html

[112] (Resource from: https://todaitlo.com/en/company

[113] Resource from: https://todaitlo.com/en/company

[114] Resource from: https://www.ducr.u-tokyo.ac.jp/en/activity/venture/incubation/index.html

[115] "Current Status of Full-time Faculty Research Projects Funding", Stats & Report, Research, SNU, accessed June 7, 2021, https://en.snu.ac.kr/research/activities

[116] "Current Status of Full-time Faculty Assignments", Stats & Report, Research, SNU, accessed June 7, 2021, https://en.snu.ac.kr/research/activities

[117] "Current Status of Full-time Faculty Thesis", Stats & Report, Research, SNU, accessed June 7, 2021, https://en.snu.ac.kr/research/activities

[118] "Part of Research Fund Central Management," Research Management, SNU R&DB Foundation, accessed August 20, 2020, https://snurnd.snu.ac.kr/en/?q=node/194.

[119] "IRP Management", IP Management, SNU R&DB Foundation, accessed August 20, 2020, https://snurnd.snu.ac.kr/en/?q=node/28

[120] "Technology Licensing", Technology Licensing & Commercialization, SNU R&DB Foundation, accessed August 20, 2020, https://snurnd.snu.ac.kr/en/?q=node/33

[121] "R&D Education Center", R&D Education, SNU R&DB Foundation, assessed August 20, 2020, https://snurnd.snu.ac.kr/en/?q=node/197

[122] "Research Funds", SNU R&DB Foundation, accessed May 21, 2021, https://snurnd.snu.ac.kr/?q=node/49

[123] "Technology Licensing", Technology Licensing & Commercialization, SNU R&DB Foundation, accessed August 20, 2020, https://snurnd.snu.ac.kr/en/?q=node/33

[124] Seoul National University, "Seoul National University Royalty Distribution Guidelines", 2015, https://snurnd.snu.ac.kr/en/sites/default/files/board/materials/%2812%298.%20Seoul%20National%20University%20Royalty%20Distribution%20Guidelines%28Revised%20on%20February%2023%2C%202015%29.pdf

[125] Seoul National University, "Seoul National University Royalty Distribution Guidelines", 2015, https://snurnd.snu.ac.kr/en/sites/default/files/board/materials/%2812%298.%20Seoul%20National%20University%20Royalty%20Distribution%20Guidelines%28Revised%20on%20February%2023%2C%202015%29.pdf

[126] Overview, Artificial Intelligence Institute SNU, accessed May 26, 2021, https://aiis.snu.ac.kr

[127] Overview, SNU Startup Incubation Center, accessed May 26, 2021, https://startup.snu.ac.kr/

[128] Overview, SNU Engineering Consulting Center, accessed May 26, 2021, http://snuecc.snu.ac.kr/

[129] "Ideadfactory", Overview, SNU Engineering Consulting Center, accessed May 26, 2021, http://snuecc.snu.ac.kr/ideafactory/

[130] "Gongzone34", Overview, SNU Engineering Consulting Center, accessed May 26, 2021, http://snuecc.snu.ac.kr/gongzone34/

[131] "SISP", Overview, SNU Engineering Consulting Center, accessed May 26, 2021, http://snuecc.snu.ac.kr/SISP/

[132] Overview, Artificial Intelligence Institute SNU, accessed May 26, 2021, https://aiis.snu.ac.kr

[133] Building Beyond Tomorrow, National University of Singapore, https://nus.edu.sg/annualreport/

[134] Academic Appointments. NUS. https://www.nus.edu.sg/careers/acadappt.htm

[135] Uncovering the Power of Innovation. Unbound, https://www.unbound.live/about

[136]Typical cases of strengthening intellectual property management of achievements in Beijing, 2021, accessed July 25, 2022, http://www.echinagov.com/news/310185.htm

[137] "Granted patents": Patents that have been certified by the China National Intellectual Property Administration.

[138] "Valid patents": Patents are still in the legal protection period after granted. For example, the patentee needs to pay the annual fee according to the regulations.

[139] "Well-cited": The Institute of Science and Technology Information of China proposed that in each discipline field, the number of a paper cited is higher than the world average of the number of papers cited should be regarded as an "well-cited" paper.

[140] High-technology companies certificated by the national government means those companies that conform to the administrative measures for the identification of high-tech enterprises issued by the Ministry of Science and Technology of China.

[141] Yuri Milner is an Israeli-Russian billionaire who was instrumental in the creation of Mail.Ru, Russia's first home-grown social media company. He is also a venture capitalist and founder of DST Global, which has provided financing support for the world's major social-media giants, notably Facebook and Twitter. DST Global's main offices are located in three different countries: United States (Silicon Valley and New York City), United Kingdom (London), and China (Beijing and Hong Kong). Further reading: Olson, P. (September 28, 2017). A Q&A With Internet Guru Yuri Milner: Moving On From Russia And The Future Of E-Commerce. Forbes, link retrieved from https://www.forbes.com/sites/parmyolson/2017/09/28/yuri-milner-russia-dst-facebook-e-commerce/?sh=844f77a7339e.

[142] All the major start-up unicorns mentioned above are located outside Hong Kong. For further elaboration: Spotify is headquartered in Stockholm (Sweden), Zoom in Silicon Valley (United States), Flipkart in Bangalore (India), Alibaba in Hangzhou, Zhejiang (China), and Xiaomi in Beijing.

[143] While Beijing ranked first globally in the Nature Index 2020 ranking, Chinese cities – in aggregate – only occupied 3 of the top-10 position (the other two being Shanghai and Nanjing). The United States, in aggregate, continues to possess the largest number of science hubs, both within the top-10 position (in which there are 5 such regions), and 55 within the entire list (N = 200). In comparison, Mainland China has, in total, 27 such science hubs. The 5 biggest US-based hubs in the top-10 position are: New York metropolitan area, Boston metropolitan area, San Francisco-San Jose (Silicon Valley), Baltimore-Washington agglomeration, and Los Angeles metropolitan area. The other two hubs within the list are: Tokyo metropolitan area (Japan) and Paris metropolitan area (France).

[144] BOE Technology Group, originally known as Beijing Oriental Electronics, was established in 1993 as a result of privatization – and eventual merger – of multiple electronics-component factories and spin-offs from several leading research institutes based in Beijing: North China Radio Equipment Joint Factory, Beijing Cable Power Factory, North China Institute of Optoelectronics, Beijing Institute of Vacuum Electronics, and Beijing Dongguang Electronics Factory. The privatization was made possible upon the approal by Beijing Economic System Reform Office in that year. The new company was founded, and is currently led, by Wang Dongsheng. In addition to their specialization in liquid crystal display (LCD), organic light-emitting displays (OLED), and flexible displays, the company has also begun expanding aggressively into the area of Internet-of-Things (IoT) devices, particularly in smart display technologies. Their ambitious efforts at innovation paid off: by 2018, BOE ranked first worldwide in terms of the number of shipments for: 1) smartphone LCD displays, 2) computer tablet displays, 3) notebook/laptop displays, 4) monitor displays, and; 5) TV displays. More information is on the archived webpage on BOE's company information: https://web.archive.org/web/20200807234408/https://www.boe.com/about/gsjs/pag.html.

[145] As of 2020, BOE Technology Group has also accumulated a total of 70,000 patents (inclusive of patent grants and patent applications under review). 65% of these patents happen to be domestically-filed – mainly to China's State Intellectual Property Office (SIPO), with the remaining 35% filed to overseas patent offices, e.g. USPTO, EPO, JPO, etc. Of domestic patents, most of them were filed under the invention-patent category, which is equivalent to USPTO's utility-patent model. Furthermore, in 2021 alone, BOE had secured a total of 2,135 USPTO patent grants, making the company as one of the top-50 companies globally in terms of patent assignment. Further reading: IFI Claims Patent Services. 2021 Top 50 US Patent Assignees. Link retrieved from https://www.ificlaims.com/rankings-top-50-2021.htm.

[146] Readers can observe a major truncation pattern in post-2015 patent filings. This pattern does not indicate Beijing's declining role as an innovation hub in recent years; rather, such phenomenon is due to the fact that a significant proportion of patent applications – especially those in recent years (from 2016 onward) – are still under review by patent examiners at USPTO, many of which are yet to be granted (or even when they have been granted, they are yet to be updated in the PatentsView database, which we utilize to obtain our data). As Griliches et al. (1986) have pointed out, truncation is a recurrent issue that many other patent-related studies have dealt with. Read: Griliches, Z., Pakes, A., and Hall, B. H. (1986). The value of patents as indicators of inventive activity. NBER Working Paper No. 2083. Link retrieved from: https://www.nber.org/system/files/working_papers/w2083/w2083.pdf.

[147] Lenovo achieved its initial success given their risk-taking approach in introducing China's first simplified Chinese-friendly computer keyboards and non-state manufacturing of personal computers (PCs), at a time when non-state activities were often treated by state apparatus with skepticism and suspicion. While the company's success endeared it towards favorable state treatment, their ongoing reliance on state procurements in driving Lenovo's revenue ended up significantly slowing down their innovation activities. Despite their multiple acquisitions of foreign technology firms (most notably with IBM's personal computer division), the company's absorptive capacities remained limited by the time Fuller conducted in-depth interviews with industry executives and other business professionals within mainland China. It was only from 2013-2018 period onward (beyond the purview of Fuller's period of analysis) that Lenovo began to invest more significantly in R&D and enriching their absorptive capacities.

[148] Spin-offs generated from research institutes and universities in China, back in the 1980s and 1990s, were quite different from those studied in the West. In terms of institutional structure, these spun-off enterprises remained state-owned, but were privately run (by the scientists formerly in charge of the original research labs that generated those spin-offs in the first place). Moreover, the spin-offs were created out of economic and financial necessity, as the Chinese central government had substantially cut these organizations' research budget, forcing the latter to 'release' those research units, and push them to survive and thrive on their own.

[149] Tsinghua and Hon Hai-Foxconn establish and operate a joint research center ("Tsinghua-Foxconn Nanotechnology Research Center"), but our investigation from Nature Index appears to demonstrate that outputs from the research center have been declining in recent years. Link: https://www.natureindex.com/institution-outputs/china/tsinghua-foxconn-nanotechnology-research-center/5361a3f3140ba0fd32000000.

[150] Temasek Holdings is one of Singaporean government's two major sovereign wealth funds (SWFs) – the other being the Government of Singapore Investment Corporation (GIC), and is one of the largest such funds in the world. The company has actively invested in numerous technology start-ups across Singapore and the globe.

[151] Beyond Shenzhen, other first-batch SEZs include Shantou (Guangdong), Zhuhai (Guangdong), and Xiamen (Fujian). The opening-up of these zones was primarily intended to attract overseas capital from neighboring countries and/or regions; Shenzhen and Zhuhai were designated as SEZs in order to attract investors from Hong Kong and Macau, while Shantou's designation was intended to attract overseas Chinese entrepreneurs and business groups in Southeast Asian countries, many of whom could trace their ancestral origins to the city; Xiamen's designation, simultaneously, was aimed to attract both Taiwanese and Southeast Asian capital.

[152] In the original book, O'Donnell et al. (2017) primarily highlighted 3 stages of events, instead of 4.

[153] The idiosyncrasies of Shenzhen's enterprise-driven innovation system have received considerable attention by the central government to the point that the National Development and Reform Commission (NDRC) subscribed to the "four 90%" features when characterizing the city's innovation ecosystem: 1) over 90% of talents are recruited and employed by enterprises; 2) more than 90% of research funding is contributed by enterprises; 3) more than 90% of existing research institutes are established by enterprises, and; 4) more than 90% of patent applications are filed by enterprises.

[154] Before the relocation, there was a significant internal division among the scientists and the management team regarding the notion of moving to Shenzhen. In addition, another factor that motivated BGI to relocate is related to pecuniary motives: Shenzhen municipal government offered substantial resources and generous support for the organization in case they decided to relocate.

[155] One of Kuang-Chi's main co-founders is Ruopeng Liu, at present also the company's main leader. He received his undergraduate education at Zhejiang University, followed by a PhD in Duke University in the United States, in which his primary research was centered on metamaterials, best exemplified – colloquially – by 'invisible cloaks'. Nevertheless, there have been controversies surrounding the founding of Kuang-Chi, as some in the US – and in which even Federal Bureau of Investigation (FBI) was involved – alleged that Liu might have engaged in research espionage by 'replicating' the entire laboratory of his then-supervisor, David Smith (a major pioneer of metamaterials), back into China. Further reading: McFadden, C., Nadi, A., and McGee, C. (July 24, 2018). 'Education or espionage? A Chinese student takes his homework home to China'. NBC News, link retrieved from https://www.nbcnews.com/news/china/education-or-espionage-chinese-student-takes-his-homework-home-china-n893881.

[156] One major challenge with identifying assignees related to Hon Hai-Foxconn is to look into different names of the Taiwanese industry conglomerate's subsidiaries. Their patent filings often show up in the database with a wide variety of company names, such as Hon Hai Precision, Hong Fu Jin, Foxconn, FIH, Fu Zhun Precision, Futaihong Precision, Innocom Technology, etc. In order to match their distinctive names to the parent company, we reviewed Hon Hai-Foxconn's annual corporate reports, in which they provided elaboration on the annual performance of their affiliate companies.

[157] Mayer's in-depth analysis was based on his case studies of three innovation hubs in the United States, namely: Portland (Oregon), Boise (Idaho), and Kansas City (Missouri). While these three metropolitan regions do not possess highly-ranked research-intensive universities with similar stature as MIT or Stanford, they host dense

clusters of innovative technology companies, particularly in ICT-related areas. Boise provides the best illustration as it serves as the global headquarters of Micron Technology, one of the world's largest semiconductor firms.

[158] The 2021-2025 STI Five-Year Plan also envisions that Shenzhen's GDP will over 40% within the five-year planning period, from RMB2.8 trillion (approx. US$440 billion) in 2021 to RMB4 trillion (approx. US$628 billion) by 2025. The municipal authorities aim to drive the city's GDP growth from emerging, high-tech industries such as artificial intelligence, 6G Internet (as successor to 5G), quantum computing, autonomous vehicles, and intelligent networks supporting smart city-related technologies.

[159] These municipalities also comprise part and parcel of the 11-city Greater Bay Area initiative that was introduced by the Chinese central government in early 2019. Beyond the eight cities already listed, the initiative also incorporates Shenzhen, Hong Kong, and Macau. Further information: Greater Bay Area Initiative. Link retrieved from https://www.bayarea.gov.hk/en/home/index.html.

[160] Tencent may be indirectly described as a 'spin-off' of Shenzhen University (SZU), but its establishment – all by SZU alumni – had nothing to do with research taking place at the university. The founders, namely Ma Huateng, Tony Zhang, Xu Chenye, Chen Yidan, and Zeng Liqing, worked at various Chinese companies for several years before establishing the company in 1998.

[161] CRISPR method (and in this case, utilizing bacteria to ward off viruses given their antiviral property) has long been applied in industry settings before Doudna and Charpentier's breakthrough. This finding was based on a 2005 paper by French researchers Rodolphe Barrangou and Philippe Horvath, when both were employed as industry scientists in Danisco, a Danish multinational food and beverage company. Barrangou subsequently left Danisco to pursue PhD in the United States; at present, he is a professor of chemistry at North Carolina State University (NCSU).

[162] Specifically, the authors took issue with He's approach of disabling CCR5 gene, which was considered to be responsible for heightening the risks of HIV infection for fetuses from HIV-positive parents. The authors voiced concern about the potential debilitating impacts of CCR5 gene disabling, especially for East Asian people. The authors further argued that altering CCR5 composition (e.g. disabling the gene) does not immediately lead to better protection for affected people by HIV strains. This issue has also been brought up in Walter Isaacson's 2021 book, The Code Breaker.

[163] TCL, unlike other technology firms, was both founded – and remains headquartered – in Huizhou, Shenzhen's neighboring city to the east. Nevertheless, given the very close proximity between Shenzhen and Huizhou, TCL operates manufacturing, research, and distribution facilities in these localities.

[164] Zhang (2012) provided three further examples in his article on Shenzhen's primary role as an 'experimental laboratory' in China's oftentimes contentious market reform process, and these include: 1) the implementation of China's first, Hong Kong-inspired flexible, contract-based labor and wage model in early 1980s; 2) the establishment of China's first stock exchange in 1990 (when regulation governing capital market was still very tight throughout the rest of the country), and; 3) the development of China's first semi-privatized housing market, in which the country's real estate industry began to boom afterwards. Zhang's case study also overlapped with extensive case studies by O'Donnell et al. (2017).

[165] Shanghai municipality, in China's administrative taxonomy, is placed at the same first-level administrative division level as other provinces and autonomous regions. It is also one of the country's four directly-governed municipalities (the other three being Beijing, Tianjin, and Chongqing), in the sense that mayoral and party secretary appointments in these places are directly determined by the Chinese central government.

[166] Neighboring cities for which their enterprises, having collaborated with Fudan and SJTU researchers, would be considered as instances of university-industry collaboration, are: Nanjing, Suzhou, and Wuxi (in Jiangsu province), followed by Hangzhou and Ningbo (in Zhejiang province). Shanghai has been increasingly well-connected with its neighboring cities, thanks to the widespread proliferation of inter-city high-speed railway networks in recent years.

[167] Morningside Venture Capital was established in 2008 by Ken Shi and Richard Liu. Both of them had previously worked as investment managers in the Morningside Group that is operated by the Gerald Chan family in Hong

Kong. The Chan family provided strong support for Shi and Liu in the initial years of operating their own VC fund, to the extent that the 'Morningside' name was also utilized as the company's name. Further reading: Chen, L. Y. (2021). "Venture Firm That Made $30 Billion on Chinese Video App Plans New Fund". Bloomberg, link retrieved from https://www.bloomberg.com/news/articles/2021-02-18/venture-firm-that-made-30-billion-on-kuaishou-plans-new-fund. It was officially renamed as 5Y Capital in October 2020. Further reading: Ku, L. (October 22, 2020). 'Morningside Venture Capital rebrands as 5Y Capital'. AVCJ, link retrieved from https://www.avcj.com/avcj/news/3021501/morningside-venture-capital-rebrands-as-5y-capital.

[168] SOSV identifies itself as an impact investing-focused venture capitalist, in which they seek to financially support technology companies across the globe that promises not only significant future revenues from their commercialization, but also positive societal impacts. This helps explain why most of their investments have been targeted towards companies promoting clean energy, life sciences, seamless Internet connectivity, etc. In addition to Chinaccelerator in Shanghai, SOSV also operates HAX (a hardware start-up incubator in Shenzhen), IndieBio (a biotech start-up incubator in San Francisco), and DLab (an accelerator-incubator-VC fund trio dedicated for blockchain-themed start-ups, with a basis in New York City). Further reading: SOSV (2022). 'Impact investing'. Link retrieved on February 22, 2022 from https://medium.com/sosv/tagged/impact-investing.

[169] Lilly Asia Ventures was initially established in 2008 by a group of overseas Chinese returnees who were still working for Eli Lilly as corporate scientists and professionals. Although the former has since been spun off from the latter, the two entities continue to maintain a close collaborative relationship, particularly in supporting Chinese biotechnology companies explicitly backed by the latter. An example is Lynk Pharmaceuticals, which recently received a US$50 million investment deal from Lilly Asia Ventures. Further reading: Gelman, M. (August 27, 2021). 'Backed by Eli Lilly, a little-known and secretive Chinese biotech fills the tank as it heads to the clinic'. EndpointsNews, link retrieved from https://endpts.com/backed-by-eli-lilly-a-little-known-and-secretive-chinese-biotech-fills-the-tank-as-it-heads-to-the-clinic/.

[170] Nevertheless, in recent months, the relationship between SBCVC and its parent company (Softbank) has not been a smooth sailing, particularly with regard to direction on investment strategies in China's technology sector. Given the ongoing restructuring efforts by the Chinese government on the country's economy and high-tech industries, Softbank's senior management decided to indefinitely pause their Chinese-focused investments. Nevertheless, SBCVC – in a since deleted post – insisted that they would continue identifying promising early-stage technology firms in China. How the relationship will proceed in the future remains to be seen. Further reading: Liao, S. (August 12, 2021). 'SoftBank's China VC arm deletes response after parent pauses China investments'. Yicai Global, link retrieved from https://www.yicaiglobal.com/news/sbcvc-deletes-wechat-comment-on-softbank-decision-to-suspend-investments-in-china.

[171] Noland (2007) attributed the high degree of inter-organizational linkages in Japan to the explicit push by Japanese government for affiliate firms in business groups (keiretsu) to build close relationships with each other, particularly in joint R&D efforts on technologies deemed to be of Japan's strategic interests. One common approach that was adopted by the Japanese government was to explicitly discourage foreign direct investment (FDI) by non-Japanese firms in sectors and/or technologies where local enterprises already enjoyed competitive advantages. One consequence of such industrial policy, however, has been the persistence of cross-shareholding networks among these affiliate enterprises (Witt, 2014), which – more often than not – resulted in weak corporate governance and limited shareholder control over decisions taken by board members. Such approach was often further complicated by numerous cross-keiretsu group mergers and board reconfigurations.

[172] Greater Tokyo Area is, at present, the world's most populous urban agglomeration, with an estimated 38 million people living within the metropolitan area, equivalent to roughly 30% of Japan's entire population. Nearly 40% of Japan's GDP (approximately US$1.8 trillion) is concentrated within this region. Further reading: Liu, Y. (February 18, 2019). 'Can China's Greater Bay Area really rival the likes of Tokyo, New York and San Francisco?' South China Morning Post, link retrieved from https://www.scmp.com/business/china-business/article/2186681/can-chinas-greater-bay-area-really-rival-likes-tokyo-new.

[173] At present, Panasonic (formerly known as Matsushita Electronics) is headquartered in the city of Kadoma, Osaka Prefecture. Nevertheless, the company – with average annual revenue of about US$70 billion – continues to maintain a significant number of R&D centers across the country, mainly in Tokyo, Yokohama, Osaka, Keihanna, Shiga, and Fukuoka. In terms of patenting, a large proportion of Panasonic's patents were based on inventive activities taking place in R&D centers within Tokyo metropolitan. Source: Panasonic. Global R&D Map.

Link retrieved from https://www.panasonic.com/global/corporate/technology-design/r-and-d.html. Simultaneously, Canon, while headquartered in Tokyo, also hosts a large number of R&D facilities throughout, mainly in Tochigi (Canon Medical Systems), Kawasaki, Tamagawa, Kosugi, Hiratsuka, Ayase, Fuji-Susono, Utsunomiya, and Toride. Source: Canon. Global R&D. Link retrieved on February 22, 2022 from https://global.canon/en/technology/frontier12.html.

[174] The collaboration was part of a broader consortium-based partnership between the university's Institute of Industrial Science (IIS), Toyota Tsusho (an affiliate firm of Toyota Group), Prime Planet Energy and Solutions (PPES), and Panasonic that was recently set up in early 2022. Further reading: Toyota Tsusho (January 26, 2022). 'Institute of Industrial Science, The University of Tokyo, Prime Planet Energy & Solutions Inc., Panasonic Corporation, Toyota Tsusho Corporation commences industry-university collaborative research on battery resources and recycling'. Toyota Tsusho, link retrieved from https://www.toyota-tsusho.com/english/press/detail/220126_004968.html.

[175] One thing worth noting from our observation of Todai's U-I co-publications is the fact that Ajinomoto – depending on one's point of view – could also be classified as one of the university's most successful, and earliest, research spin-offs. Ajinomoto was established in 1908 as a corporate vehicle to commercialize research on monosodium glutamate seasoning that was pioneered by Professor Kikunae Ikeda at the university, which was originally known as Tokyo Imperial University.

[176] The only Japanese unicorn company located outside Tokyo is Spiber. A biomaterial company established in 2007 and based in Tsuruoka (480 km north of Tokyo), the company commercializes their core innovation in QMONOS, a synthetically-made spider silk fiber. This material was developed based on their 'Brewed Protein' research, which resulted from microbial fermentation. The company was founded, and is currently led, by Kazuhide Sekiyama and Junichi Sugahara, based on their research as graduate students in bioinformatics at Keio University (which is located in Tokyo). Further information: https://spiber.inc/en/.

[177] Instead of simply listing out 10 organizations, we decided to include 11 (with Daewoo added to the list, and italicized). Daewoo, at one point, was one of South Korea's largest business conglomerates – and indeed was almost on par with Samsung Group, but the business group subsequently fell in disgrace in the aftermath of 1997-1998 Asian financial crisis, due to the excessive amount of bad debt the affiliate companies had accumulated given their reckless expansion throughout the 1990s.

[178] While Kia Motors is owned by Hyundai Motor Group (which also operates Hyundai Motor Company), Kia is run as a largely independent business on their own. SK Hynix was established in 1983, originally as a subsidiary of Hyundai Group; indeed, their original name was 'Hyundai Electronics'.

[179] ETRI, established in 1976 by the South Korean government, is currently headquartered in Daejeon, where KAIST is also located. Nevertheless, ETRI continues to run research facilities across the country, especially in Seoul. KIST, established in 1966, was one of the two progenitors (the other being KAIS, Korea Advanced Institute of Science) that would constitute KAIST, which originally had their main campus based in Seoul. KIST retains some of their research functions in Seoul, at present.

[180] The 1997-1998 Asian financial crisis has laid bare the 'ugly' truth about business groups in South Korea: their collective addiction to long-term cheap debt. Bulk of this was, historically, attributed to the longstanding support by the South Korean government (especially from 1960s onward) for these enterprises in developing industries and technologies deemed to be of critical priorities for national development. Witt (2014) added, however, that such 'support' was provided not with unconditional terms; under the authoritarian rule of Park Chung-hee in the 1960s and 1970s, businesses were seen as 'subservient' to the state, and were 'morally obligated' to contribute to national development, especially in highly capital-intensive industries (e.g. steel, shipping, automobiles, infrastructure, construction, etc) for which many of these chaebol firms initially had low absorptive capacities to begin with. Through heavy government intervention, financial institutions were pressured to provide a large amount of long-term credits to support these enterprises. With the chaebol-government relationship becoming increasingly cozier over time, this resulted in a high degree of reliance among these enterprises to rely on government support. The Asian financial crisis subsequently challenged the viability of such linkages, and eventually 'forced' thes chaebol firms to improve their absorptive capacity, as well as corporate governance, albeit with mixed outcomes for the latter.

[181] The decision to build Daedeok Science Town in Daejeon was made by Park Chung-hee, the longest-ruling president in South Korea (1961-1979). Two major factors motivated him to relocate majority of research-performing organizations into Daedeok: 1) the desire to 'shield' these organizations from bureaucracy and political dynamics in Seoul, and; 2) to address regional inequalities given the uneven outcomes of South Korea's economic development, which had mostly benefitted Seoul and its surrounding localities. Nevertheless, Park's decision was made without consultation with researchers at these organizations, most of whom resisted the plan due to the relative geographical isolation of Daejeon in comparison to Seoul.

[182] One major reason that explains close relationships between KAIST and KIST relates to the former's genesis: KAIST was created in 1981 under the government-brokered merger of Korea Advanced Institute of Science (KAIS) and Korea Institute of Science and Technology (KIST). In order for KIST to continue operating in its current form, its predecessor was broken up by the government, as well as underwent through considerable reorganization and administrative changes.

[183] KIST's success was also inevitably attributed to the decision by some overseas Korean scientists and professors to return to the country. Before the institute was established, the South Korean government commissioned a study involving US and Korean researchers to survey over 600 Korean factories and 1,000-plus overseas Korean scientists (mostly in the United States). Regarding the latter, they were asked – and encouraged – to return to South Korea to develop and implement the country's S&T development plans. While only 32 (response rate: approximately 3%) answered the call, these returnees would play an instrumental role in enabling KIST to achieve their success to this day.

[184] Collectively, SNU, Korea University, and Yonsei are better known for their 'SKY' abbreviation; this refers to a colloquial term to describe South Korea's three best, and most elite, universities among their counterparts in the country. Prospective students often toil in 16-hours-a-day, 7-days-a-week cram-school sessions to study in preparation for entrance examinations into these universities, which have been described as among the hardest, and most grueling, in South Korea. Two major issues that emerge from such practice are depression (especially for failed candidates) and suicidal tendencies for cram-school students. Further reading: Choe, S.-H. (August 12, 2008). A taste of failure fuels an appetite for success at South Korea's cram schools. The New York Times, link retrieved from https://www.nytimes.com/2008/08/13/world/asia/13cram.html.

[185] The outcome for Brain Korea 21, however, has so far been mixed. Based on interviews and surveys of existing literature on South Korea's research performance, Hawkins (2015) found that two major by-products of the law have been: 1) overwhelming emphasis on quantifying faculty performance indicators (prioritizing quantity of output over quality), and; 2) publish-or-perish phenomenon (in which faculty members with numerous journal articles are more likely to obtain tenure than those with few papers).

[186] Findings by Sohn et al. (2009) were also representative of the ongoing regional inequalities within South Korea, in which majority of the country's largest enterprises, top universities, and economic activities continue to be concentrated in Seoul metropolitan region, which encompasses Seoul and its surrounding satellite cities in the neighboring Gyeonggi province. A successive number of administrations (from Roh Moo-hyun to Lee Myung-bak and Park Geun-hye) have sought to address such issues by encouraging further U-I collaboration linkages among HEIs and industries outside the capital region. The outcome has also been mixed: outside Seoul, universities were shown to build larger innovation networks than enterprises, but the Silicon Valley-like dynamics remain missing due to a lack of entrepreneurial drive, especially in start-up formation.

[187] One policy approach that the South Korean government embarked on was to gradually move government agencies and SOEs out of Seoul into the rest of the country. Many government agencies, for example, have been relocated to Sejong City, a planned city about 120 km south of Seoul which may eventually serve as South Korea's new administrative capital. Other SOEs include: POSCO (headquartered in Pohang), KEPCO (based in Naju, South Jeolla Province), Korea Gas Corporation (in Daegu), K-Water (located in Daejeon), KRCC (in Uiwang), and Korea Aerospace Industries (headquartered in Sacheon, South Gyeongsang Province).

[188] The proposed collaboration with SAIT will envision 20 professors from 4 schools and departments (Physics & Astronomy; Chemistry; Mathematical Sciences; Statistics) working in 5 smaller project teams with their counterparts at SAIT through a combination of academic publications, regular seminars, forums, workshops, etc. The collaboration will be centered on long-term basic science, instead of short-term applied research. Further reading: Kim, C. H. (2018). 'SNU scientists join forces with Samsung technicians'. Seoul National University,

link retrieved on February 21, 2022 from https://en.snu.ac.kr/snunow/snu_media/news?md=v&bbsidx=125186#:~:text=On%20March%2027%2C%20the%20SNU,the%20future%20of%20Korean%20industry..

[189] Samsung's KRW100 billion commitment to local universities is a small component of their three-year, KRW180 trillion (equivalent to over US$150 billion) plan to strengthen Samsung Group's competitive strengths in semiconductor, artificial intelligence, 5G Internet, IoT, as well as other future emerging technologies. Further reading: Baek, B.-Y. (August 14, 2018). 'Samsung, SNU sign partnership to foster semiconductor research'. Korea Times, link retrieved from https://www.koreatimes.co.kr/www/tech/2020/01/129_253864.html.

[190] Samsung Electronics' four-year degree programs will be introduced not only to SNU, but also to the country's other top universities, namely: KAIST, Yonsei, and Ulsan National Institute of Science and Technology (UNIST). The university-industry joint program will be introduced with support from the South Korean government, in which admitted students will be provided with full scholarship by Samsung and given research and/or internship opportunities at the company's facilities. Samsung has had an ongoing joint program with Sungkyunkwan University in this area. Further reading: Hwang, S.-M., and Kim, M. (March 27, 2019). 'Samsung, Korean universities to join forces to groom chip talents'. Pulse News, link retrieved from https://pulsenews.co.kr/view.php?year=2019&no=184890.

[191] Hyundai Motors, in turn, will invest over KRW30 billion (equivalent to US$25 million) in a joint research center within SNU campus, and will provide funding for the next 10 years. The center, once in operation sometime in 2022, will house over 100 Master's and PhD students, as well as 15 professors from SNU and other partner universities in South Korea. The center will be held by Profesor Choi Jang-wook, a globally leading expert in battery technologies. Further reading: Lee, K. (November 4, 2021). 'Hyundai Motor, Seoul National University to develop next-generation battery technology'. The Korea Bizwire, link retrieved from http://koreabizwire.com/hyundai-motor-seoul-national-university-to-develop-next-generation-battery-technology/203519. Simultaneously, Hyundai Motor has intensified their investments in the global EV industry, and is focusing on releasing affordable EV models. Further reading: Park, S.-J. (November 3, 2021). 'Hyundai partners with Seoul University to develop next-generation EV batteries'. Aju Business, link retrieved from https://www.ajudaily.com/view/20211103152556540.

[192] Regarding collaboration on next-generation display technology, further reading: The Korea Herald (July 21, 2012). 'LG Display, SNU join hands for next-generation displays'. Link retrieved on February 21, 2022 from https://www.asiaone.com/print/News/Latest%2BNews/Science%2Band%2BTech/Story/A1Story20120721-360441.html.

[193] Further reading: Lee, M.-H. (December 19, 2016). 'LG Chem boosting bio business with SNU'. The Korea Times, link retrieved from http://www.koreatimes.co.kr/www/tech/2018/08/133_220421.html.

[194] LG Science Park began operation in 2018 and currently houses R&D facilities from various LG Group-affiliated firms, namely LG Electronics, LG Display, and LG Innotek, with a total of 20,000 full-time researchers working within this zone. In the case of AIIS, over 2,000 professors, researchers, and students are affiliated with the institute. Further reading: Park, E.-J. (June 17, 2020). 'LG Science Park and AIIS collaborate on AI development'. Korea JoongAng Daily, link retrieved on February 22, 2022 from https://koreajoongangdaily.joins.com/2020/06/17/business/industry/AI-LG-Seoul-National-University/20200617181900274.html.

[195] Further reading: Kim, B.-W. (July 29, 2020). 'LG Chem launches digital transformation center with SNU'. Link retrieved from http://www.koreaherald.com/view.php?ud=20200729000820.

[196] SK Telecom and SNU Bundang Hospital established a joint venture – known as HealthConnect – in which they provide computerized, electronic medical health record systems, engage in 3D mapping of hospital rooms to predict areas and/or patients requiring immediate attention, as well as indoor positioning technology. Further reading: Light Reading (April 22, 2013). 'SK Telecom launches smart hospital solutions'. Link retrieved from https://www.lightreading.com/sk-teleom-launches-smart-hospital-solutions/d/d-id/702303.

[197] SK Telecom has also collaborated with SNU researchers, as well as various social enterprises and aging-care facilities in Seoul, to pilot the implementation of AI-enabled care services for the growing elderly population not

only within the city, but also throughout the country. The provision of medical support system has also been increasingly urgent in the face of COVID-19 pandemic. Further reading: SK Telecom (April 22, 2020). 'SK Telecom's AI Care to provide 24/7 care for the elderly'. Link retrieved on February 22, 2022 from https://sktelecom.com/en/press/press_detail.do?idx=1454.

[198] Further reading: SK Bioscience (February 5, 2021). 'SK Bioscience to collaborate with GSK on COVID-19 vaccine development and initiate phase 1/2 trial'. Link retrieved on February 22, 2022 from https://www.skbioscience.co.kr/en/news/news_01_01?mode=view&id=40.

[199] Singapore's former, and longest-ruling, Prime Minister, Lee Kuan Yew, wrote in his 2013 memoir ('One Man's View of the World') that he signed Singapore's declaration of independence out of reluctance. While Singapore officially joined the Federation of Malaya in 1963 after achieving its high autonomy from the British colonial administration in 1959, the union was short-lived due to racial conflicts; this culminated in the 1964 race riots between ethnic Malays and Chinese in Singapore. Due to tensions between Malaya's ruling coalition and the authorities in Singapore (then led by PAP), Singapore was 'expelled' from the Federation in 1965. Further reading: Lee, K. Y. (2013). One man's view of the world. Singapore: Straits Times Press.

[200] Since 2017, SIM (Singapore Institute of Management) has been restructured by the government into a new university titled "Singapore University of Social Sciences", abbreviated as SUSS.

[201] There was no public explanation about NUS' decision to unilaterally put an end to the Yale-NUS College. Nevertheless, interviews by The Yale Globalist with some administration insiders pointed out to several possible reasons explaining the seemingly one-sided decision in which Yale administrators were not fully consulted in advance. The first reason was possibly attributed to irreconcilable differences between the two sides in interpreting academic freedom, and the perception among NUS senior administrators that Yale-NUS College had 'crossed the red lines' in this regard. Another reason given was the ongoing inability of Yale-NUS College in achieving capital fundraising target set by the NUS and the government. The article further hinted that the two sides' misunderstanding over the concept of 'liberal arts education'. Here, Yale defined it as a highly selective, and elitist, admission process but with strong attention to diversity and inclusion for its students. By contrast, NUS and the Ministry of Education would conceptualize it from a mass-education perspective. It is speculated that the new college replacing Yale-NUS College will eventually abolish liberal-arts education. Further reading: The Octant (August 28, 2021). 'A planned catastrophe: Yale-NUS College to close in 2025'. Link retrieved from https://theoctant.org/edition/issue/allposts/news/a-planned-catastrophe-yale-nus-to-close-in-2025/.

[202] Mathews (1999) noted that Hewlett-Packard's presence in Singapore was not limited to production of consumer goods alone; they were also responsible in the development of integrated-circuit (IC) industry in the city-state. Indeed, HP established Asia's first IC design center in Singapore (which also happened to be the country's first such dedicated center).

[203] ExxonMobil, historically, was one of the oldest foreign firms with a centuries-old presence in Singapore. The company's activities in the city-state commenced as early as 1893 when its predecessor, Vacuum Oil (then a subsidiary of Standard Oil that was broken up by US government's antitrust action into multiple companies in early 1910s) established a trading company. Vacuum Oil afterwards merged with Standard Oil New York, forming a new entity named STANVAC. In the aftermath of World War II, STANVAC merged with several other oil and gas companies into Mobil Oil. They were the first company to establish one of Singapore's first oil refineries in Jurong Island, as well as turning it into one of the largest refinery hubs in Asia-Pacific (increasing production from 18,000 barrels per day / bpd in mid-1960s into over 300,000 bpd by early 1980s). Read: ExxonMobil – Our history in Singapore. Link retrieved on January 20, 2022 from https://www.exxonmobil.com.sg/Company/Overview/Who-we-are/Our-history-in-Singapore.

[204] While A*STAR, in its current form, existed only from January 2002 onward, its predecessor was National Science and Technology Board (NSTB), which was established in January 1991 as the result of the upgrading of Science Council of Singapore into a statutory government agency. NSTB was tasked, under the country's first five-year science and technology plan, to provide strategic support for R&D in industries of strategic interest, namely: IT, microelectronics, electronic systems, manufacturing technologies, new materials, energy, water,

environment, food and agrotechnology, biotechnology, and medical sciences. Further reading: Moasi, R. Agency for Science, Technology and Research (A*STAR). Singapore Infopedia, link retrieved from https://eresources.nlb.gov.sg/infopedia/articles/SIP_2015-08-12_094457.html.

[205] GlobalFoundries is an American semiconductor contract manufacturing and design firm based in Silicon Valley. It was established in 2009 as a spin-off of the manufacturing division for Advanced Micro Devices (AMD), and soon after its spin-off, was acquired by Advanced Technology Investment Company (ATIC), a technology investment arm of Mubadala Development Fund, a US$230 billion sovereign wealth fund owned by the government of the United Arab Emirates (UAE). Its board of directors includes professionals from Silicon Valley as well as from the UAE. Further reading: Mubadala (December 8, 2008). 'AMD, the Advanced Technology Investment Company, and Mubadala amend transaction agreements'. Mubadala, link retrieved from https://www.mubadala.com/en/news/amd-advanced-technology-investment-company-and-mubadala-amend-transaction-agreements.

[206] We tried to search comprehensively to better understand why Chartered Semiconductor and STATS-ChipPAC, despite all efforts by the Singaporean government over the last 20+ years, did not succeed in the global semiconductor industry. Nonetheless, there appeared to be limited references on factors explaining their failure. One exception, however, was from a Substack channel named 'Asianometry', of which one of their blog posts provided an in-depth elaboration regarding their demise. Some core reasons offered by the author were: 1) inability to compete with more resourceful players outside Singapore, e.g. semiconductor foundries in China awash with capital, land reserves, and very generous government support (such as SMIC), TSMC (Taiwan), and Samsung (South Korea); 2) the companies' recurrent, non-stop losses for more than 20 years, in spite of government subsidies; 3) their overwhelming, near-singular focus over leading-edge technologies – often in collaboration with foreign MNCs, e.g. IBM, that mostly end up licensing their joint technology development to these companies' rivals – rather than product development, and; 4) the companies' tendencies to rely more on foreign talents rather than on local Singaporeans in operating the businesses. Further reading: Jon, Y. (June 24, 2021). 'What happened to Singapore's TSMC?' Asianometry, link retrieved from https://asianometry.substack.com/p/what-happened-to-singapores-tsmc.

[207] Specific to Novartis, the Swiss company at one time solidified itself in Singapore – and in the global pharmaceutical industry more broadly – as a major hub for conducting research on tropical diseases, as demonstrated by the presence of Novartis Institute for Tropical Diseases (NITD). Established in 2002 as a research partnership with Singapore's Economic Development Board (EDB), the company eventually announced, in 2016, to relocate the research institute and integrate the R&D unit with one of Novartis' R&D centers in Emeryville, California, in the United States. The company's management argued that this move was made as part of Novartis' broader consolidation plan in streamlining their global R&D operations. Further reading: Chia, Y. M. (October 5, 2016). Novartis moving research facility out of Singapore. The Straits Times, link retrieved from https://www.straitstimes.com/business/economy/novartis-moving-research-facility-out-of-singapore. At one point, NITD conducted significant research activities on drug discovery for three major tropical diseases: dengue fever, malaria, and tuberculosis (TBC). NITD also opened research positions, and at one point jointly ran a master's program with NUS, Swiss Tropical Institute, and the University of Basel on addressing tropical diseases.

[208] Eli Lilly's decision to shut down their drug-discovery center in 2010 was part of their global cost-cutting activities in the aftermath of the 2008-2009 global financial crisis, which affected their stock value and revenue growth significantly. Globally, Eli Lilly reduced their expenditure by US$1 billion, but at a cost of 5,500 laid-off employees across the globe.

[209] Since their listing, however, Grab (which was officially listed in December 2020) and Sea (with IPO on October 2017) have experienced different turns in their fortunes. Grab has lost over 55% of its market value from its initial listing price at US$12.4 to now US$5.5 (as of February 25, 2022), with their market cap at US$20.6 billion, substantially below their pre-exit final valuation. By contrast, Sea Limited has seen its stock price drastically soar from US$16.3 in October 2017 to US$122.8 (also as of February 25, 2022), despite its significant decrease from its peak value at US$358 in November 2021. At present, the market capitalization for Sea Limited stands at US$68.5 billion, a more than 10-fold increase in comparison to their pre-exit valuation.

[210] As of March 18, 2022, according to Sovereign Wealth Fund Institute (SWFI), HKMA Exchange Fund manages assets worth over US$585 billion, equivalent to an excess of HK$4 trillion. Unlike its Singaporean counterparts in Temasek and GIC, however, the number of recorded transactions involving Exchange Fund remains

infinitesimal, with only 20 such recorded deals. Further reading: SWF Institute (March 18, 2022). 'The Exchange Fund of the Hong Kong Special Administrative Region (HKMA IP)'. Link retrieved from https://www.swfinstitute.org/profile/598cdaa50124e9fd2d05b3a7.

[211] It is also worth noting, however, that not all Israeli citizens are legally required to undergo through military conscription. Beyond the Jewish population and male citizens of Druze and Circassian origin, the remaining Israeli citizens – mostly ethnic Arabs, who constitute nearly 25% of the country's population – are exempted from military service obligation, although they are open to serve in the military on their own volition. However, even among Israeli Jews, a small – albeit growing – proportion among them have been given exemptions by the state, and these apply for: 1) religious communities (mostly ultra-orthodox Jewish groups); 2) individuals with physical and/or mental disabilities; 3) individuals with criminal records, and; 4) Israelis residing overseas. As of 2013, slightly over 1/4 of Israeli Jews were granted such exemption. Further reading: Yehoshua, Y. (2013). "Number of IDF recruits to hit 20-year low in 2013". Ynetnews.

[212] Known as Yom Kippur War, this conflict pitted Israel (at this point supported by the United States) against a coalition of Arab states, namely Egypt, Syria, Saudi Arabia, Jordan, Iraq, Libya, Algeria, Tunisia, Morocco, Kuwait, Sudan, supported by Soviet Union, Cuba, East Germany, and North Korea. Lasting for three weeks, the battle pitted nearly 400,000 Israeli soldiers and reservists against more than 1 million troops from the Arab state coalition. Nevertheless, the war ended in Israel's victory, as they ended up besieging the Suez Canal area as well as a significant proportion of Syrian territories.

[213] Israel's steep decline in its military spending-to-GDP ratio reflected a similar phenomenon taking place worldwide. According to the data from World Bank, global military expenditure-to-GDP ratio has been dropping from 6.5% in 1960 down to 2.5% as of 2020. Israel's figure, although dropping, has remained consistently above the global average; its recent ratio in 2020 was about 5%.

[214] RAFAEL's ability to forge a strong connection with leading universities outside Israel (mostly in the United States) can be attributed to the strong bilateral relations between Israel and the US, especially since the early 1970s. One such agency, US-Israel Bi-national Industrial Research and Development (BIRD) Foundation, has played a major role in facilitating the networking between RAFAEL and these institutions.

[215] Weizmann Institute of Science was established in 1934 by Chaim A. Weizmann, a Russian-born Israeli scientist and Zionist leader who would subsequently serve as Israel's first, founding president.

[216] In the 2020 ecosystem report, the Tel Aviv municipal government defines the greater Tel Aviv region as encompassing the following cities and towns: Azur, Bat-Yam, Bnei Brak, Ganey Tikva, Givat Savion, Givat Shmuel, Givatayim, Herzliya, Holon, Kibbutz Glil-Yam, Kiryat Ono, Or Yehuda, Petach Tikva, Ramat Efal, Ramat Gan, Ramat HaSharon, Savyon-Gani Yehuda, and Yehud.

[217] The report also pointed out about the widening gap in access to quality education between those belonging to upper- and upper-middle-class strata of the society and those from lower-middle-class and low-income origins. Furthermore, the researchers found that education performance for children of Arab-Israeli and Ultra-Orthodox Jewish backgrounds to be even worse than their other Israeli-Jewish peers.

[218] Elscint was considered as one of Israel's earliest university spin-offs. It was established in 1969 by Avraham Suhami, then a professor at Technion – Israel Institute of Technology. The company aimed to commercialize innovations in medical imaging technologies, particularly in CT scanner. Given the initial funding it received from Elron (also an affiliate company of Elbit Systems), it subsequently became an Elron subsidiary. Elscint was acquired in 2005 by GE Healthcare, a medical-device subsidiary of U.S.-based General Electric, one of the world's largest device-related multinational companies.

[219] What we also found interesting about multinational firms in Israel was their tendency to – first and foremost – focus on higher value-added, R&D-based activities before embarking on manufacturing-based activities, rather than vice versa (lower-value-added manufacturing, followed by subsequent upgrading towards more complex, research-based ventures). Much of this was enabled by the high density of research-intensive organizations (notably universities and research centers), as well as the high waves of Jewish immigration from ex-Soviet Union countries throughout the 1990s (Breznitz, 2007). What was particularly outstanding about Soviet-based immigration waves was the fact that majority of the 1-million-plus migrants were highly educated and trained in

science and engineering fields – often with PhD degrees, thus creating a large supply of highly-skilled manpower that Israel needed to address.

[220] In this regard, we refer to Tel Aviv District, which is one level above the status of Tel Aviv Municipality (a component city of the district). In Israel, first-level administrative divisions are designated as 'districts', for which Tel Aviv District is one of the most populous. The district comprises of 10 cities (namely Tel Aviv, Bat Yam, Bnei Brak, Givatayim, Herzliya, Holon, Kiryat Ono, Or Yehuda, Ramat Gan, and Ramat HaSharon), and 2 local councils (namely Azor and Kfar Shmaryahu).

[221] Yozma (not listed in the top-25 investor list on Table 4-83) has been considered a 'trailblazer' of Israel's modern VC industry, as well as a fascinating subject for comparative studies by various scholars (c.f. Avnimelech and Teubal, 2006; Klinger-Vidra, 2018). The amount of interest generated, in particular, was in large part due to the policy innovation that Yozma entails. In this regard, the Israeli government established Yozma as a collection of 10 hybrid funds with joint funding by the government and relevant industries supporting the funds. Some of the major co-investors in these hybrid funds included representatives from major financial institutions, both from Israel and abroad. Interestingly, 8 out of the 10 hybrid funds had founders and/or managing partners that were successful entrepreneurs with strong expertise in science, technology, and engineering-related fields. These combined features, in turn, enabled Yozma to invest in promising start-ups with adequate funding support and guidance from these well-established experts.

[222] CityU is the latest university to launch a large-scale innovation and entrepreneurship program, under the umbrella of 'HK Tech 300'. Established very recently in December 2021, the program – through a multi-tiered combination of seed funds (up to HK$100,000), angel funds (up to HK$1,000,000), and launching funds (with external funds up to HK$10,000,000) – aspires to produce 300 university-based start-ups in the next 3 years. More information: https://www.cityu.edu.hk/hktech300/about-hk-tech-300/about-programme.

[223] These joint research schemes offered by UGC are listed as follows: National Natural Science Foundation of China (NNSF)/RGC Joint Research Scheme (with mainland China); French National Research Agency (ANR)/RGC Joint Research Scheme (with France); European Union (EU)-Hong Kong Research and Innovation Cooperation Co-funding Mechanism; Germany-Hong Kong Joint Research Scheme, and finally; PROCORE – France/Hong Kong Joint Research Scheme. As we have argued, these collaborative schemes are largely limited to scientific research.

[224] The term "advanced manufacturing" that emerged in the 2009 policy plan was described as "businesses which use a high level of design or scientific skills to produce technologically complex products and processes. Because of the specialized requirements involved, these are usually goods and associated services of high value' (Department for Business, Innovation and Skills (BIS), 2009: 1).

[225] The turning point of its development could be traced back to 2008. In July, Matthew Biddulph, the co-founder of Dopplr, mentioned the region as 'Silicon Roundabout' in his tweet after joking with his friends, and afterwards received lots of requests from some mainstream media including Financial Times and Evening Standard, as well as from the UK government including Department of Trade and Industry (DTI).

[226] Volpicelli cautioned, however, that the Tech City program did not succeed as much as it was originally intended by the UK government. Before the introduction of the initiative, numerous start-up companies have relocated to the East London region, due largely to low rents and widespread availability of working spaces (especially in the aftermath of 2007-2008 financial crisis). Nevertheless, the program itself also attracted another 'unexpected' by-product: rampant real-estate development, followed by soaring property prices. As a large number of skyscrapers are being constructed within this region, residential and commercial properties have seen their valuation more than double, causing significant challenges for start-up and SME entrepreneurs in retaining their rental spaces in East London.

[227] The UK government defines SMEs under three different layers as follows. In the first, 'micro' layer, such enterprise is defined when it employs fewer than 10 people with annual revenue under £2 million. The second, 'small' layer, refers to companies with at least 10, but fewer than 50, employees, with annual turnover of under £10 million. The third, and finally 'medium' layer, is defined for companies with at least 50, but fewer than 250, employees, with annual revenue under £50 million. Companies employing over 250 people and with turnover above the 'medium' threshold would qualify as large enterprises. Further reading: UK Department of International

Trade. 'Small and medium-sized enterprises action plan: 2020 to 2022'. Link retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/961722/SME-Action-Plan.pdf.

[228] Topics proposed under the COIN meetings are highly diverse, ranging from sharing economy-based urban infrastructure, tackling the challenge of high streets, accelerating digitalization in construction, crisis adaptation, etc. Further reading: University College London (UCL). Challenge-Oriented Innovation Meetings. Link retrieved from https://www.ucl.ac.uk/enterprise/challenge-oriented-innovation-coin-meetings.

[229] Innovate UK EDGE was established in 2015 by UKRI. It provides three types of support services for existing firms as follows: 1) exploiting business innovation (e.g. strategy development, IP protection, management reform, etc.); 2) sourcing funding and finance (applying early-stage capital, finding investors, etc.), and; 3) opening new markets (working closely with firms to identify promising markets overseas). Further reading: UK Research and Innovation. 'Innovate UK EDGE: About us'. Link retrieved from https://www.innovateukedge.ukri.org/about-us.

[230] Further reading: University College London (March 2021). 'UCL helps GiveVision transform the lives of visually impaired people'. Link retrieved from https://www.ucl.ac.uk/enterprise/case-studies/2021/mar/ucl-helps-givevision-transform-lives-visually-impaired-people.

[231] King's College London (May 9, 2019). 'King's and NVIDIA join forces to build UK's first AI platform for hospitals'. Link retrieved from https://www.kcl.ac.uk/news/kings-and-nvidia-to-build-uks-first-al-platform.

[232] LSE Grantham Institute (June 8, 2020). 'CANDRIAM and the London School of Economics Grantham Research Institute announce partnership to support a sustainable and inclusive climate recovery'. Link retrieved from https://www.lse.ac.uk/granthaminstitute/news/candriam-and-the-london-school-of-economics-grantham-research-institute-announce-partnership-to-support-a-sustainable-and-inclusive-climate-recovery/.

[233] National Research and Development Corporation (NRDC) had a complex history. Established in 1948, NRDC was responsible for coordinating technology transfer practices of innovation in military-related technologies into commercial, civilian application purposes. Interestingly, NRDC was also established in India at the same time. NRDC's duties were complemented by the creation of National Enterprise Board (NEB), which could be described as one of the first national-level 'technology transfer offices' (TTOs) in the world in terms of catalyzing the transfer of government-funded inventions for private-sector commercialization. By early 1980s, however, under the Margaret Thatcher administration, the government agency's scope and powers were reduced as both NRDC and NEB were merged into a new entity, British Technology Group (BTG), and began to be privatized by the early 1990s. The company was publicly traded in London Stock Exchange in 1995, and earned a large portion of their revenues from licensing their magnetic resonance imaging (MRI) technology to medical-device firms worldwide. It was eventually acquired by Boston Scientific, an American multinational health-device maker, in 2018, for a value of US$4.2 billion, and subsequently delisted from the stock exchange.

[234] These universities (with the exception of ICL) are currently constituent members of the University of London, a federal research university responsible for most publicly-funded universities within London metropolitan area. As of 2019, the full members of the university are: Birkbeck University of London (BBK), City University of London (CUL), Courtauld Institute of Art (CIA), Goldsmiths University of London (GUL), Institute of Cancer Research (ICR), KCL, London Business School (LBS), London School of Economics and Political Science (LSE), London School of Hygiene and Tropical Medicine (LSHTM), QMUL, Royal Academy of Music (RAM), Royal Central School of Speech and Drama (RCSSD), Royal Holloway University of London (RHUL), Royal Veterinary College (RVC), School of Oriental and African Studies (SOAS), St. George's University of London (SGUL), and UCL. ICL left the University of London in 2008 and is now an independent university.

[235] In 1976, a group of unionized engineers and workers in Lucas Aerospace, a subsidiary of Lucas Industries, launched what would be known as "The Lucas Plan". This plan was launched in response to threats of laying off a significant proportion of workforce in the company. Led by Mike Cooley, a PhD-trained aerospace engineer who worked in the company, the plan entailed a significant restructuring of industrial workforce in the company with an emphasis on manufacturing "socially useful products" and reorganizing the workforce into teams of engineers and 'factory-floor' laborers working together in those 'socially useful products'. The plan was considered revolutionary as it envisioned – and put into catalog – a total list of 150 socially useful products, many of which were back then considered 'far-fetched', e.g. solar panels, wind turbines, energy-efficient houses, electric

vehicles, etc. The company's management, however, was angered by this plan, and Mike Cooley was subsequently fired from the company, and the plan never got implemented. Read: Wainwright, W. (1981). The Lucas plan. New York: Schocken Books.

[236] Back in the 19th and early 20th centuries, Western Electric was one of the world's most important industry players in the emerging telephone and telegraph industry; indeed, it was pivotal in supplying materials and technologies to American Telephone and Telegraph (AT&T), which would eventually surpass Western Electric in its global dominance, and continues to exist to this day; had it not been for Western Electric's technologies, AT&T would not have existed. AT&T remains a major telecom giant in the United States.

[237] In one of the book's chapters ("Learning from the wrong master: lessons from UK industrial decline"), Atkinson and Ezell elaborated 20 reasons that explain the country's industrial 'fall from grace', namely: 1) uneven management quality; 2) cuts in corporate R&D; 3) excessive focus on overseas over domestic investments by most firms; 4) primary focus on short-term returns and dividend payments; 5) firms' tendency to resist the government's role in industrial upgrading and development; 6) labor unions' excessive push for compensation; 7) labor unions' similarly short-term focus in comparison to those of industries; 8) resistance by firms and laborers to emerging technologies; 9) adversarial industry-labor relations; 10) the government's excessive emphasis on macroeconomic stability; 11) policymakers' ceasing attention on reversing industrial decline; 12) presence of investment-deterring policies; 13) lack of distinction between 'spending' versus 'investment' activities; 14) overwhelming focus of R&D on military research; 15) policymakers' strong support of a strong currency; 16) practices of neoliberal economics; 17) the existing political system that overlooks persistent economic issues; 18) a political system overly attuned towards redistribution over novel creation; 19) tendency by political elites to underestimate the role of manufacturing, and; 20) the reluctance by existing elites to acknowledge the existence of industrial decline.

[238] Universities with the highest cumulative number of spin-offs in London are Imperial College London (ICL), followed by the University College London (UCL) and King's College London (KCL). From Del-Palacio and Chapman's calculation, since 2000 up to August 2013, ICL has been in the leading position, with 88 research-based spin-offs generated. In comparison, within the same period 55 technology firms were spun off from research at UCL, and 24 from KCL.

[239] Parkwalk Advisors has – as of end of December 2021 – signed investment agreements with at least 18 UK research universities to invest in their spin-offs, the following list by which consist of: Aberdeen, Bradford, Bristol, Cambridge, Cardiff, Durham, Glasgow, Heriot-Watt, ICL, Leeds, Manchester, Middlesex, Oxford, Southampton, Strathclyde, Surrey, UCL, and East Anglia.

[240] InnoHK is a recent scheme by Innovation and Technology Commission (ITC) of the Hong Kong government to further incentivize scientific collaboration between Hong Kong universities and their non-local counterparts, whether in mainland China or elsewhere. This program places priorities on Hong Kong universities' research collaboration with some of the most globally leading research universities in the world, primarily in emerging scientific and technological areas, e.g. medical robotics, therapeutics, AI-driven chips, etc. More details: https://www.itc.gov.hk/en/technological_infrastructure/innohk_clusters.html.

[241] Patent aggregators refer to firms that specialize in acquiring patents and/or patent rights from other organizations and/or individual inventors, but do not engage in efforts to commercialize them into actual products and/or services. Oftentimes, these firms – also known as non-practicing entities (NPEs) – earn their revenues by engaging in patent litigation against companies and/or individuals with patents whose content allegedly bear resemblance to their patent portfolio. Beyond litigation, these companies also monetize their patent portfolio by licensing them to other organizations. An article by Andrei Hagiu and David B. Yoffie explains how the illiquid-market nature of patent transactions (given the enormous uncertainties surrounding their commercialization prospects) leads to the rise of such patent intermediaries. Source: Hagiu, A., and Yoffie, D. B. (2013). The new patent intermediaries: platforms, defensive aggregators, and super-aggregators. Journal of Economic Perspectives, 27(1): 45-66. Link: https://www.aeaweb.org/articles?id=10.1257/jep.27.1.45.

[242] ZymoGenetics was established in 1981 by two professors from the University of Washington (UW), namely Earl W. Davie and Benjamin D. Hall, and one professor from the University of British Columbia (UBC): Michael Smith. Smith would eventually earned a Nobel Prize in Chemistry based on his works on recombinant protein, which was the commercial basis behind the founding of the firm. It was one of the earliest pioneers of

biotechnology industry, in addition to companies like Genentech. ZymoGenetics was subsequently acquired by Bristol-Myers Squibb in 2010. Information was retrieved from the link below: https://web.archive.org/web/20170507044648/https://www.bms.com/about-us/our-company.html.

[243] There was an initial decline in the number of patent filings from Boeing for both 1989-1994 and 1995-2000 periods, relative to the total patent output in the 1983-1988 period. Nevertheless, this was not related to Boeing's relocation of their corporate headquarters from Seattle to Chicago (which actually occurred in 2001). Indeed, the state of Washington continues to occupy the largest proportion of Boeing's 140,000+ employees, with approximately 40% of them based in the state. Most of the employees in Washington (specifically in the Seattle metropolitan area) are based in the Commercial Airplanes Division, which is responsible for the manufacturing and assembly of Boeing passenger planes. Source: Boeing. 'Overview'. Link retrieved from https://www.boeing.com/company/general-info/#/employment-data.

[244] Even after hosting the second largest employee base after their headquarters in Menlo Park, Facebook continues to expand their business operation in Seattle. In July 2021, Facebook recently signed a lease for an 11-storey building in Bellevue, WA, a satellite city of Seattle; this building will serve as another operational base for the company (link: https://www.geekwire.com/2021/facebook-inks-another-lease-seattle-area-now-7k-employees-3-3m-square-feet/). Currently, Google is also investing in new office space cosntruction in Kirkland, WA, another satellite city of Seattle, and plans to hire more people in the metropolitan area (link: https://www.geekwire.com/2021/google-still-betting-new-offices-plans-hire-10000-invest-7-billion-2021/).

[245] Degree centrality and betweenness centrality measures are highly correlated, with one primary difference: degree centrality simply counts the number of direct linkages a node has with other nodes in a network (A → B, A → C, A → D, etc), whereas betweenness centrality measures the number of connections by any nodal pairs that passes through the node of interest (B → A → C, B → A → D, C → A → D, etc). Betweenness centrality has often been preferred as a measure of network centrality given their presumption of nodes as not only carriers of information, but also as 'bridges' (or brokers) that facilitate the transmission of information among any possible dyads of other nodes in a network. Read: Freeman, L. C. (1977). A set of measures of centrality based on betweenness. Sociometry, 40: 35-41.

[246] Microsoft was originally conceived as Paul Allen's idea. He would subsequently convince Bill Gates to drop out of Harvard in order to take advantage of new opportunities with the emerging microcomputer industry, a predecessor of the personal computing (PC) industry. Back then, the microcomputer industry cluster was strongly concentrated in Albuquerque, New Mexico, given the presence of Micro Instrumentation and Telemetry Systems (MITS), the manufacturer of Altair microcomputer, the device that motivated Allen to build this company. Read: Paul Allen's personal memoir. Allen, P. (2011). *Idea man: a memoir by the co-founder of Microsoft*. Portfolio/Penguin.

[247] Our designation of 'local firms' basically refers to any collaborating firms located within the vicinity of Seattle metropolitan region, which covers King County, Snohomish County, and Pierce County. In addition to Seattle, the region also encompasses major satellite cities and towns such as Tacoma, Bellevue, Everett, Redmond (the global headquarters of Microsoft), etc. 'Non-local firms', meanwhile, refer to industry collaborators based outside the metropolitan region, but within the broader United States territory. Any remaining collaborating enterprises based outside the US would be classified as 'foreign firms'.

[248] Langston, J. (July 7, 2016). 'UW, Microsoft researchers break record for DNA data storage'. University of Washington (UW) News, link retrieved from https://www.washington.edu/news/2016/07/07/uw-microsoft-researchers-break-record-for-dna-data-storage/.

[249] Holtz, J. (May 28, 2020). 'UW launches new Center for Research and Education on Accessible Technology and Experiences with $2.5 million investment from Microsoft'. University of Washington (UW) News, link retrieved from https://www.washington.edu/news/2020/05/28/create-announced/.

[250] Bishop, T. (March 31, 2021). 'Microsoft gives $5M to UW Medicine to use AI to accelerate response to next pandemic'. GeekWire, link retrieved from https://www.geekwire.com/2021/microsoft-gives-5m-uw-medicine-use-ai-accelerate-response-next-pandemic/.

[251] Boeing Advanced Research Center (BARC). Link retrieved from https://www.washington.edu/research/research-centers/boeing-advanced-research-center-barc/.

[252] More details on events, activities, and research projects by Boeing Advanced Research Center (BARC) are available in BARC's webpage in UW School of Engineering website. Link retrieved from https://depts.washington.edu/barc/node/1. Additional information on Boeing's professional continuing education program is shown in the following link: https://www.pce.uw.edu/boeing.

[253] Historians and other Silicon Valley-related observers have attributed the term 'Silicon Valley' to a casual conservation between Electronic News journalist Don Hoefler and Ralph Vaerst, himself an entrepreneur based in the region and a founder of Ion Equipment Corporation, one of the myriads of semiconductor-related firms in the Silicon Valley area.

[254] According to Silicon Valley Historical Association, Silicon Valley was historically known as Santa Clara Valley. Before the semiconductor-led technological revolution, the valley was largely known for their agricultural produce. Link: https://www.siliconvalleyhistorical.org/where-is-silicon-valley.

[255] After inventing the triode vacuum tube in 1906, Lee de Forest worked in several places before moving to California to work as a researcher at the Federal Telegraph Company (FTC) and contributed to further improvement of the technology in terms of its ability of transmission, reception and signal amplification. By providing gateways to later emergence of related technology such as long-distance telephone lines, it had drawn the U.S. Navy's attention as they demanded larger power transmitter stations during WWI.

[256] According to Ester and Maas, one notable example was Eitel-McCullough, which produced 150,000 tubes per month in 1943; their scope of production was the highest among all other electronics companies in this region.

[257] UC Berkeley was famous for its research in atomic physics and nuclear physics and was therefore engaged in several contracts or projects with the army to develop the atomic bomb. A renowned project which produced the first nuclear weapons, Manhattan Project in 1942, involved UC Berkeley physics professor, J. Robert Oppenheimer, to design the bombs.

[258] One way IBM catalyzed the emergence of dense patent co-inventor networks in Silicon Valley was their postdoctoral research program, which attracted numerous graduates from local universities, notably from Stanford and UC Berkeley. With an average period of two years for each hired postdoctoral researcher, the recruited individuals forged close relationships in knowledge exchange and technology development efforts. Fleming and Frenken (2007) noted that even after many years since their 'graduation' in IBM's post-doctoral program, the alumni – who had ended up working in different companies or launching their own technology start-ups – had continued to maintain close ties and exchange the latest technological insights.

[259] Patent assignment for the University of California (UC) campuses does not differentiate the specific university with which it was affiliated (whether to UC Berkeley, UCSF, UCLA, UCSD, UC Davis, UC Irvine, UCSB, UC Riverside, UC Merced, or UC Santa Cruz). The university administration has stipulated that patents originating from research works at any of these UC-linked campuses are directly assigned to UC's central unit.

[260] These 'eight best talents' were: Jay Last, Robert Noyce, Sheldon Roberts, Julius Blank, Eugene Kleiner, Jean Hoerni, Gordon Moore, and Victor Grinich. We would – for the purpose of simplicity – primarily pay attention to the profiles of Robert Noyce, Gordon Moore, and Eugene Kleiner, as Noyce and Moore would launch Intel, which subsequently became one of the world's leading memory-chip companies, whereas Eugene Kleiner ended up launching one of the world's earliest and largest venture capital (VC) funds. We shall also note that Julius Blank substantially contributed to the development of semiconductor technologies, particularly in the invention of silicon computer chips, together with the other seven talents.

[261] Various historical accounts have described how Shockley's management was so abusive that all employees, at one point, were required to undergo intensive lie-detector tests before they started their work. Shockley Semiconductor eventually shut down for good, and William Shockley ended up being estranged from most of his colleagues, friends, and even his own family members. Other controversies surrounding Shockley included his view on eugenics (and his racial views against ethnic minority groups), as well as tensions with his wife and his children due to what he perceived as 'gaps in cognitive intelligence'.

[262] Nevertheless, maintaining the balance between competition and cooperation is easier said than implemented in practice. In 2019, only slightly a year after Intel-AMD partnership on Intel Core 8 chips, Intel unilaterally decided to end their 'rare' partnership with their rival due to weak demands for the resulting joint technology. Read: Nguyen, C. (October 8, 2019). The rare partnership between Intel and AMD is dead as the rivalry intensifies. Digital Trends, link retrieved from https://www.digitaltrends.com/computing/intel-kaby-lake-g-canceled-amd-partnership/.

[263] To be specific, we refer the collaborating local firms to those based within the vicinity of San Francisco Bay Area (which we proxy as Silicon Valley). Domestic non-local firms refer to U.S. businesses that are located anywhere within the country, but outside the Bay Area region, and this encompasses firms from the rest of California. Foreign firms refer to any companies headquartered outside the U.S. For enteprises domiciled in Ireland (usually for tax purposes), but with main business operation in the U.S., we label them as either 'local' or 'domestic non-local', depending on the location of their operational headquarters.

[264] Some research directions that SCRUB is working on include: innovation on both software and hardware architecture to enable more secure computing, improving security of smartphones and tablets, methods to enhance personal data protection and minimize data breaches, as well as innovations in security analytics. Further information is shown in the link as follows: https://scrub.cs.berkeley.edu/.

[265] Specifically, the joint teams from UC Berkeley and Intel are developing MESO devices (based on magnetoelectric and spin-orbit materials), which have potential to entirely upend the current transistor-based semiconductor technologies. Read: Sanders, Robert (December 3, 2018). UC Berkeley News, link retrieved from https://news.berkeley.edu/2018/12/03/new-quantum-materials-could-take-computers-beyond-the-semiconductor-era/.

[266] The partnership will be named "Alliance for Therapies in Neuroscience" (ATN) and be hosted in Weill NeuroHub, a neuroscience research center at UC Berkeley campus. Read: Sanders, Robert (February 25, 2021). UC Berkeley News, link retrieved from https://news.berkeley.edu/2021/02/25/weill-neurohub-joins-with-genentech-roche-to-advance-neuroscience-research/.

[267] We referred to the landmark decision by the U.S. Supreme Court in 1980 (Diamond v. Chakrabarty), in which the justices ruled, in a 5-4 majority, that genetically engineered bacteria constitute a 'patentable invention'. The background of this ruling relates to an effort by Ananda Mohan Chakrabarty, then a genetic engineer working in General Electric's R&D unit, who genetically modified Pseudomonas bacteria for the purpose of chemically breaking down crude oil – a potential breakthrough in treating oil spill accidents, and attempted to file a patent application to protect his invention. USPTO rejected his bid under the reasoning that biological organisms cannot be patented. The legal back-and-forth between Chakrabarty and USPTO lasted several years until it reached the Supreme Court. The court's subsequent ruling, in concurrence with the passing of Bayh-Dole Act of 1980, became a major impetus for the emergence of modern biotechnology industry.

[268] Langston, J. (July 7, 2016). 'UW, Microsoft researchers break record for DNA data storage'. University of Washington (UW) News, link retrieved from https://www.washington.edu/news/2016/07/07/uw-microsoft-researchers-break-record-for-dna-data-storage/.

[269] Holtz, J. (May 28, 2020). 'UW launches new Center for Research and Education on Accessible Technology and Experiences with $2.5 million investment from Microsoft'. University of Washington (UW) News, link retrieved from https://www.washington.edu/news/2020/05/28/create-announced/.

[270] Bishop, T. (March 31, 2021). 'Microsoft gives $5M to UW Medicine to use AI to accelerate response to next pandemic'. GeekWire, link retrieved from https://www.geekwire.com/2021/microsoft-gives-5m-uw-medicine-use-ai-accelerate-response-next-pandemic/.

[271] Boeing Advanced Research Center (BARC). Link retrieved from https://www.washington.edu/research/research-centers/boeing-advanced-research-center-barc/.

[272] More details on events, activities, and research projects by Boeing Advanced Research Center (BARC) are available in BARC's webpage in UW School of Engineering website. Link retrieved from

https://depts.washington.edu/barc/node/1. Additional information on Boeing's professional continuing education program is shown in the following link: https://www.pce.uw.edu/boeing.

[273] For a more detailed elaboration, at present A*STAR consists of 10 research institutes and 2 platform centers. The research institutes are mainly: 1) A*STAR Infectious Disease Labs; 2) A*STAR Skin Research Labs; 3) Bioinformatics Institute; 4) Bioprocessing Technology Institute; 5) Genome Institute of Singapore; 6) Institute of Bioengineering and Bioimaging; 7) Institute of Molecular and Cell Biology (IMCB); 8) Singapore Immunology Network; 9) Singapore Institute for Clinical Sciences (SICS), and; 10) Singapore Institute of Food and Biotechnology Innovation (SIFBI). The two platforms listed are: 1) Biological Resource Center, and; 2) Research Support Center.

[274] As an illustration, Cho and Valler quoted from Philip Yeo, chairperson of Economic Development Innovations Singapore (a government agency to promote integration of innovation activities into economic development), who once described the SSP as "The buildings all stand alone, nobody talks to each other… It's how you design the facilities so that people don't have to run around from building to building, place to place. You make it as compact as possible. In a high-rise building, most people know the people on top, people below. If you want them to interact socially, network wisely, you want to build literally in clusters." Source: Yeo, P. CLC Lecture Series 2011, Center for Livable Cities. Link: http://www.clc.gov.sg/Events/2011lectures.htm.

[275] Many of the scientists that Cho and Valler interviewed apparently expressed their nonchalance at the cultural amenities and refurbishments the government has dedicated into, arguing that while these 'engineered aesthetics' provided better branding for Singapore as a 'cosmopolitan' innovation and research ecosystem, they were largely irrelevant for their daily working lives. One interviewee indeed remarked to them: "It's symbolism, it's not functional in that way".

[276] The constraints imposed by the existing KPI system further reinforce the linkages between scientists' general nonchalant perception of cultural artifices and the realities of their daily working practices. In general, they highlighted challenges with publication performance and the lack of incentives to promote cross-organizational and cross-disciplinary collaboration, with one interviewee describing: "KPIs disincentivize people from doing cross disciplinary collaborative research because it is just horribly time-consuming, it's the worst, so who would do that unless it is strongly incentivized?"

[277] University Grants Committee, *Notes on Procedures 2021 Edition*, https://www.ugc.edu.hk/doc/eng/ugc/note/Full.pdf.

[278] UK Research and Innovation, *Knowledge Exchange Framework: Decisions for the first iteration*, https://webarchive.nationalarchives.gov.uk/ukgwa/20210802101912/https://re.ukri.org/sector-guidance/publications/knowledge-exchange-framework-decisions-for-the-first-iteration/.