OUR HONG KONG FOUNDATION
團結香港基金

The Ecosystem of Innovation and Technology in Hong Kong

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Executive Summary

General

1. Riding on its competitive edge as an international financial hub, Hong Kong needs to develop an innovation and technology strategy to ensure its sustainable development. According to the *World Economic Forum 2015-16 Global Competitiveness Report*, Hong Kong ranks a respectable No.7 in overall competitiveness, but fares significantly lower in the metrics of innovative capacity, and availability of scientists and engineers.

2. Hong Kong's total spending on R&D is 0.73% of GDP, lower than that of Singapore's 2.1%, Korea's 4.2%, China's 2.1% (including 4% for Shenzhen and 6% for Beijing) and the OECD average of just over 2%. Several studies point out the positive impact of R&D investment on long-term economic growth.

Human Resources

3. In Hong Kong, career prospects of science, technology, engineering, and mathematics (STEM) graduates are considered less attractive than professions such as business and finance, let alone medicine and law. This creates a vicious cycle of weak demand for and supply of scientists and engineers.

4. The Hong Kong SAR Government lags behind in R&D investment. Public spending on R&D amounts to 0.4% of GDP, half the average of about 0.8% for its Asian and OECD counterparts. Downstream, applied research in particular requires more attention.

5. Hong Kong's universities have made great strides in academic achievement over the past decade. However, there are insufficient incentives for academics to translate academic output into impact on the economy and society, in the form of product innovations and commercialisation. Under the current university systems, KPIs for academics place much higher emphasis on academic output than on impact. Moreover, more cross-disciplinary and/or cross-institutional collaborations are required to stimulate research excellence.

6. While more and more university research funding allocation is linked to the success of getting competitive research grant, the bulk of research funding is not awarded on competitive basis. Moreover, the majority of competitive research funding is dispersed among many smaller projects. These factors limit the quality and scale of research projects.

Business

7. Migration of Hong Kong's manufacturing industry to the Mainland has resulted in a small industrial sector in the SAR. In other economies, the industrial sector is an important driver of applied research. Moreover, the relatively small domestic market limits the development of technology-intensive services such as e-commerce. These are among the reasons for the low business R&D expenditure, at 0.3% GDP, compared to over 1% of other major economies.

8. There has been a surge in start-up activities in the past couple of years. However, the community remains small compared to other international cities. The ecosystem of early stage investments is yet to mature. Some success stories will help inject a sense of confidence into young people, and nurture social attitudes and support towards entrepreneurship.

9. The rise of China creates an insatiable demand for advanced technologies to solve its social and economic challenges. The emergence of Shenzhen as a technology hub opens up opportunities for Hong Kong's strong basic research fundamentals to leverage on. Advocating for a technology cluster with Shenzhen will fill the industrial and business demand for R&D.

Government

10. The Government, as faithful follower of laissez-faire and fiscal prudence doctrines, did not develop a holistic and long-term approach to innovation and technology.

11. In the context of the Mainland's ambitious 13th Five-Year Plan, which places a high priority on investing in innovation and technology development, the HKSAR Government's underperformance in public R&D investment is highlighted.

12. The Government does attempt to promote a smarter city. However, its efforts and impact lag behind those of other advanced countries and cities. Many studies point out that Hong Kong falls behind when it comes to open government data, a unified standard for geospatial data across government departments, and free public Wi-Fi service.

Key Recommendations

The HKSAR Government needs to develop a long-term strategy and to take a holistic approach in driving innovation and technology. Focus should be on fostering a healthy ecosystem and strengthen linkages between upstream, midstream and downstream knowledge creation and transfer.

1. **Substantially increased investment in research capacity.** Talent is the key to a thriving innovation and technology ecosystem. To kick start a virtuous cycle of talent development and economic growth, the Government needs to take the initiative to substantially increase investments to strengthen Hong Kong's research capacity. Building up a critical mass of talents in competitive niches will enable Hong Kong to tap into R&D outsourcing opportunities by multinational corporations (MNCs) in Asia as well as from Mainland China. More importantly, it will become the springboard of start-ups entrepreneurs who can foster the development of new knowledge-based industries. We recommend the Government to establish a HK$50 billion endowment fund on applied research, and to target public R&D to 1% of GDP to catch up with regional and international peers.
2. **Reform KPIs of universities and research funding mechanisms.** To make universities more responsive to economic and societal needs, the University Grants Committee (UGC) needs to review the current performance evaluation system that places high emphasis on publications to also consider wider impact. In addition, to promote research excellence and to align Hong Kong with international best practice, all new research funding should be channelled to the Research Grants Council (RGC) to increase the relative weight of project-based, competitive-driven research to discretionary institutional funding. Finally, as public research funding takes centre stage in many countries' innovative and technology strategies, research councils are best to be given an independent status with strong linkages with the government, industries and other stakeholders.
3. **Review regulatory environment to create space for innovation.** The Government should leverage on Hong Kong's advantages and infrastructure as an international financial hub and a cosmopolitan city to drive innovation and technology. To do so require a careful assessment of any policies that constrain the growth of firms. Regulatory bodies need to strike a balance between innovations,

competition and other regulatory roles. Simplified regulatory approaches could be considered for start-ups so long as certain principles are met. Threshold levels could be set when tighter compliance rules are required.

4. **Priming a sustainable start-up ecosystem and foster business dynamism.** The Government should focus on a market-based approach to support the development of venture capital and private incubator industries via co-investment schemes and other incentives, as well as promoting entrepreneurial activities inside universities and attracting non-local talents into Hong Kong, rather than seeking to pick winners. To encourage start-ups, business and MNCs to invest in R&D, Hong Kong needs to boost its R&D tax incentives or subsidies to make them competitive viz. regional peers.

5. **Collaboration with Mainland China.** Hong Kong's legal and infrastructural advantages as well as geographical proximity to Mainland China make it uniquely positioned to act as a "super-connector" between China and the world. An innovation and technology policy should include strategies to attract local and non-local researchers and start-ups to develop Hong Kong as an important node in the global supply chain of product designing-prototyping-testing-sampling-manufacturing-marketing as well as to drive collaboration between Hong Kong/s universities and research centres with companies in Shenzhen and Pearl River Delta.

6. **Strengthen the Basic Foundation of Smart City.** We agree with the Government's intention to examine its smart city initiatives including building Hong Kong as a well-connected Wi-Fi city and expanding open government data and its use. While expanding open government data in order to spur new research and development of new products, the Government should also review how to modify and expand Web API to provide more personalised and convenient updates of new information to citizens and users. The Government should introduce standards for government departments in the release of their data and statistics online. Since most Smart City applications are location-based, the establishment of a spatial data infrastructure (SDI) of Hong Kong lays an important foundation for further development of Smart City applications.

Introduction

Innovation and technology have been two of the major drivers of global economic growth since the dawn of the Industrial Age. Invention and commercialisation of new sources of power (from steam to electricity) and new materials (such as steel and plastic), combined with innovative ways of organising production and businesses, have propelled strong productivity gains in many advanced economies.

Several studies have highlighted the impact of innovation on the economy. Ho et al. (2009) concluded that in Singapore, every 1% increase in the stock of R&D capital will lead to 8.14% increase in Total Factor Productivity in the long run, and the long-run rate of return to R&D is 132%. This means every S$100 increase in R&D stock raises Singapore's GDP by S$132 in the long run. Likewise, Ulku (2004) suggested that in OECD countries, there would be 0.08% increase in per capita GDP as a result of 1% increase in their patent stock (number of existing patents), and for non-OECD countries, the corresponding per capita GDP increment would be higher, at 0.11%.

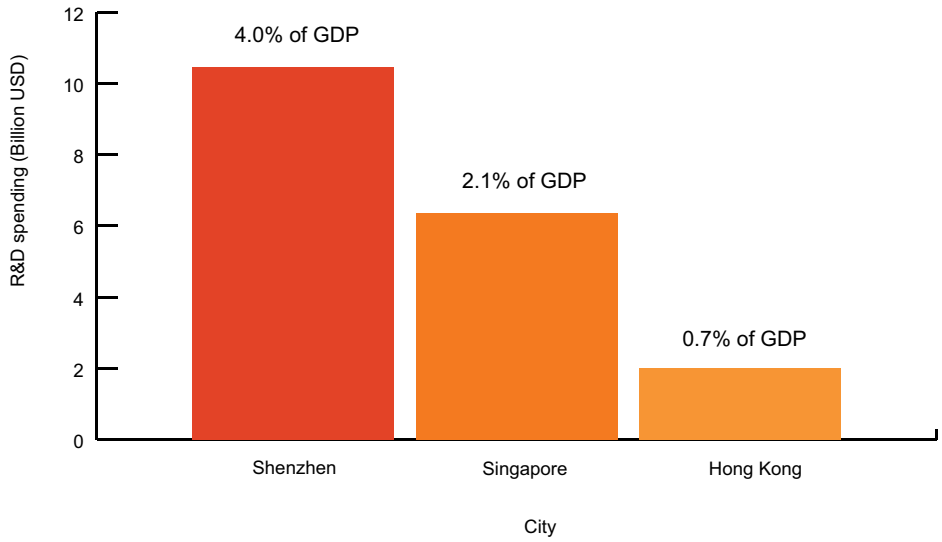
In addition to economic productivity, the effect of innovation on employment and upward social mobility is also fairly well studied. Bogliacino and Vivarelli (2012) illustrated that in the EU, for 1% increase in R&D expenditure, the number of employees (including manufacturing and service sectors) would increase by 0.025%-0.049%. Taking 2013 EU data as an example, investing €100,000 in R&D can create 1.9 to 3.8 jobs in the EU. Aghion et al. (2015), on the other hand, showed that innovation can facilitate upward social mobility. With social mobility defined as the income ranking of a child compared with that of his/her parents in a society while innovation was measured as the number of patents per capita, their study concluded that 1% increase in the number of patents per capita induces a 0.024% increment in the income ranking for the child whose parents belong to the bottom 25% of the income distribution in the US.

Therefore, as the world moves into the information technology and internet-centric era, against a backdrop of increasing globalisation, innovation and technology is becoming ever more important a factor for Hong Kong's sustainable development. And as an economy matures, it needs to constantly move up the value chain to offset rising costs of production and to diversify into a knowledge-based economy (KBE). Innovation and technology is an important path to upgrade.

Hong Kong, with a heavy reliance on financial and real-estate sectors, is lagging behind its neighbours in terms of innovation and technology

investment, as Figure 1 illustrates. Shenzhen's R&D spending of US$10 billion, for instance, is five times that of Hong Kong's. Singapore, often compared to Hong Kong, is also aggressively investing in R&D. Hong Kong has much to catch up.

Figure 1: R&D Spending of Hong Kong, Singapore and Shenzhen



Source: IMF, OECD, Census and Statistics Department (Hong Kong), CEIC

However, successful stories such as the Silicon Valley cannot be simply copied. Many countries have tried and failed. The formula for success is more complex than putting together an industrial park, a university and some government infrastructure. The innovation technology ecosystem encompasses bigger, less tangible things such as social culture, business environment, industrial structure, creative entrepreneurship, education system, government policies and collaborative practices at all levels.

This report attempts to take a look into the existing ecosystem of Hong Kong. We categorise it into three main parts: human resources, business, and government. This report will examine the current landscape, and the strengths and challenges of each of the three parts in order to get a broader understanding of their dynamics.

In preparing this report, the Victor and William Fung Foundation has provided initial drafts of the research paper through the work of the Fung Business Intelligence Centre. We would like to thank Deborah Weinswig, John Harmon, Sunny Chan, and Charlie Poon for their help.

Moreover, Our Hong Kong Foundation has hosted multiple roundtable discussions and consultation meetings with many stakeholders between June and October 2015 to discuss and seek opinions to refine the report and provide recommendations. These stakeholders include members of the academia, business and financial sectors as well as government and public bodies. A list of these individuals and organisations is attached in Appendix I.

Human Resources: Innovation & Creativity

Background and Current Landscape

Human capital is one of the essentials of innovation and technology (I&T). Education, particularly university, plays an important role in nurturing I&T talents. In Hong Kong, there are 19 degree-awarding higher education institutions, eight of which are funded through the UGC. Six of the eight offer science-related curricula in both undergraduate and postgraduate programmes and one is a teacher-training institution. In the 2014/2015 academic year, a total of 87,600 full-time students and 3,900 part-time students enrolled in UGC-funded undergraduate and postgraduate courses. These includes 15,000 enrolments in first-year/first-degree undergraduate courses. Moreover, there were around 7,000 research postgraduate students, of whom around 5,600 were supported by government grants.

Besides universities, the Innovation and Technology Commission (ITC) also has five affiliated research centres (discussed in the "Government" chapter), focusing on business-related research in the areas of automotive parts and accessories, information and communication technologies, textile and apparel, logistics and supply chain management, and nano and advanced materials.

Strengths and Challenges

Strengths

Academic Excellence

Over the past 20 years, Hong Kong's education has made great strides in quality as well as global reputation.

Secondary Education

Hong Kong has a well-established secondary education system that nurtures science and mathematics talents. It is highlighted by the 2012 Programme for International Student Assessment (PISA), in which Hong Kong ranked second and third in science and mathematics respectively. Hong Kong secondary education lay a strong foundation for more advanced scientific training.

Table 1: 2012 Programme for International Student Assessment Mathematics Ranking and Scores

Country/ region	Rank	Score	Country/ region	Rank	Score
Shanghai	1	613	France	25	495
Singapore	2	573	United Kingdom	26	494
Hong Kong	3	561	Norway	30	489
Taiwan	4	560	Italy	32	485
South Korea	5	554	Russia	34	482
Japan	7	536	Spain	34	484
Canada	13	518	United States	36	481
Germany	16	514	Sweden	38	478
Australia	19	504	Israel	41	466

Source: OECD

Table 2: 2012 Programme for International Student Assessment Science Ranking and Scores

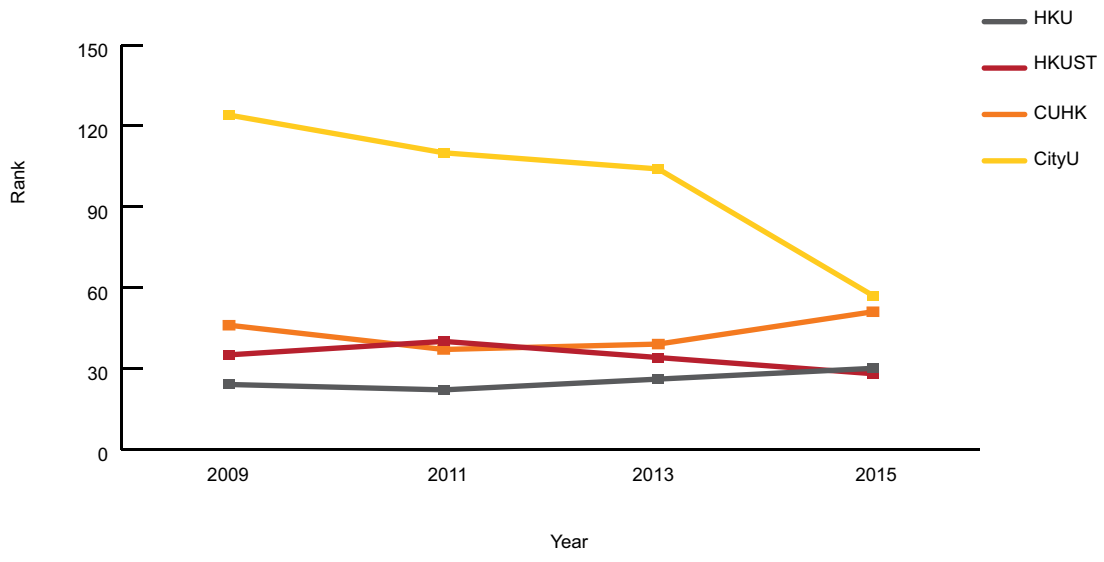
Country/ region	Rank	Score	Country/ region	Rank	Score
Shanghai	1	580	United Kingdom	20	514
Hong Kong	2	555	France	26	499
Singapore	3	551	United States	28	487
Japan	4	547	Spain	29	496
South Korea	5	538	Norway	31	495
Canada	10	525	Italy	32	494
Germany	12	524	Russia	37	486
Taiwan	13	523	Sweden	38	485
Australia	16	521	Israel	41	470

Source: OECD

Tertiary Education

While Hong Kong's tertiary education is still some way from the world's summit, its institutions do occupy respectable positions. In the QS University Ranking (QS Quacquarelli Symonds, 2015), five out of the eight publicly-funded institutions are in the top-200, with two in the top-50. In the Times Higher Education 2014-15 ranking, four of the publicly-funded universities are in the top-200. It is also worth pointing out Hong Kong's newer universities made good progress in the past years, and fare well against their international counterparts.

Figure 2: Hong Kong Universities' QS Ranking



Source: QS World University Ranking 2015

In science and engineering, Hong Kong universities' academic achievement are all the more impressive. In subjects such as computer science, mathematics and electronic engineering, several Hong Kong universities achieve world-leading levels, ranking in the top 30.

Table 3. Hong Kong Universities with Top-100 Ranking by Subject

Subject	University (Rank)
Electronic Engineering	HKUST (19), HKU (22), CUHK (25), CityU (37), PolyU (51-100)
Computer Science	HKUST (8), HKU (12), CUHK (18), Poly U (51-100), City U (51-100)
Mathematics	HKU (20), CityU (29), HKUST (33), CUHK (42)
Chemical Engineering	HKUST (27), HKU (51-100), CUHK (51-100)
Chemistry	HKU (23), HKUST (25)
Medicine	HKU (28), CUHK (51-100)
Physics & Astronomy	HKUST (51-100)

Source: QS World University Ranking by Subject 2015

Besides, in the 2014 Research Assessment Exercise (RAE) conducted by UGC, a total of 46% of the research reviewed received either a four-star "world leading" (12%) or a three-star "internationally excellent" (34%) rating. Hong Kong's result is on par with the RAE done in the UK in 2008, showing 17% with four-stars, and 37% with three- stars. As such, Hong Kong's basic research is competitive vis-à-vis global peers and that provides a strong human resource foundation for innovation and technology advancement.

Moreover, some research has been successfully converted into commercialised products, industry research collaborations or other forms of impact to the society and the economy. The Table below highlights some success stories of technology transfer, business-university collaboration, and business spinouts.

Table 4. Selected Achievements of Hong Kong's Universities

Institution	Achievement
The Chinese University of Hong Kong (CUHK)	The Faculty of Medicine pioneered a new platform of molecular diagnostics using circulating cell-free DNA in blood. One application of this approach is in non-invasive prenatal testing (e.g. for Down syndrome), which has now been used globally by over a million pregnant women. Another application is in the non-invasive detection and monitoring of cancer, commonly referred to as 'liquid biopsies'. Chinese University holds key patents in this area. These patents have been licensed and sublicensed globally, and have resulted in start-ups in this field.
CUHK	A partnership Laboratory was established between the Chinese University and the State Key Laboratory of Agrobiotechnology. Such deep collaboration is tackling important agriculture problems by combining state-of-the-art technology, and traditional wisdom of breeders. This biotechnology can be used to enhance nutrition of crops such as high lysine rice, while genomic studies can be employed to explore wild germplasms for crop improvement; for example, cloning of a salt tolerance determinant from wild soybean for crops in water with high salt content.
CUHK	The Institute of Network Coding has successfully developed a low-complexity network coding scheme, called BATS code (which stands for BATched Sparse Code), that can significantly improve the throughput of communication networks with packet loss. The advantage of BATS code over existing approaches has been demonstrated on commercial wireless routers. It is expected that BATS code will find important applications in 5G and other future mobile networks.

Source: CUHK, HKU, HKUST, PolyU, and Nature

Table 4. Selected Achievements of Hong Kong's Universities

Institution	Achievement
City University of Hong Kong (CityU)	Students designed an award-winning business plan to commercialise a new toxicity testing technology invented by a CityU Professor's team using transgenic fish embryos. After graduation in 2010, they licensed the technology from CityU, and set up Vitargent (International) Biotechnology Limited. Vitargent secured incubation funding and subsequent venture capital investments. In April 2015, the invention and the start-up clinched the Grand Prix Prize at the 43rd Geneva International Exhibition of Inventions, for its first-in-the-world "transgenic medaka" and "zebrafish fish" embryo toxicity (FET) testing technologies, to enhance global product safety testing standards to protect consumers' health.
CityU	"Pureland - Inside the Mogao Grottoes at Dunhuang" marked a new modality of archeological exhibition for museums, using digital interpretation and sustainable preservation. The 360° virtual reality display, housed at the School of Creative Media, creates the best way to introduce the murals, paintings and sculptures of the Mogao Grottoes. The Pureland system also incorporated the latest 3-D viewing technology and a rich set of animation and video segments of re-enacted ancient dances, musical performances, and other artifacts "coming straight off the murals", to enhance audience experience. The system has been installed at various sites and caught the interest of many potential collaborators throughout the world.
CityU	A CityU Professor has pioneered an innovative way to manufacture ultra-high strength steel combining nanocluster-strengthening with traditional strengthening methods, which provides extra toughness, weldability, and corrosion resistance, at reduced weight. The technology was licensed to a high-tech steel machinery manufacturer in Mainland China, whose steel products are used by more than 70 large and medium sized steel plants including overseas markets like India, Brazil and Saudi Arabia.
Hong Kong Baptist University (HKBU)	The Department of Physics has developed a thin film technology to deposit sapphire thin film onto substrate with a weaker hardness such as quartz, fused silica or toughened glass. This combination is better than crystal sapphire substrate as it combines the surface hardness of sapphire with the toughness of the underlying substrate. This patents pending technology – the AmorGlass™, is manufactured using conventional manufacturing processes and is very cost effective. Potential applications are mobile phone camera cover `glass', mobile phone, tablet and ultra-book, hybrid notebook and watches. This technology is now licensed to a start-up led by the inventors. The start-up has attracted venture capital funding within five months from formation.
HKBU	The School of Chinese Medicine has developed a quality control technology using high performance gel permeation chromatography (HPGPC) for the identification of some specific quality control (QC) markers in the authentication of Dendrobium officinale Kimura et Migo, which is a well-known expensive Chinese medicine - Tiepi Shihu (鐵皮石斛). The uncharacteristic appearance and high price of Tiepi Shihu could lead to the occurrence of the adulterants, confused species, and counterfeits. Therefore, authentication and quality evaluation of Tiepi Shihu is crucial for ensuring its safety and efficacy. This patented technology is the only currently known technology to quickly and accurately authenticate Tiepi Shihu at a cost effective price. This technology is currently in use as quality control for Tiepi Shihu.
HKBU	A research team from both the Department of Biology and Department of Chemistry has developed a neural stem cell technology which successfully extracts neural stem cells from adult animals and transplants the manipulated stem cells back into the brain of the same animal to repair neuron damages. This patented technology has direct applications in treating neurodegenerative diseases such as Alzheimer's, Parkinson's or any brain damage due to injuries or strokes. This technology is now licensed to a start-up led by the inventors. The start-up has won numerous technology awards, including winning both the Red Herring Top 100 Asia and the Red Herring 100 Global Awards in recognition of their achievements and contributions to science and mankind.
The University of Hong Kong (HKU)	The exclusive transfer of the research outcome on hepatitis E vaccine to Yangshengtang, a Mainland pharmaceutical company over a decade ago. The work was further developed into a vaccine, Hecolin, which was approved by China's State Food and Drug Administration in December 2011. It has potential for great impact in many developing countries where hepatitis E is most prevalent.
HKU	A team at the Department of Chemistry has successfully developed a suite of new materials for next-generation Organic Light Emitting Diodes (OLEDs). These inventions were successfully transferred to a global consumer-electronics manufacturer in 2015 to be further developed for highly energy-efficient and vivid display applications.
HKU	A team in the Faculty of Medicine successfully developed Oral Arsenic Trioxide, called Arsenol, as the first patented prescription drug in Hong Kong, to treat Acute Promyelocytic Leukemia (APL), and possibly other cancers. Arsenol will likely replace the current intravenous formulation of arsenic trioxide, Trisenox, which has many undesirable side effects. Arsenol is more cost-effective due to a lower price and the lack of a need for hospitalisation during the treatment. The new drug will undergo clinical trials in different countries by licensed partners.

Source: CUHK, HKU, HKUST, PolyU, and Nature

Table 4. Selected Achievements of Hong Kong's Universities

Institution	Achievement
Hong Kong University of Science & Technology (HKUST)	DJI, the world's largest camera-carrying quadcopter drone manufacturer, headquartered in Shenzhen, is a successful entrepreneurial venture by a student under the guidance of his professor at HKUST. With R&D centres in China and Hong Kong, DJI was an incubatee company of the HKUST Entrepreneurship Programme.
HKUST	Huawei, the world's largest telecommunication equipment company, based in Shenzhen, set up a joint research lab at HKUST. Under the theme of next-generation communication and networking technologies, the lab has conducted over 50 frontier research projects in areas that include big data and analytics, wireless networking, multimedia standards, multicore network-on-chip, cloud-computing architecture, and high-performance networking.
HKUST	The Sulphate Reduction Autotrophic Denitrification and Nitrification Integrated process for wastewater treatment uses sulphate-reducing bacteria in seawater to oxidise and remove pollutants, resulting in less sludge, lower energy consumption and greenhouse gas emission. In collaboration with Hong Kong's Drainage Services Department, a large scale trial was successfully launched in Sha Tin Sewage Treatment Works.
Polytechnic University of Hong Kong (PolyU)	Optic-fibre-based sensors that detect and monitor train movement and performance metrics, such as temperature, acceleration, stress, weight and other factors. The system has been applied in railways in Hong Kong as well as in the High Speed Rail of China.
PolyU	A camera-pointing system jointly developed by PolyU and China Academy of Space Technology has been deployed in the recent, successful moon landing of the Chang'e3.
PolyU	An aviation services research centre sponsored by Boeing, with support from local aviation services companies such as HAECO, HAESL and CASL. The centre will focus on ways to improve maintenance, repair and overhaul of aviation services.

Source: CUHK, HKU, HKUST, PolyU, and Nature

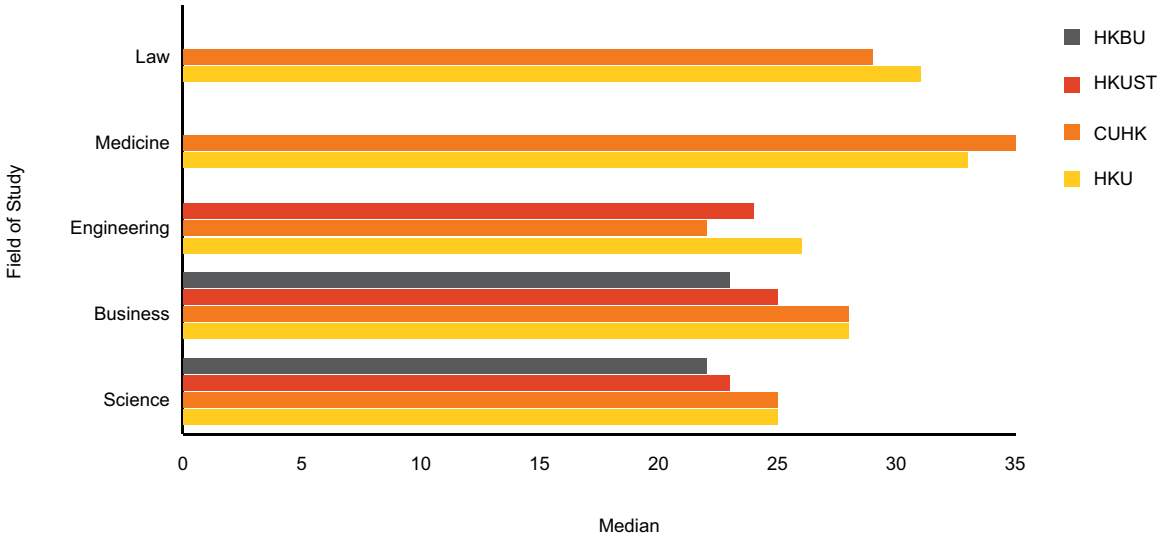
Moreover, Hong Kong is favored by several world-renowned research institutions. Cornell University initiated in 2010 a collaboration with CityU to create the first veterinary medicine academic program, filling the need for veterinarians in Hong Kong. In February 2015, Sweden's leading medicine university Karolinska Institutet established an overseas research branch in Hong Kong, focusing on disease areas in which Karolinska Institutet and some Hong Kong universities have unique expertise, including stem cell technology. MIT has recently announced the setting up of an MIT Node in Hong Kong in 2016 to take advantage of Hong Kong's "ready access to a unique manufacturing infrastructure that encourages prototyping and scale-up", according to Charles Sodini, faculty director for the node. These activities and international collaborations highlight Hong Kong's attractiveness.

Challenges

Difficulties in Attracting Students to Science, Technology, Engineering and Mathematics (STEM)

According to the 2015-16 Global Competitiveness Report by the World Economic Forum, Hong Kong ranks relatively low in "innovative capacity" - 29th, and "availability of scientists and engineers" - 41st. Indeed, a major challenge to Hong Kong's innovation and technology advancement is that STEM programmes face strong competition to attract students with the best academic results, as reflected by the universities' admission medians of various degree programmes. According to 2014 Joint University Programmes Admission System data, not only are the admission requirements for engineering and science degrees significantly lower than those of law and medicine, they are also lower than that of business programmes.

Figure 3. 2014 Hong Kong Universities' Admission Median

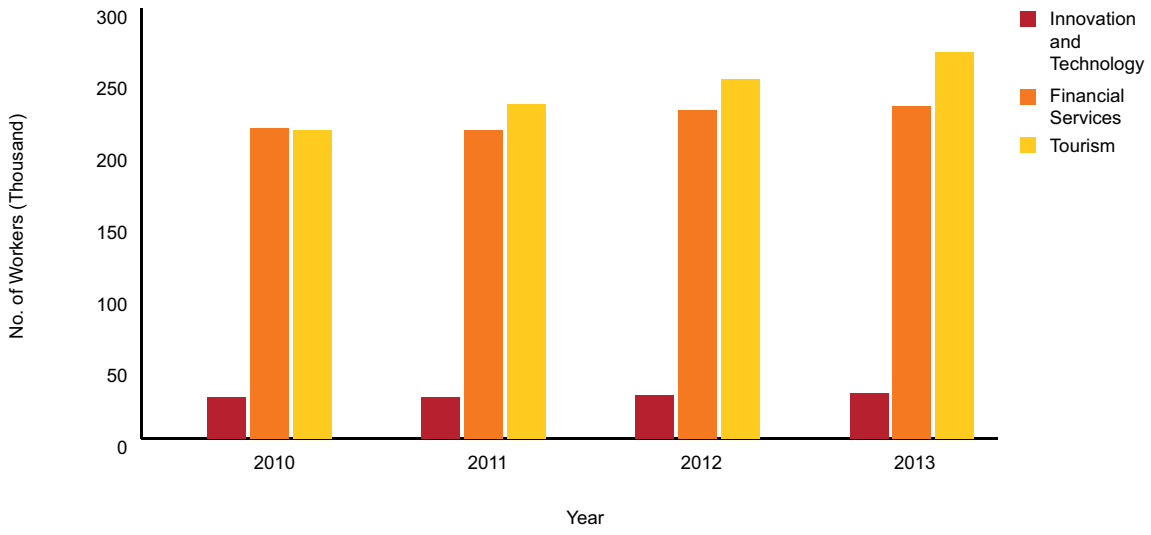


Source: Joint University Programmes Admission System

This Figure illustrates how the STEM programmes fail to attract students with the best academic results. The human resource implications of this phenomenon may have a negative effect on the development of Hong Kong's innovation and technology industry.

One possible explanation to science and engineering degrees being less attractive to prospective students is the limited career prospects. For a city focusing so much on the financial and service sector, Hong Kong's innovation and technology industry lags behind the development of other major industries, such as tourism. The small scale of the industry is highlighted by the fact that the number of jobs available in the IT industry accounted for only 0.9% of total employment in 2013.

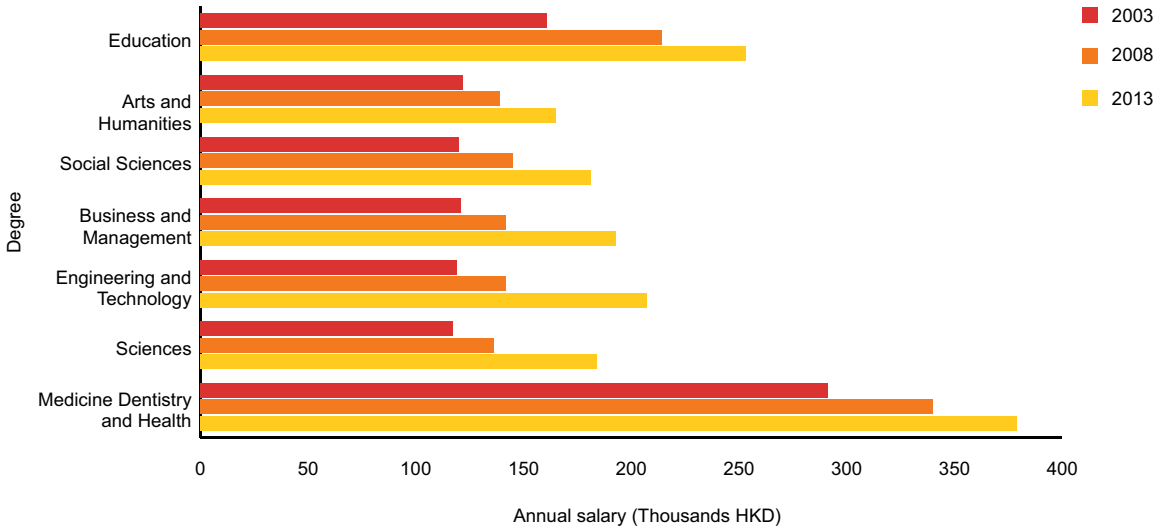
Figure 4. Employment in Various Industries



Source: Hong Kong Monthly Digest of Statistics April 2013, April 2015

Besides limited job opportunities, income of the STEM undergraduates is also not particularly attractive, as illustrated by the Figure below.

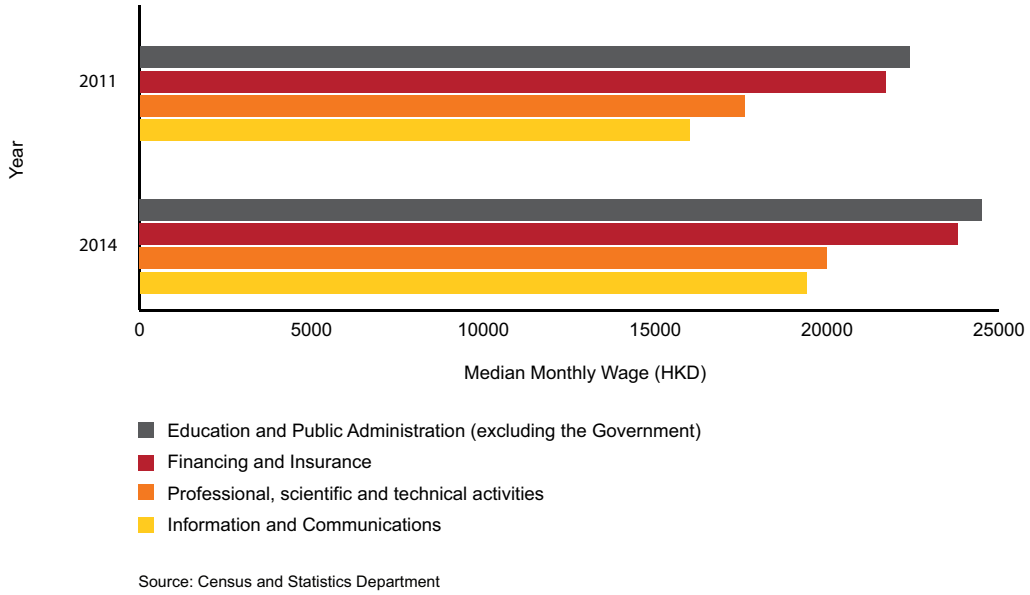
Figure 5. Average Annual Salaries of Undergraduates of Different Degrees



Source: University Grants Committee

The median monthly wage for "professional, scientific and technical activities" is lower than that of "financing and insurance" and "education and public administration".

Figure 6. Median Monthly Wage by Occupational Group

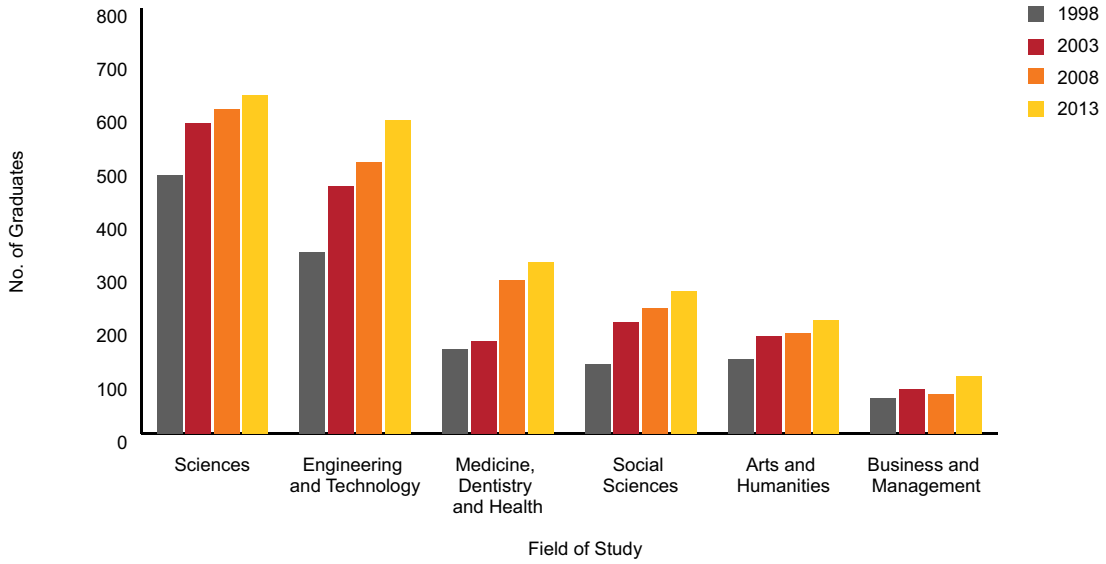


Source: Census and Statistics Department

Considering their relatively unattractive career prospect and salary level, it is not surprising that STEM programmes are not the most popular with prospective students.

It is worth pointing out that science, as well as engineering and technology programmes make up the largest student population in research postgraduate studies. In 2013, there were 1,224 science and engineering & technology postgraduates, more than the combined population of other research postgraduate programmes.

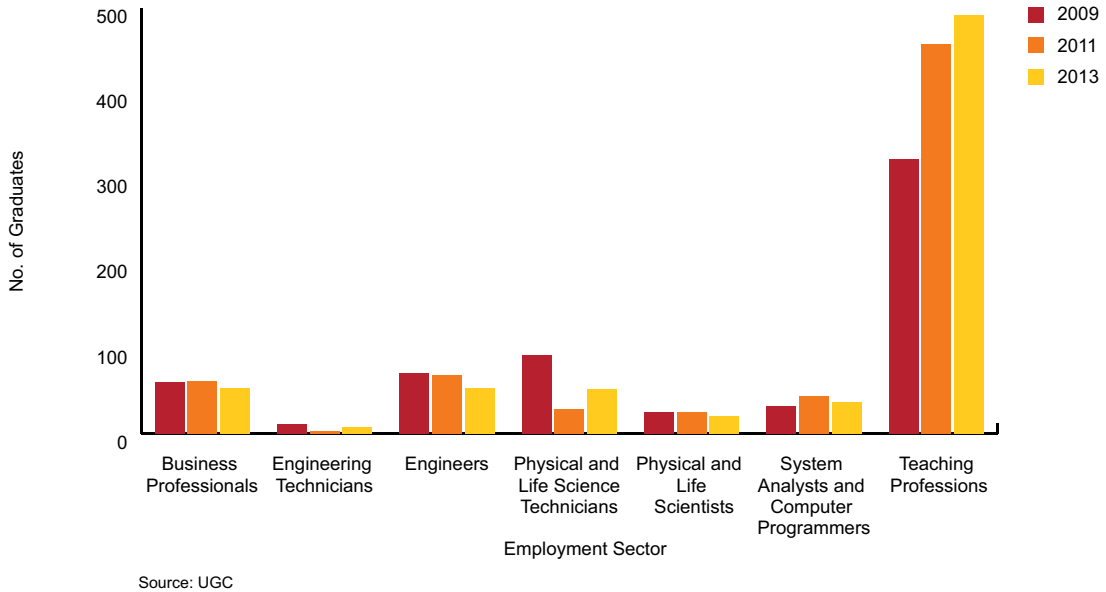
Figure 7. Number of UGC-funded Research Postgraduate Programme Graduates



Source: UGC

However, a large number of STEM research postgraduates is not leading to a large pool of STEM professionals. Only a small portion, 133 in 2013, ended up in non-academic professions related to their studies.

Figure 8. UGC Research Postgraduate Employment Situation

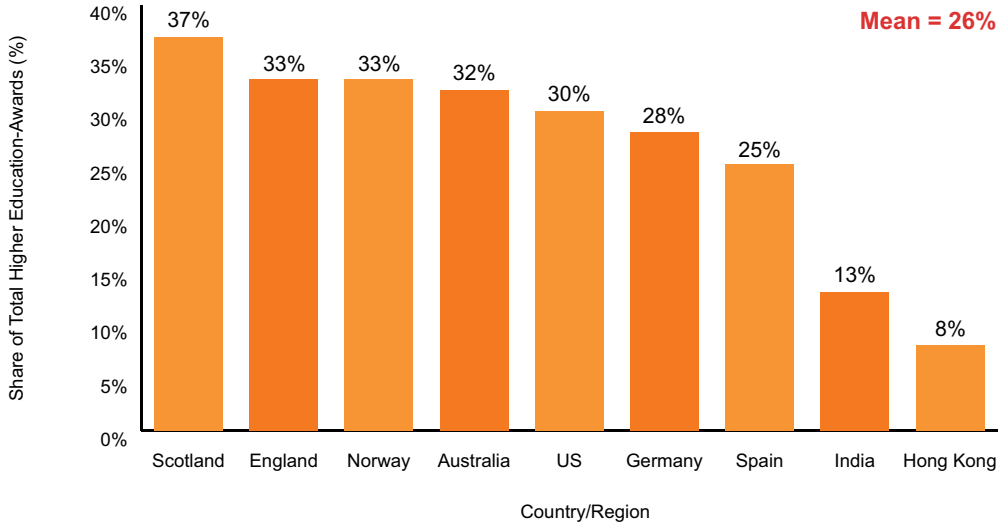


Source: UGC

Small Pool of Researchers

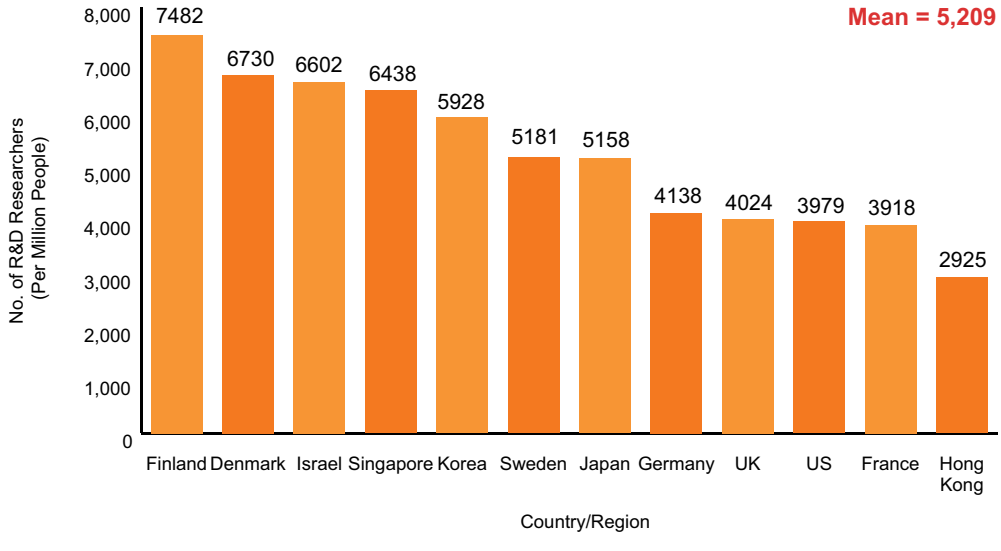
Hong Kong's postgraduate awards, as a percentage of higher-education awards, is around 8%, lower than that of many OECD countries. Moreover, the total number of R&D personnel of Hong Kong, including those in the private sector, is only 26,000 (Census and Statistics Department, 2014). Its ratio of R&D professionals to the overall population is lower than that of many OECD countries (Figure 9). In order to improve Hong Kong's innovation and technology capacity, and expand the currently small scale of the industry, Government must increase investment.

Figure 9. Research Postgraduate Awards as a Percentage of Higher-Education Awards



Source: Clark and Lunt, Census and Statistics Department

Figure 10. R&D Personnel per Million Population

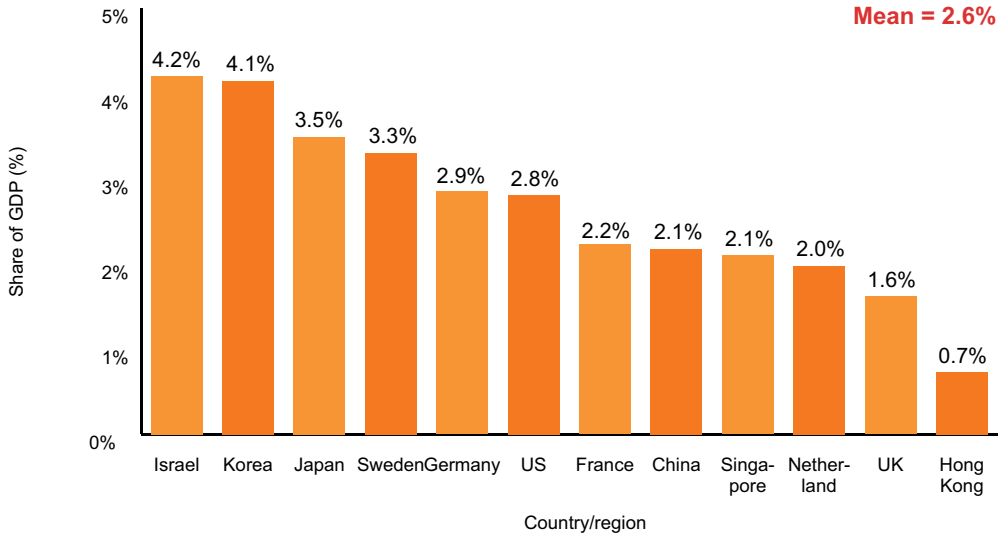


Source: World Bank

Government R&D Spending Level R&D Lags that of Other OECD Countries

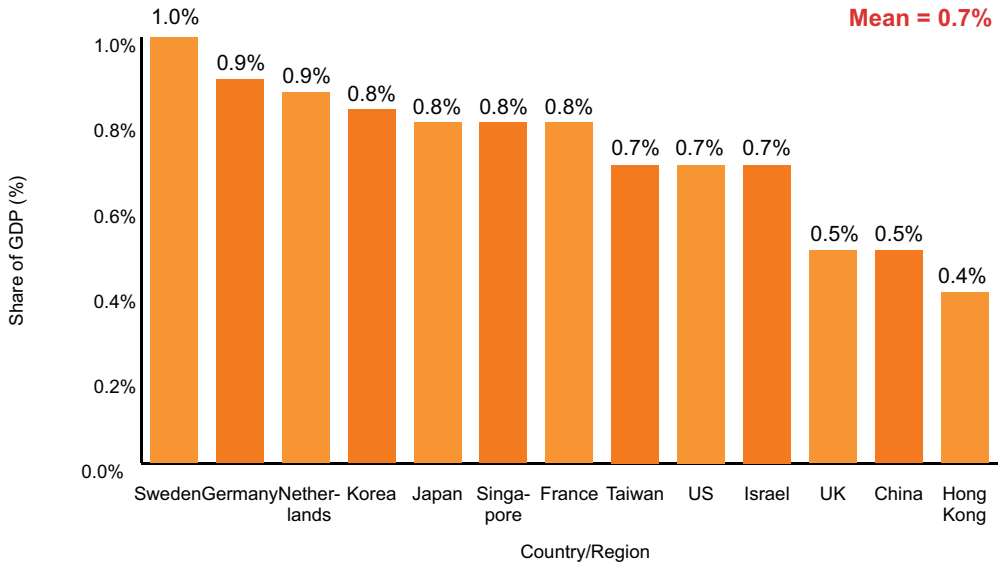
The HKSAR Government lags behind in investing in R&D, relative to its regional peers and other OECD countries. Total R&D investment in Hong Kong was around HK$15.6 billion in 2013, or 0.73% of GDP; with public (government and higher education) accounting for 55% and 45% by the business sector. The ratio is much lower than that of most OECD countries and other Asian peers. In public R&D spending, Hong Kong's ratio of 0.4% to GDP is below 0.7% of the US, 0.9% of Germany and 0.8% of Singapore, Korea and Japan.

Figure 11. Total R&D Spending as a Percentage of GDP



* 2012 for Singapore and 2013 for all others.
Source: OECD, Hong Kong Government Statistics

Figure 12. Government R&D Spending as a Percentage of GDP



* 2012 for Singapore and 2013 for all others.
Source: OECD, Hong Kong Government Statistics

A low level of public R&D investment has its consequences. As Guellec and van Pottelsberghe (2001) point out, R&D performed in the public sector, particularly in higher education, has substantial impact on long-term economic growth.

Countries which stand out in science and technology, such as Israel, Sweden, Japan and the US, all have high ratios of public R&D spending to GDP. As discussed in the introduction, innovation also plays a crucial role in driving economic productivity (Ho et al., 2009), employment (Bogliacino and Vivarelli, 2012) and upward social mobility (Aghion et al., 2015).

Under-Investment in Applied Research

While overall government research funding is low in Hong Kong as a percentage of GDP, the shortfall in applied research is even greater. The ratio in the US between basic and applied research is close to 1:1 in the last decade (Shapiro, 2013). According to the 2014 Budget Speech (Tsang, 2014), government annual investments on the Innovation and Technology Fund (ITF), which has a strong focus on business-related, downstream "applied" research, is around HK$533 million. Compared to the annual RGC budget of around HK$1.1 billion, which has a stronger focus on upstream, primarily basic research, investing on applied (including midstream and downstream) research has even more catching up to do.

The Hong Kong Government does invest in applied research through the five government-affiliated research centres (see Government section). Although with strategic focuses, there are opinions that the R&D initiatives funded by the HKSAR Government are by and large short-term-oriented, and too dispersed. This hinders the building up of research scale and excellence (Shih and Chen, 2010). Moreover, of the stakeholders we consulted, some from academia have expressed concern that some of the research centres have become funding agencies, acting as an additional layer between the government and the universities.

Besides, there have been concerns over administrative issues of these institutions. The Government typically sets a 12 to 15 month horizon for each project with stringent requirements on industry matching, and approval is required per project by the ITC. Having followed closely the operation of R&D centres over the years, the LegCo Panel on Commerce and Industry noted that industry was not very keen on conducting R&D projects with the Centres, due to the restrictive funding arrangements under ITF. Moreover, the vetting requirements and procedures are considered too complicated, thus putting off worthy projects (LegCo, 2015). Whether the government expenses are effectively utilised by the R&D Centres is also in doubt.

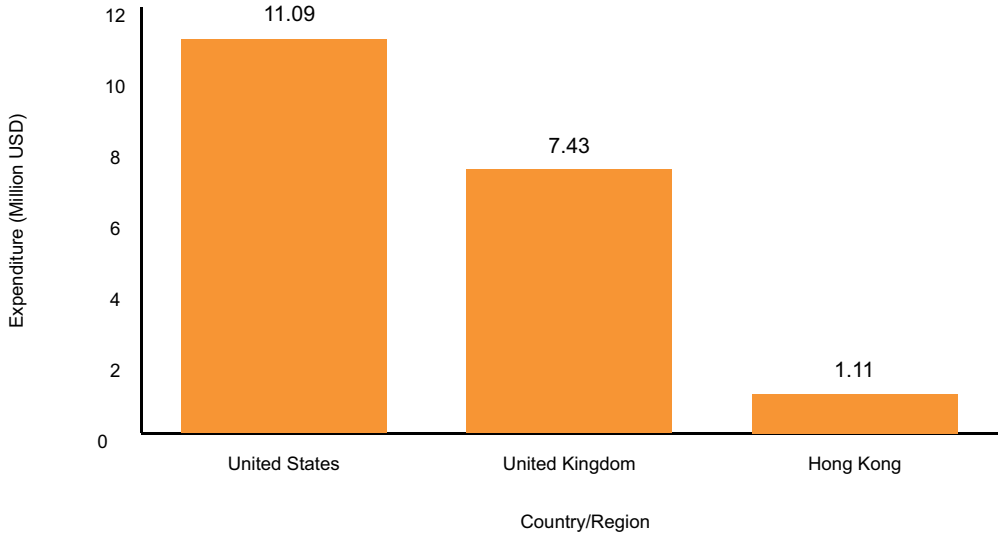
A strong public research funding system needs to strike a proper balance between basic, translational and applied research. Currently, the most inadequate in Hong Kong is midstream/translational research that aims to bridge basic and applied research. Translational research is research carried out to expand the knowledge base in a certain area to a point when more directed development work becomes possible that leads to desired applications (Nurse, 2015). Being globally competitive in basic research, it is

undeniable that Hong Kong should continue to sharpen its edge there. As Shapiro (2013) has noticed, in the US, basic research affects many markets and provides the largest spillover benefit externalities. Lau and Xiong (2015:24) also stressed "break-through discoveries and innovations can only consistently occur in an economy with a strong foundation of basic research". However, considering that the resource allocation on basic and applied research should not be a zero-sum game, investment in midstream and downstream applied research deserves more attention at this stage.

Output-Impact Gap

Despite the strong academic fundamentals, Hong Kong R&D suffers from a relatively weak link between universities and industry. This is dramatically in contrast to the US, where the innovation and technology ecosystem is underpinned by strong university-industry collaboration. For instance, the National Science Foundation's (NSF) (2003) Industry/University Cooperative Research Centres Programme established 45 centres, involving 80 universities and 600 industrial partners. In Hong Kong, industry contributes less than US$10 million to the research expenditure of the UGC-funded universities,. This amounts to US$1 per population and is just one-tenth and one-seventh the level of the US and the UK respectively.

Figure 13. Higher Education R&D Expenditure per Capita Sourced from Industry



*Hong Kong's data are for UGC-funded universities
Source: Office for National Statistics (UK), NSF (US), UGC (Hong Kong)

Knowledge Transfer and Impact: Room for Improvement

Hong Kong and the UK share remarkable similarities in the way they assess their academics. Both systems use performance-based evaluations, called the RAE in Hong Kong and the Review Excellence Framework (REF) in the UK, to assess the research capability of their higher educational

institutions in allocating institutional funding for research. The RAE, adopted by the Research portion of the UGC Block Grant, is heavily focused on academic output. According to the UGC (2013),

A. 80% of the weighting is based on the quality of research outputs;

B. 20% of the weighting correlates with other assessments on a cost-centre (i.e. academic unit) basis, namely

   i. Research inputs, i.e. the number and magnitude of external competitive peer-reviewed research grants received; and

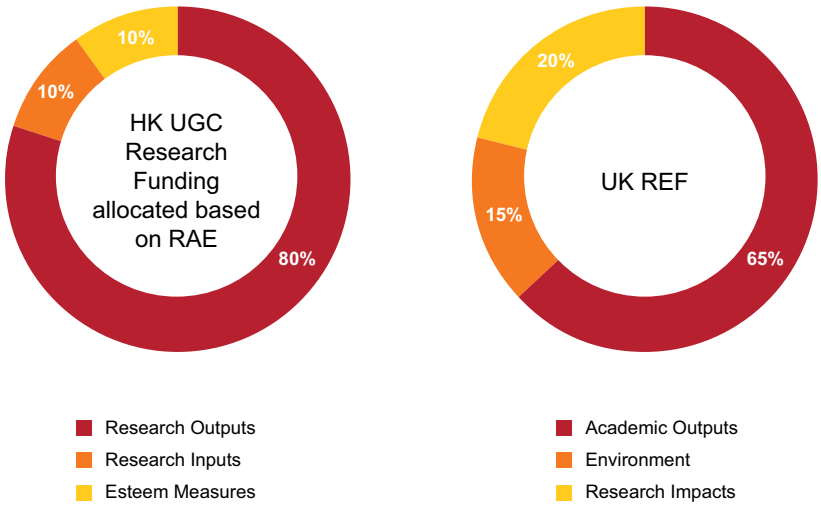
   ii. Esteem measures e.g. awards and editorship in prestigious academic publications

While we recognise that the RAE adopts an inclusive definition for research output covering publications, patents, artefacts, that are publicly accessible, contains an element of innovation and contributes to scholarship, the majority of academics we engaged have noted that publication remains the dominant output in the RAE, thus implying that the KPIs for universities' research efforts are skewed towards publication.

In 2014, the UK began to give additional recognition to non-academic impact, giving a 20% weighting to the 'reach and significance' of research impacts on the economy, society and/or culture, introduced into its REF assessment, whereas academic outputs remain the most valued item (65%). Contribution to the vitality and sustainability of the wider discipline or research base make up the remaining 15% (REF, 2012).

In comparison, there are no uniformed research evaluation systems in the US, where research is awarded 100% on a competitive bidding basis. Research funding of NSF, the second largest university R&D federal funding sponsor, considers broader societal impacts as well as intellectual merits. As public and private contract research grants constitute a major part of university income, universities' KPIs towards their faculty often place significant focus on metrics other than research publications, such as success in competing for nationwide research funding and industry research contracts, community services, amount of venture capital investments, number of entrepreneurial spinouts, retention ratio and social mobility.

Figure 14. Comparison of the KPIs of Public Research Funding Mechanisms between Hong Kong and the UK



Note: The default weighting split between research inputs and esteem measures is 10/10, but a panel may justify a departure from the default weighting split (to either 15/5 or 5/15)

Source: UGC(Hong Kong), REF (UK).

Indeed, Professor Dame Ann Dowling's 2015 review of business-university research collaborations confirms that since the REF assessment in 2014 included the 'Impact' of research, universities and academics have paid more.

> "This (introducing 'Impact' to assessment) in turn appears to be changing the way in which university-business collaborations are viewed and valued — a message that came through strongly in evidence to this review. Impact would therefore appear to be a useful tool in encouraging further collaborative work."
> (Dowling, 2015: 29)

In addition to the UK, academic and industry collaboration is an invaluable component of the innovation value chain that many governments are working to improve. As Hazelkorn (cited in Tomsk, 2006) noted, countries such as Canada and Ireland recognise the importance of knowledge-intensive industries and services to economic growth, thus structure support to nurture the links between educational establishment and commercialisation ventures.

According to the UGC (2014), research sponsorship from local industry was less than US$8 million, or a mere 2%, of the total (including private and public) funding for new research grants in 2013/2014. Foreign funding, including industry and non-industry, amounted to US$15 million, or 4%, of total new research funding. In Hong Kong, as the industry contributes fairly little to the research efforts of the academic sector, the Government will need to carefully and strategically consider means to engage the business sector.

Table 5. New Research Project Funding for UGC-funded institutions, 2013/2014

Project	Amount (HKD Mil.)	Share (%)
RGC & UGC earmarked research	1,241	45
UGC (Others)	311	11
Hong Kong charities	410	15
HKSAR Government	506	18
Hong Kong industry	62	2
Hong Kong others	111	4
Non-Hong Kong	120	4
Total	**2,761**	**100**

Source: UGC

Problem with the RAE

As with many performance assessment systems where there are often gaps between the design blueprint and their actual consequences, the RAE system of the UK has been subject to many criticisms, despite several reforms. They include the problem of "game-playing" adopted by universities and departments to ensure good rating. "People talk about planning research for RAE, not for knowledge generation", according to Eric Thomas, Vice-Chancellor of the University of Bristol, UK. "The transfer market for academics has been unnatural, with the star researchers moving to the more highly-ranked universities on a cycle mirroring the RAE". Michael Sterling, vice-Chancellor of the University of Birmingham, criticised the RAE for inhibiting interdisciplinary research and a lack of support for teaching and applied research. According to the Royal Society of Chemistry of the U.K., "universities have used RAE ratings as a management tool, leaving academics distinctly uncomfortably" (Royal Society of Chemistry, 2015).

Similar grievances over RAE are shared by academics in Hong Kong. Faculty members in the humanities discipline, for instance, have raised concerns that the RAE fails to appreciate locally-oriented academic work that make an impact to the local community but may find it hard to get into international journals. On the other hand, RAE is being highlighted by some stakeholders that it is obstructing research collaboration among universities, in addition to the tremendous effort and manpower spent on preparing the papers for RAE.

Evaluation of the performance assessment mechanism is essential to ensure that funding is allocated to promote research excellence. Whitley (2007:3) noted that in most countries, state investment on ex-ante research evaluation is considerably higher than ex-post evaluation of the results but also quoted Cozzens that "institutions and nations that are not currently evaluating, regularly and with all the skill they can muster, will probably be doing so ten years hence", partly to ensure the high quality of research outputs, and partly to satisfy potential and actual demands for increased political accountability of the greatly enlarged public science system. It is also high time that Hong Kong conducts a thorough review and evaluation of its RAE to take into account its unintended costs and consequences to determine its effectiveness in promoting research excellence as well as its fitness in coping with rising needs to make universities more responsive to social and economic needs.

Public Research Funding Mechanism: Room for Improvement

Public R&D funding is one of the major instruments government could use to steer the research system to match the rising importance of innovation and technology, on top of advancement of knowledge and training of research personnel. Given limited resources, governments around the world are restructuring their funding mechanisms strategically to ensure research investments meet social and economic needs. Indeed, many OECD countries introduced reforms to their funding system to respond to new societal demands and challenges. New funding schemes and instruments, such as performance-based and competitive funding programmes, were developed to promote new projects (Maass, 2003; Steen, 2012).

Inefficient Public Research Funding Mechanism

Currently, there are two major types of government funding mechanisms globally: institutional funding, and competitive-based funding. Institutional funding is discretionary grants given to universities to support research activities, based on certain pre-determined evaluation criteria. Competitive-based grants, on the other hand, are project-specific awards given directly to researchers based on open competition.

In Hong Kong, government research spending is primarily allocated through institutional funding via the UGC while the RGC is responsible for project-based, competitive grants. The UGC allocates resources to the universities via a Block Grant, of which around 75% goes to teaching and around 25% to research, the so-called Research (R) Block. The latter is allocated based on assessment of the overall quality of research publications of the institution, or the RAE, an internationally peer-reviewed assessment of academic publications among universities. In the 2012-15 triennium, the budget for the R Block was HK$4 billion, excluding HK$1.5 billion for research postgraduate places. On the other hand, RGC funding is drawn from an HK$18 billion Research Endowment Fund established in 2009, with a HK$5 billion injection in 2013/14. According to the UGC, the annual budgeted inflow to the RGC is thus estimated to be around HK$1.1 billion, including General Research Fund and other earmarked research funding from the UGC. Based on the above data, the ratio of institutional to project funding is around 80:20.

According to OECD (2011), in order to yield higher returns in terms of knowledge creation and research output, and make research organisations more responsive to socio-economic needs, many countries have undergone a shift away from block funding in favour of more project funding. However, there are concerns that the shift may lead to short-termism, risk aversion, as well as under-investment in infrastructure. It is thus an art of finding the right balance between institutional infrastructure support and research excellence and relevance.

In fact, the UGC proposed in 2011 to inject some competition into the Block Grant allocation. It proposed that over a period of nine years, 12.5% of the Block Grant (or half of the research portion) will be progressively awarded on a competitive basis, by reference to success in obtaining RGC grants. A formula is derived by the UGC, so that in the first 2012-15 triennium, 1.3% of the Block Grant will be competitive driven, followed by 2.6% in the second year, and 3.9% in the third year. Take 2012 - 2015 budget, for instance, of the combined UGC R Block and RGC grant, the portion of competitive driven research is 29.8%, as shown in Table 6.

This still represents quite a contrast, when compared to the 100% competitive research funding in the US (Federal R&D funds) (Matthews, 2012). In terms of project-based research funding, the 65% and 80% projects-based funds in the UK and Korea are also higher than that of Hong Kong. (Maass, 2003; OECD, 2013). In other words, Hong Kong's public research funding mechanism needs to consider having a greater portion of project funding, as well as expanding the competitive element.

Table 6. UGC/RGC Research Funding (HK$Bn)

	2013/14 Actual outlay	2012-15 Annual Budget
(a) UGC total funding (Block Grant)	15.0	16.0
(b) Research(R) block	3.45	4.00
(c): - Competitive portion of R block	0.30	0.42
(d) RGC ($23bn endowment)	0.97	1.10
(c+d) Competitive funding scheme	1.27	1.52
(b+d) UGC/RGC research funding subtotal:	**4.42**	**5.10**
(c+d)/(b+d) Competitive-driven research as % of total	**28.7 (%)**	**29.8 (%)**

Source: UGC

Moreover, the opinions from stakeholders consulted indicate that the implementation of an increasingly competitive element in R Block funding is to face severe challenges, including the tension of funding shortages as universities moved from 3-year to 4-year degree programmes, continued limited external income, and opposition from smaller faculties as major obstacles.

Besides, the measure has not addressed the need to improve transparency and accountability. While many countries are moving towards various versions of Full Economic Costs models, with clear accounting of direct and indirect (infrastructure and overhead) costs associated with competitive research grants, Hong Kong does not have any program or model in place that requires detailed calculations of indirect costs. Under the current practice, indirect costs associated with RGC competitive grants is not a line item, but is grouped under the total discretionary institutional funding (the R Block). In most countries, the indirect costs to direct costs ratio is estimated to lie between 40-60%, with a reimbursement rate of 25-50% (Table 7). In Hong Kong, the R Block is four times that of the RGC grant (the latter comprises of mostly direct costs of research, excluding faculty salaries, with the exception of Areas of Excellence and Theme-based Research programmes). Although discretionary research infrastructure cost has its value (such as in promoting long-term, "blue sky" fundamental research), such a high gap between discretionary, indirect infrastructure spending to direct, competitive research is not good for transparency and accountability, and makes it difficult to do an apple-to-apple comparison for international benchmarking.

Table 7. Comparison of Indirect Costs by Major Countries

	Canada	US	UK	EU	Australia
Direct costs (all costs directly associated with a research project)	Exclude researchers' salaries	Include researchers' salaries, and exclude equipment and payments above $25,000 to subcontractors	Include researchers' salaries	Include researchers' salaries	Include researchers' salaries
Indirect costs	Facilities, research resources, management and administration, regulator requirement and accreditations, intellectual property	Facilities (incl. equipment & building depreciation, operations and maintenance, libraries) and administration costs (incl. general executive and administrative offices, departmental administration, grant and contract administration, student services	Adopted in 2005 the Full Economic Costs (fEC) concept using Transparent Approach to Costing (TRAC). Under fEC model, direct and indirect costs are not disclosed	Moved into Full Economic Costs model similar to UK's in 2007. All eligible costs which cannot be identified by the beneficiary but which can be identified and justified by its accounting system as being incurred in direct relationship with the eligible direct costs attributed to the project	No program or model in place that requires detailed calculation of indirect costs. A government-commissioned study finds that indirect costs represent 60-66% of direct costs.
Negotiated/ proposed rate	40-45%*	53%^^	n/a	n/a	50%^
Actual reimbursement rate	Flat rate of 25%	Average 34%, no single rate; negotiated on an individual institution basis	On a project-by-project basis; estimated at above 50%	Flat 40% rate (to be reduced to 20% for Horizon 2020)	30%~

Source: Association of Universities and Colleges of Canada, Funding the Institutional Cost of Research
*Advisory Council on Science and Technology recommended in 2000 a reimbursement of 40% of the direct costs of research provided by the three federal funding agencies and that the figure to be increased over three years to 45%.
^ Australian government commissioned a study by Allen Consulting Group to estimate on full costs of research. The study finds that for the two universities they looked at, indirect costs represent 60.5% and 66.2% of research grants. The consultant recommends a reimbursement rate of 50%.
^^Source: Ledford, Heidi, Indirect costs: keeping the lights on, Nature, 19 November, 2014
~ Estimate based on amount of Institutional Grants Scheme as percentage of Australian Research Council (2006)

Fragmented Funding Allocation Hampers Development of Competitive Niches and Collaboration

A strategy of alliances and a strong focus on competitive niches are important to maintain competitiveness. In the US, collaboration has been common across universities for many years. For example, prominent research universities in the American Midwest formed the Committee on Institutional Cooperation in 1958 in which members hone core competencies while sharing collective assets and foster partnerships to accomplish complex and costly shared goals (GlobalHigherEd, 2009). Hong Kong needs more collaboration among institutions.

In Hong Kong, around 30% of RGC funding goes to midsize and large projects that require some form of collaboration between institutions. Approximately 70% is allocated to small projects. The General Research Fund, the largest of RGC's funding schemes, accounting for almost half of the 2015/16 funding, has a funding rate of over 30%, with an average funding size of less than US$100,000 per project for 2 years. In the US, the average funding rate of the National Institute of Health is 10-15%. In addition, the funding amount and duration are also generous in the US. For instance, the NSF provides US$500,000 for three years and the NIH provides US$1 million for five years.

The fragmentation in Hong Kong, on top of the already small size of the funding pool, makes it difficult to develop globally competitive niches.

Table 8: RGC funding (2015/16)

	Amount (HK$Mn)	% share	Funding rate	HK$ per project
General Research Fund	595	48%	35%	0.61mn
Collaborative Research Fund (CRF)	110	9%	14%	2-10mn
Theme based research	203	16%	18%	<75mn
Areas of Excellence*	80	6%	9%	60mn
Joint Research Scheme	42	3%		
Others	211	17%		
Total:	**1,240**	**100%**		

*Annualized budget
Source: UGC

No Independent Public Research Funding Regime

Besides the trend towards competitive project-based funding, OECD (2010) points out that many governments are switching to manage their project funding by independent agencies (such as research councils), and coordinate research by broad disciplinary groups. As illustrated in Table 9, research funding agencies of major OECD countries such as US, UK, Australia, Canada and Germany all enjoy the autonomous statutory status and are independent of the education authorities. A study commissioned by the World Bank argues that R&D funding institutions should best be set up as independent organisations.

> "In contrast to the independent support organisations of the technologically leading or developed countries, many R&D funding institutions in emerging economies are organisational sub-units of ministries or other government bodies….One main problem of such subordination is that subunits of certain ministries will tend to limit their strategic considerations to the mandate of these exact ministries....placing the organisation under the Ministry of Education may lead to an undue focus on universities and neglect of other important players in the innovation system...a direct subordination to a Ministry of Science and Technology could lead to a similar effect as it would in turn prompt a neglect of educational issues. Furthermore, there is tentative evidence that units of government tend to have a stronger tendency to apply mainly political rather than evidence-based criteria to the selection of projects"
> (Kroll & Stahlecker, 2012:20).

In addition, the OECD points out that project funding is often managed by independent agencies such as research councils, except in the Czech Republic, Israel and Poland. There are close linkages between these research councils and government departments to ensure that their research objectives are aligned with national development priorities, as well

as programs to encourage interactions between industry and research institutions.

In Hong Kong, the RGC conducts its own peer-review assessment for funding decisions and the annual RGC peer-review exercise is rigorous and well organised. However, the RGC operates under the UGC, whose role is to advise the Government on funding and development of higher education policy. Considering that UGC's focus and resources allocation are largely skewed towards teaching (representing 75% of its funding), it is worth exploring the effectiveness of the current research funding regime.

Table 9. Research Funding Councils of Major OECD Countries

Country	Research councils	Statutory status	Affiliation with government department	Organisation	Major beneficiaries	Type of research
UK	Research Councils UK [Higher Education Funding Council in charge of research block grant]	An independent Non-departmental public body under the Science & Technology Act 1965	Department of Business, Innovation and Skills	Partnership of seven separate research councils representing different research disciplines	Universities, research institutions only (Innovate UK focuses on business).	Basic, applied and strategic
US	National Science Foundation	Independent federal agency created by US Congress (1950)	None	Single entity. Support all fields of fundamental science and engineering.	Universities, research institutions (Other federal departments award research contracts to universities and business).	Basic and applied
US	National Institute of Health	Government agency	Department of Health and Human Services	27 institutes and centres; each focuses on a particular disease or body system	Universities, research institutions. Also conduct intramural research.	Basic and applied
Canada	Three separate research councils	Independent federal agencies with separate legislations (2000); directly funded by and are accountable to Parliament.	Report to Parliament through various government departments	Three separate councils represents three broad research discipline including humanities, science and engineering, life sciences and medicine.	Universities, research institutions, non-profit organisations (National Research Council focuses on industry).	Basic primarily, with programs for industry-university collaboration
Australia	Australian Research Council	Independent under the Australian Research Council Act 2001	None	Funds basic and applied research	Universities	Basic and applied

Table 9. Research Funding Councils of Major OECD Countries

Country	Research councils	Statutory status	Affiliation with government department	Organisation	Major beneficiaries	Type of research
Germany	German Research Foundation [The largest among various research funding agencies]	Self-governed association with funding contributions by federal and state funds. Members consists of universities, research institutions, scientific associations and Academies of Science and the Humanities.	None	n/a	Universities and research institutions (Other research funding organisations fund industry and universities)	Basic (primarily) and strong support of international cooperation
France	French National Research Agency	Government agency	Ministry of Education & Research	Subdivided into 5 separate disciplines	Universities, research institutes and private companies	Basic and applied
Hong Kong	Research Grants Committee	Operates under UGC. Major source of funding being Research Endowment Fund.	UGC is a government body on development and funding needs of higher education.	Under UGC. Operates through subject panels and committees consisting of local and non-local academics to conduct peer reviews in assessing research grant applications.	Universities only (ITC funds applied research of public research centres and industry-university collaboration)	Basic and applied
Singapore	National Research Foundation	A department within the Prime Minister's Office (2006)	Headed by a Deputy Prime Minister	n/a	Universities, research institutes, private non-profit, start-ups (A*STAR to perform applied research with industry collaboration).	Basic primarily, with programs for industry-university collaboration.

Cross-Border Barriers Limit Attractiveness of Chinese Funding

Academic researchers in Hong Kong could compete for funding from agencies in Mainland China, including the State Ministry of Science and Technology, and provincial agencies in the Guangdong province as well as in Shenzhen. However, the Mainland policy of not allowing grant transfer across the border limits the attractiveness of the schemes.

Some Hong Kong universities have set up branches in Shenzhen to enable faculty members to perform research work in the Mainland, and to expand into the Mainland market. However, many faculty members have teaching responsibilities at their home institutions in Hong Kong, so cross-border travel is often unattractive. In addition, the high income tax regime

of China is a deterrent to spending more than 183 days across the border. In Chan and Pang's words, such limitation

"results in less desire to apply for Mainland grants, idling of projects, inefficient use of grant money or sometimes even in unnecessary waste of money spent in hiring companies to help bypass the national border restrictions" (Chan and Pang, 2015:7).

Intensifying Regional Competition for Talent

Competition for talent is increasingly intense amidst the rapid growth of Mainland China's economy, where many research institutions and universities are now offering attractive compensation packages to overseas recruits.

In December 2008, the Central People's Government initiated the "Recruitment Program of Global Experts" (also known as the "Thousand Talents Plan"), with the aim of attracting overseas Chinese talents to return to China within five to ten years and work in key government projects, state-owned enterprises and institutions, as well as various industrial parks. The "Thousand Talents Plan" is carried out through six subprojects, focusing on recruiting strategic scientists and talents with potential to create breakthroughs in key technologies.

One such subproject is the "Recruitment Program for Innovative Talents (Long Term)". Talents recruited under this scheme will be entitled to assume certain leadership, professional or technological positions in universities, R&D institutions, central state-owned enterprises or commercial and financial institutions, as well as serve as project principals in "National Science and Technology Major Projects", "National High-tech R&D Program" (also known as "863 Program"), "National Program on Key Basic Research Project" (also known as "973 Program") and "National Natural Science Fund Projects", with responsibilities overseeing project expenditure and manpower. Talents may also participate in the consultation and demonstration of China's major projects, key construction projects and the formulation of key scientific research plans and national standards. In addition, talents are also eligible for government science and technology funding as well as industrial development funding to support their scientific research and production and operational activities in China.

The scheme offers a competitive living benefits package for recruited talents and their families, in the form of tax relief, medical care, pension, medical and work-related injury insurance coverage. Spouses and children of talents will be guaranteed employment opportunities and admission to schools respectively. Moreover, talents are also entitled to a one-off and tax-exempted start-up package of RMB 1 million. Talents with Chinese citizenship will also be free to settle in any city based on their preference without restrictions from their original residence registry. As of May 2014, over 4,180 overseas talents have been recruited through the "Thousand Talents Plan".

As the innovation and technology industry is also booming in many regions, Hong Kong faces competition for talent beyond Mainland China. In fact, a recent LinkedIn (2015) study shows that Southeast Asia is above global average in terms of percentage of companies that recruit passive talents, in the sense that the companies are actively "headhunting". Moreover, China comes first globally with 83% of its companies seeking passive talents. Hong

Kong's eagerness in reaching out to talents is relatively low, at 60%, lower than the 65% of her Southeast Asian counterparts. This is not a STEM talent specific study, but it highlights the competition Hong Kong is facing.

Non-local Talents Concerns over Living Quality in Hong Kong

Given the relatively small pool of innovative scientists and STEM researchers in Hong Kong, attracting non-local talent is an expedient way to solve the talent shortage. Indeed, innovation and technology hubs such as Silicon Valley, London, and New York are formed from talent pools of great cultural diversity. For instance, from 1995 to 2005 in Silicon Valley, 52.4% of engineering and technology start-ups in Silicon Valley had one or more founders born outside the United States (Wadhwa et al., 2007).

Hong Kong has its appeal to foreign and Mainland talents. In 2014, 31,676 overseas professionals entered Hong Kong under the General Employment Policy (Information Services Department, 2015), and 10,963 Mainland students came under the Admission Scheme for Mainland Talents and Professionals, bringing Hong Kong's total number to over 74,000 (Information Services Department, 2015; UGC, 2012). Moreover, a total of 2,724 quotas were allocated to professionals admitted under the Quality Migrant Admission Scheme by the end of 2013 (HKSAR, 2013). In 2015, the government further relaxed the stay arrangements under several professional admission schemes. It also introduced a pilot scheme to attract the second generation of Chinese Hong Kong permanent residents who have migrated overseas to return to Hong Kong.

Despite these measures, Hong Kong still faces major hurdles in attracting foreign professionals and start-ups in the science and technology fields. Although ECA International (cited in KPMG, 2014) named Hong Kong a respectable position of the sixth-most liveable city in Asia in 2015, it is five notches below Singapore. The highly cited reason was environmental concerns. While the first half of 2014 saw some improvement in air quality, Hong Kong air pollution exceeded World Health Organisation air quality guidelines during the period. A second concern is education for children, given the shortage of desks in international schools. Thirdly, high housing cost remains a problem.

In summary, there is still room for improvement in our immigration policy. First, procedures for foreign start-up visas could be further streamlined. Second, Mainland Chinese should be allowed to enjoy similar start-up visa application status as foreigners, which they do not at the moment. Third, requirement and definition of "quality" under the Quality Migration Admission Scheme could be relaxed further, as well as be made more transparent. Finally, in the focus group we conducted, many stakeholders expressed difficulty in recruiting computer programmers. While the General Employment Act is easy for corporates looking to hire relatively high paid professionals or senior-level executives, it is not so friendly when it comes to recruiting mid-level labour with technical skills. As pointed out above, as the R&D sector expand, more jobs are expected to be created. In other words, attracting non-local talents would create employment opportunities for the local workforce.

Successful Examples

Successful innovation and technology ecosystems, such as Silicon Valley and Israel, often see a healthy and diverse mix of universities, industry, and government. Universities are the focal point of academic talents, and it appears that the more successful ones embrace a higher degree of cross-pollination from government and industry. Various outstanding models are discussed in Appendix III.

Recommendations

Substantial Increase in Government Research Funding to Attract and Retain Local Talents

There is strong consensus among stakeholders that science is an essential ingredient for innovation, even though innovation now encompasses more than just R&D. In view of the long-time lag of Hong Kong in public research funding, the majority of stakeholders consulted agree that Hong Kong needs to catch up with advanced economies and neighbouring countries in particular. The Government is right in making the strengthening of the foundation of human capital one of its top priorities. In doing so, Hong Kong has good chance to break the vicious cycle of poor demand and supply of quality talents and to kick-start a virtuous cycle of private-investment-led supply enhancements. In the short run, this could also create a catchment area to retain talents who might otherwise leave the Special Administration Region (SAR) due to lack of career and research prospects. Once a critical mass is reached, it could then draw in potential downstream research investment from local and Mainland Chinese industries as well as MNCs. Finally, the clustering of talents provides a congenial environment for quality entrepreneurship and innovation to take-off. We recommend that Government should promote all forms of innovation including technological and non-technological; and to boost investments to strengthen the innovative and research capacity of Hong Kong.

Substantial Increase in Public Research Funding

Government to target a public research-spending ratio of 1% of GDP over the next decade, to catch up with regional competitors..

- **Recurrent funding.** To inject substantial recurrent funding for RGC, at a level of say HK$2 billion per annum; and, ideally, by increasing RGC's endowment by HK$50 billion.
- **More applied research.** To put more focus on midstream research and, specifically, to address the obvious gap between applied and basic research and to strengthen the linkage and build a foundation for future downstream research activities from private industries.
- **New researchers.** With the new research funding, universities are encouraged to form research centres, preferably inter-institutional joint centres, in order to compete for the necessary resources to appoint full-time research-intensive staff, such as postdoctoral fellows and research associates, who are in turn eligible to apply for research grants from

UGC, RGC, ITC and other funding agencies.

- **New inter-institutional collaboration.** Joint research centres promoting cross-universities/research centres collaboration should be promoted. These can be located outside the university campus, such as the Hong Kong Science Park or Cyberport. A thorough review of the current research centres could provide possible solutions of the best collaboration model suitable to Hong Kong.
- **Shared facilities and infrastructure**. The government has a role to support the development and maintenance of infrastructure such as specialist facilities that can be shared across sectors or centres where universities, researchers and industry can come together to undertake innovation and research activities. These facilities could be located inside or outside university campuses, provided that clear and fair costs accruals are accounted for.
- **Holistic approach.** To adopt a holistic approach to take into account and ensure that housing and family education needs of the new research recruits are met. Land might also be required for new research facilities.

Reform Public Research Funding Mechanisms

As public research funding is one of the major policy instruments to shape scientific development and hence the innovation and technology ecosystem, all participants agree that funding regimes need to adjust and adapt to satisfy increasing social demands for research excellence, efficiencies, effectiveness and accountability.

We recommend a holistic review of the various funding mechanisms of the UGC/RGC/ITC to ensure adequate funding for research, proper recognition of individuals who make significant contributions to translational research and/or technology transfer, fair allocation of resources for individual institution and the promotion of academic excellence. A review of the organisational structure of current funding agencies should also be considered to ensure they could duly perform the increasingly complex tasks of responding to new socio-economic needs that involve a broader spectrum of stakeholders.

Public research funding are useful tools to frame behaviours and strategies. A strong and efficient funding mechanism could potentially shift the current mind-set of the academics that tends to focus primarily on research output to more considerations of socio-economic outcomes. It could also reshape the competitive behaviour among universities to embrace more collaboration. This could help bridge the gap between academic excellence of our higher education institutions and their impact on innovation and technology while boosting the critical mass and quality of Hong Kong's research. Proposed policy initiatives include:

1. More Competition to Drive Research Excellence

To increase the relative share of competitive, project-based research grants over discretionary institutional funding by channelling new research investments in the future to RGC in order to better align Hong Kong with international best practice in promoting research excellence. Funding programmes could be designed to achieve certain goals such as:

- **Increase scale.** To build up the critical mass of research capacity

by reducing fragmentation. More resources to be allocated for each successful application. If the total funding remains unchanged, the number of successful grant applications may be reduced so that outstanding projects can be fully supported.

- **Increase research pooling.** RGC to encourage more inter-disciplinary, inter-university research collaboration through funding programmes. A fresh review of the current Areas of Excellence and Theme-based Research programmes may be conducted to evaluate their effectiveness in driving excellence. Schemes to promote collaboration and cooperation among universities, and with businesses, should be further developed.

2. **Coordination of Public Research Funding**

To meet new socio-economic needs and to recognise the increasing importance of research funding as an effective policy instrument to drive innovation and technology, on top of generation of knowledge and training of research personnel, we recommend the establishment of a new research funding regime to consolidate and integrate basic and applied research among various government and public agencies to enhance coordination and efficiency in overall research funding. This will include RGC, ITC and other government funding programmes.

- **RGC to be the coordinating body.** As RGC has built up a well-recognised peer-review system for competitive research funding over the years, it is considered an ideal agency to take on additional, complex tasks to shape research focus to align with public policy priorities and to drive structural changes via programme funding. Taking on the new role may require separation of RGC from UGC.
- **Division by broad disciplines.** There are distinctive differences among different research disciplines, i.e., biology and medicine, natural sciences and engineering, and humanities and social sciences. The RGC could be separated into three distinctive agencies accordingly, in order to adopt disciplinary perspectives in allocating funding, to cater for different characteristics and funding needs of different discipline groups, and to meet the different needs of social impact. Strong coordination among the agencies is essential to promote inter-disciplinary research.
- **Governance.** It would be desirable for the governance boards of the respective agencies to include representatives from academia, government and business, to ensure strong linkages between research activities and societal and economic needs in the specific disciplines. Inclusion of international expertise in the agencies, as currently being done in the RGC, should be continued to ensure global perspectives in selecting research direction and funding practices, and enhance collaboration. A thorough review of the overall governance structure is recommended to ensure a proper balance between the objectives of independent scientific discovery and responsiveness to societal needs.
- **Business-academic collaborations.** To promote collaboration of research between academics and industries, the RGC could create two separate arms within its structure: one serving the basic and applied research needs of the universities and other research organisations; and another to drive technology transfer and research collaboration between business and universities along strategic areas of priority. If two separate agencies are required to handle funding allocation to business and start-ups and to academics and researchers due to

different sources of funding, then there must be strong cooperation between the two.

- **Broaden beneficiaries.** Currently, RGC funding is eligible only to full-time academic staff of UGC-funded universities as well as other self-financing degree awarding institutions. To maximise the development of research potentials in Hong Kong, funding should be broadened to include all academics in universities as well as other pre-qualified research entities or individuals.

3. Enhance Evaluation and Transparency of Discretionary Institutional Funding

Improve current allocation mechanism of the R Block in the UGC's Block Grant to the institutions to promote competition in research funding while encouraging collaboration among universities. At the same time, clear and transparent indirect costs of research needs to be fully accounted for to ensure sustainability of research support.

- **New KPIs to universities.** Review the UGC's evaluation system that is currently based on RAE that focuses on research output. Could first consider reducing the weighting of RAE in calculation of the R Block in the UGC's Block Grant to the institutions, while adding those of competitive grant successes as well as other impact metrics such as size and country composition of international patents, patent grants, royalties from licensing agreements, number and survival of spin-off, books publication and local community services. In the long run, the UGC could consider phasing out RAE and replacing it with other performance and impact metrics.
- **Indirect costs.** UGC to commission an independent study of the indirect (infrastructure and administrative) costs related to competitive research grants to promote transparency and responsible financial management. UGC to make arrangement with RGC to ensure sustainability of research to complement the proposed increase in competitive research funding via RGC, with the goal of capturing full economic costs of research as practised in other jurisdictions. Around the world, it is showed that indirect costs account for 40-60% of direct costs of research and most governments reimburse between 25-50% to institutions.
- **Inject competition in Block Grant allocation.** Institutional funding is vital to support the research infrastructure of the institutions. Universities should also be allowed to develop research directions that are not immediately "fundable" by the available RGC funding schemes. Therefore, while the UGC should continue to push forward its initiative to introduce competition in its Block Grant allocation to align Hong Kong to international practice, it is not advisable to eliminate the R Block entirely at this moment. According to the current plan, 12.5% of total UGC funding or 50% of the R Block will be progressively allocated, over a period of nine years by 2020, on a competitive basis with reference to successes in obtaining RGC grants. We support this moderate approach. However, university administrations should also be transparent in reporting how the R Block is being utilised in individual institutions.
- **Align academic output to outcome.** Universities to offer incentives to encourage academics to think beyond basic research to consider socio-economic impact of their research. Some KPI examples to consider include: high impact book publication, community services, and industry research collaboration.

Facilitate Collaborations between Mainland China and Overseas Institutions in Research and Talent Training Activities

Experiences in many countries show that international research collaborations enhance research quality and contribute to finding solutions to global issues and challenges shared by countries. In addition, Hong Kong offers superior infrastructural advantages such as in IP protection, free flow of information and cosmopolitan living that can help Mainland Chinese companies to attract overseas R&D talents. Therefore, joint research programmes between Hong Kong and Mainland China, as well as joint programmes with foreign countries, should be promoted.

We recommend that more funds be made available for cross-border collaborations to foster mobility and collaborations in doctoral training and post-doctoral qualification, and to expand opportunities to build large-scale infrastructure to enable long-term cross-border collaborations. In addition, companies from Mainland China should be encouraged to set up R&D centres in Hong Kong.

1. **Collaboration among Research Performing Institutions**

- **More collaborations.** With more funding, the RGC should expand the scope and depth of collaboration agreement and joint programmes with partners in Mainland China and other countries.
- **Cross-border funding.** Government to negotiate with mainland authorities for special treatment to allow Mainland government research fund to come into Hong Kong.
- **Tax harmonisation.** To arrange tax harmonisation for Hong Kong's researchers working on Mainland funded research projects in the Mainland, to deal with the huge income tax rate gap between Mainland China and Hong Kong.
- **More flexibility**. Universities to provide flexible work schedule arrangements to encourage university researchers to work in Mainland-based projects.

2. **Leverage on China's Industrial Modernisation to Drive Hong Kong's Research Capacity**

As China becomes more internationalised, companies reach out to tap global talents in its R&D initiatives. Given Hong Kong's IP protection, its free trade port status, subject to less technology import restrictions from the West, and its metropolitan appeal to overseas talents, the SAR government should encourage mainland companies to establish research facilities in Hong Kong by offering taxation and other incentives.

3. **Cooperation between Mainland/Overseas Companies and Students**

Exchange and internship programmes for Hong Kong students outside Hong Kong should be encouraged to widen their global perspectives and experiences. Currently, ITC sponsors internship programme for Hong Kong students in local companies only. It would be desirable to expand the scope of this programme to overseas and mainland corporations.

Other suggestions raised by stakeholders

Secondary education. Education Bureau (EDB) to conduct a thorough review of the Diploma of Secondary Education (DSE) syllabus to ensure that Hong Kong's science education is competitive with global peers in offering an interdisciplinary education that confirms to modern trends in scientific studies. Specifically, students need to be given a comprehensive exposure to all science subjects such as pure and applied mathematics, chemistry, physics and biology in order to ensure a smooth transition to university education.

Attract MNCs. Given the important role MNCs can play as strategic anchor in a technology cluster including the provision of value-added jobs and training grounds for future entrepreneurs as well as being part of the funding chain for start-ups, government should pump up its effort to attract more MNCs to Hong Kong for R&D.

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Business

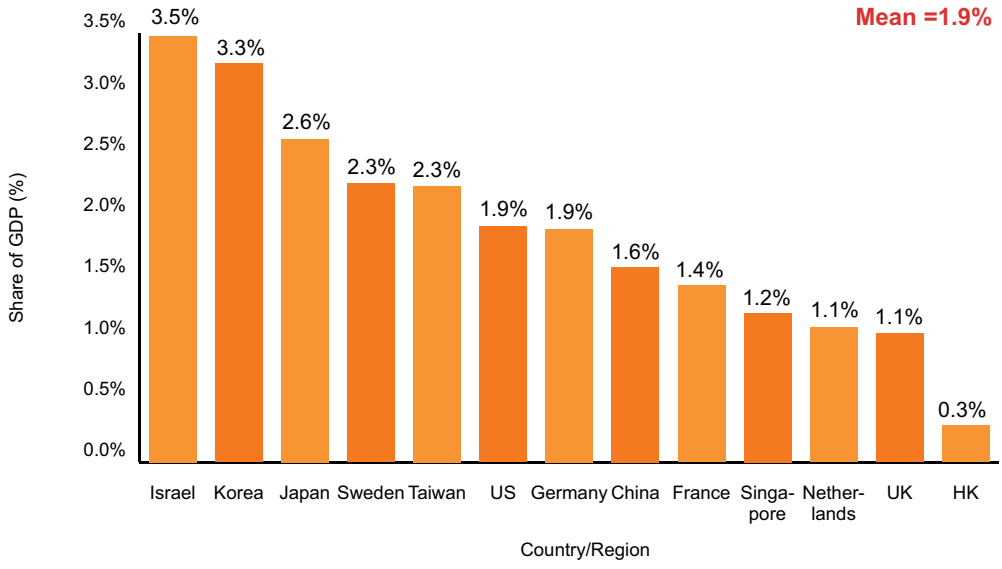
Background and Current Landscape

The business sector constitutes a key component of a country's technology and innovation ecosystem. First, it is the largest component of R&D spending in most OECD countries, contributing more than half of most countries' total R&D spending. Businesses are also collaborators with universities and research institutes in R&D. Owing to their market orientation, businesses are often major drivers of research commercialisation of innovative concepts and prototypes. As Guellec and van Pottelsberghe (2001) point out, business R&D often results in higher quality of output, as well as in new goods and services. Many empirical studies conclude that business R&D matters to productivity.

Moreover, analysis done by Guellec and van Pottelsberghe (2001) suggests business R&D increases the ability of the business sector to absorb technology coming from abroad, government, and universities. In other words, the high spillover effects mean business R&D offers more than private return.

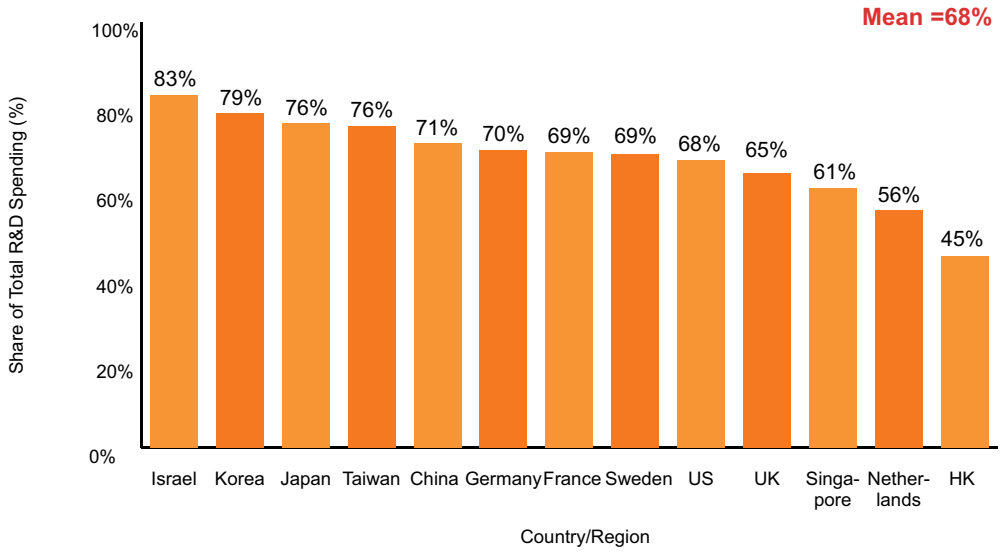
As Figures 15 and 16 show, Hong Kong's business sector spends relatively less on R&D, when compared to wealthy counterparts around the world. This chapter will investigate the strengths of Hong Kong's business sector, as well as the factors that hinder business R&D investment.

Figure 15. Business Spending on R&D as a Percentage of GDP



* 2012 for Singapore and 2013 for all others.
Source: OECD, HK Government Statistics

Figure 16. Business R&D Spending as Percentage of Total R&D Spending



* 2012 for Singapore and 2013 for all others.
Source: OECD, Hong Kong Government statistics

Strengths and Challenges

Strengths

Hong Kong's common law legal system, metropolitan culture, high-quality infrastructure, and geographic location make it an attractive platform for doing business in Asia, particularly with Mainland China. Indeed, Hong Kong has been a major beneficiary of China's economic modernisation. Today, Hong Kong continues to enjoy preferential access to the Mainland. The Closer Economic Partnership Arrangement (CEPA) goes beyond China's World Trade Organisation commitments, giving Hong Kong's products and companies preferential access to the Mainland market.

Moreover, as the most significant international financial hub in Asia, Hong Kong serves as the gateway for Chinese companies seeking foreign funding, as well as for foreign companies seeking investing opportunities in China. These advantages are demonstrated by the fact that many MNCs establish regional headquarters in Hong Kong, including those from the Mainland.

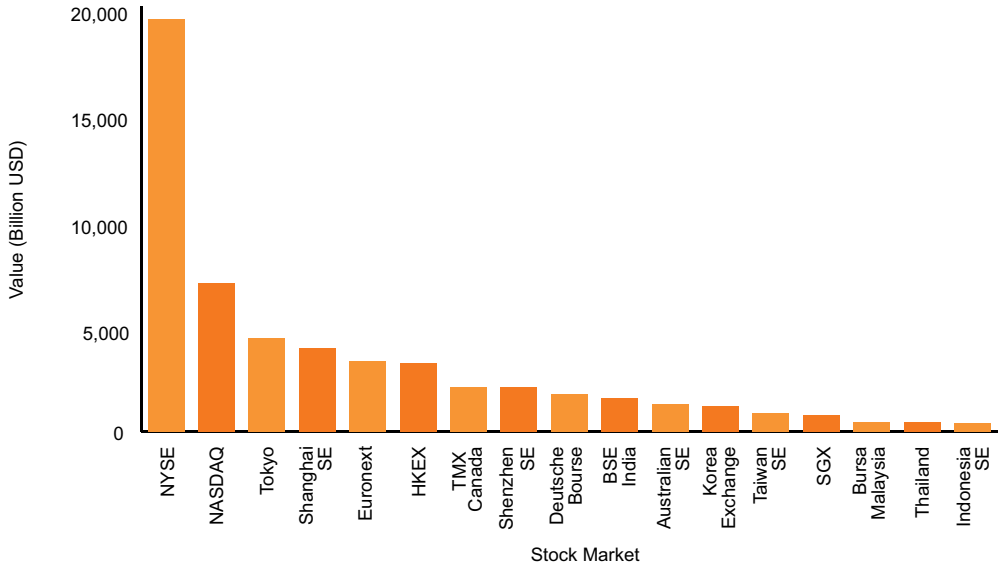
The World Economic Forum's Global Competitiveness Report 2015-2016 confirms Hong Kong's strengths, ranking it seventh globally for three years in a row, highlighting its infrastructure, financial markets, efficiency of its goods and labour market, and rapid adoption of advanced technology as among the very best in the world (Schwab, 2015).

Table 10. Summary of World Economic Forum Global Competitiveness Index Rankings for Hong Kong

Criterion	Ranking	Score
1. Institutions	8	5.7
2. Infrastructure	1	6.7
3. Macroeconomic environment	16	6.1
4. Health and primary education	29	6.3
5. Goods market efficiency	2	5.7
6. Labour market efficiency	3	5.6
7. Financial market development	3	5.5
8. Technological readiness*	8	6.1
9. Market size	32	4.9
10. Business sophistication	16	5.2

*The technological readiness pillar measures the agility with which an economy adopts existing technologies to enhance the productivity of its industries, with specific emphasis on its capacity to fully leverage information and communication technologies (ICTs) in daily activities and production processes for increased efficiency and enabling innovation for competitiveness.
Source: The Global Competitiveness Report 2015–2016, World Economic Forum

Figure 17. Hong Kong's Rank in Stock Market Size



Source: World Federation of Exchanges

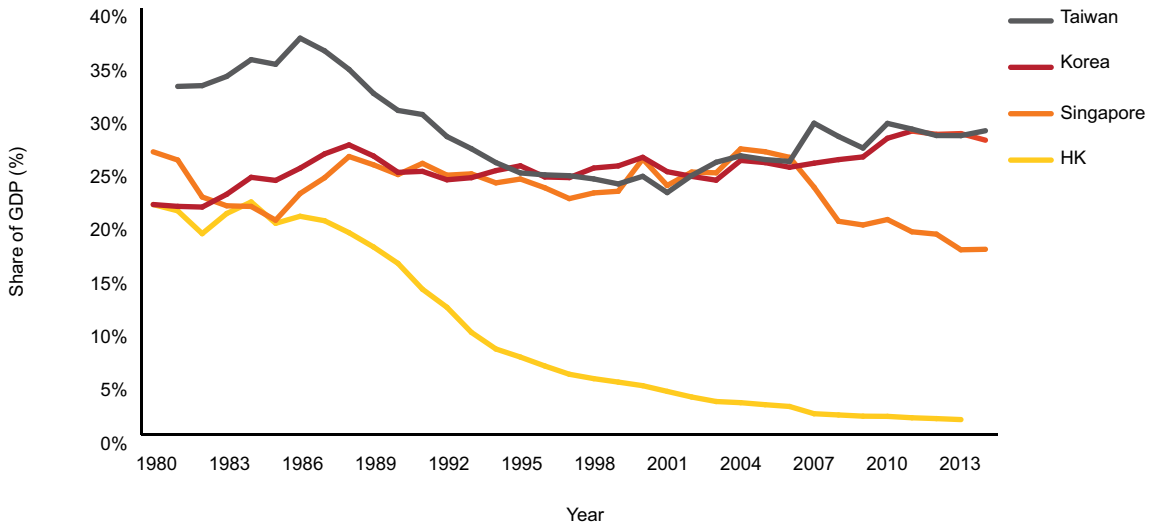
Challenges

Weak Manufacturing Base

According to the OECD, the manufacturing industry is the major driver of a country's innovation and technology. Manufacturing firms tend to undertake more in-house innovation and are more likely to introduce new-to-market innovations than service firms in general (OECD, 2010). Started as an entrepôt between China and the world, Hong Kong, like other Asian Tigers, moved into manufacturing after World War II. However, as Mathews & Cho (2007), and Chow (2010) pointed out, while Korea, Singapore, and Taiwan continue to upgrade their manufacturing industries by expanding into higher-value-added industries such as electronic components, Hong Kong took a divergent path. Many Hong Kong industrialists took advantage of the cheap labour brought about by the economic modernisation of China, and relocated their factories across the border to drive down costs. This cost-down focus distracted many Hong Kong businesses in the past decades from building a more sustainable competitive advantage via technology upgrades.

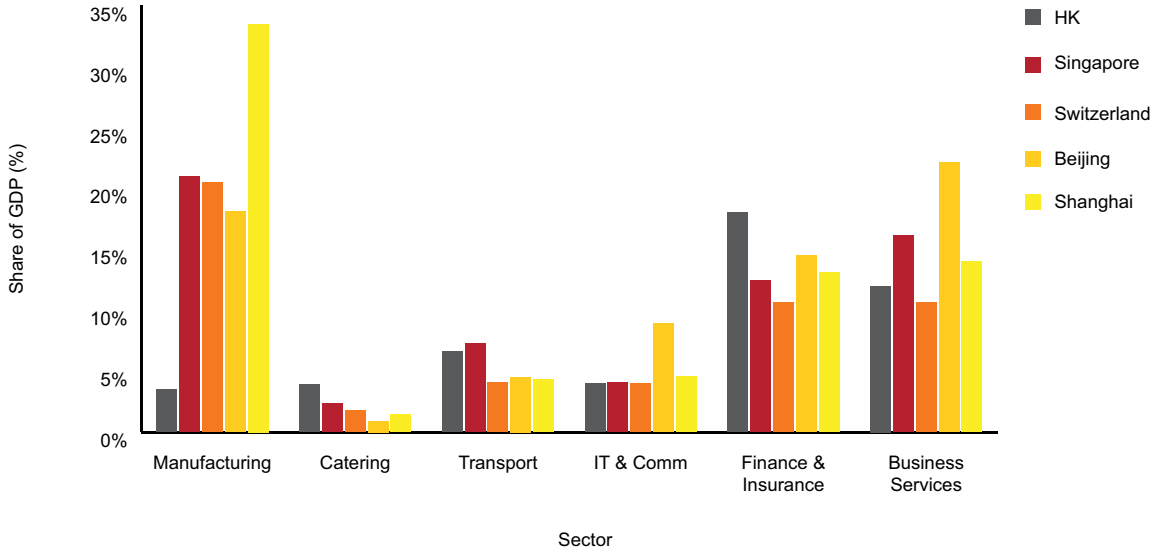
Today, Hong Kong's manufacturing sector is small compared to regions with otherwise similar economic makeup (Figure 18). This smaller manufacturing scale is another possible explanation of the relatively low level of business R&D and related incentives (Guellec and van Pottelsberghe, 2001) (Figures 18 and 19).

Figure 18. Manufacturing Sector as % of GDP



Source: CEIC

Figure 19. Breakdown of Sector GDP for Selected Regions and Industries



Source: CEIC

A Financial Hub But Not Yet a Technology Hub of Finance

Besides manufacturing, the OECD also highlights that there are some "knowledge intensive business services" such as finance and telecommunication that have in-house R&D and innovation rates similar to those in high-technology manufacturing (OECD, 2010). The finance sector is where Hong Kong has strong competitive advantage. As suggested by The World Economic Forum's Global Competitiveness Report (Schwab, 2015), the financial sector is an area where Hong Kong possesses good economies of scale, a cluster advantage and well established institutional infrastructure (such as the rule of law and a simple tax regime). Hong Kong's stock market has depth (transaction volume and market capitalisation) and openness (little restrictions to trading), backed by a sound regulatory and legal system. In the Global Financial Centres Index published by the Z/Yen Group (2015), Hong Kong has been among the top five since 2010. The financial hub consists of an amalgamation of foreign banks, investment banks, insurance companies and asset management firms that house a large pool of global, Mainland Chinese as well as local talents of investment professionals, accountants, lawyers as well as IT engineers.

The financial sector is technology intensive, and Hong Kong boasts a versatile IT infrastructure that includes traditional banking, stock and bond trading, currency exchange, derivative valuation and trading and risk management systems. Moreover, as the largest offshore Renminbi (RMB) centre, Hong Kong is set to benefit from increasing RMB convertibility as well as further financial liberalisation from China. The potential of derivative and RMB bond markets offers experimental ground for the development of innovative transaction technologies, such as blockchain, an open architecture technology that underpins bitcoin that enables a faster, cheaper and more transparent transaction of financial as well as non-financial assets and contracts.

Despite all the potential, Hong Kong has yet to develop into a regional technology centre of the financial industry. To some extent, its early success has become an impediment to innovation. An example is the Octopus Card system, a simple but efficient electronic payment system where Hong Kong spearheaded many advanced economies when it was launched in the 1990s. Following years of development and merchandise network expansion, Octopus Card has become the de facto standard of e-payment in the city. However, its dominance could create barrier for new entrants in innovative e-wallets or e-payment. Besides, Octopus Card, as a monopoly, faces the temptation of continuing only with its present mode of operation, instead of diversifying and upgrading into the next wave of e-payment system (Ma et al. 2008).

Secondly, foreign financial firms, despite their sophisticated IT infrastructure and trading systems, rarely use Hong Kong as a technology development ground. Similar to other MNCs, most foreign financial firms use Hong Kong as regional sales and marketing offices. Their core technologies are developed in overseas headquarters or are selectively developed in places where a large pool of talents exist. To lower costs, most turn to India for outsourcing for simpler coding and applications based solutions. As a result, Hong Kong is mostly used merely as a small development centre for products catered specifically for the domestic market.

Blockchain is generally regarded as the latest technology that can trigger innovative applications in the financial sector and has wide implications for the legal system and beyond. The Bank of England, the UK's central bank, released a couple of reports on blockchain in 2014. One of the reports titled "The Key Innovation" says,

> "Although the monetary aspects of digital currencies have attracted considerable attention, the distributed ledger underlying their payment systems is a significant innovation"
> (Ali et al., 2014:1).

In July, 2015, Bank of England said it is looking at "hybrid systems using Bitcoin's blockchain technology" (Allison, 2015).

> "There is more than one way in a which a distributed ledger system can work, and remuneration would have to be designed in such a way as to incentivise honest participation in the system without leading to socially inefficient over-investment in transaction verification";
>
> "Further research would also be required to devise a system which could utilise distributed ledger technology without compromising a central bank's ability to control its currency and secure the system against systemic attach".

The technology is recently given a big push by the financial industry, which has formed a consortium to create a common framework. In September 2015, nine of the world's biggest banks including Goldman Sachs, Barclays, UBS, JP Morgan, Credit Suisse, State Street, Royal Bank of Scotland, Commonwealth Bank of Australia and BBVA have joined forces with a US-based financial technology firm, R3CEV, to develop common standards for blockchain technology (Stafford, 2015).

Currently, international financial hubs like New York and London have a head start in exploring blockchain technology while Hong Kong has yet to exploit its potential. The UK government announced in March, 2015 that it will commit £15 million to support research in digital currencies. At the same time, regulatory bodies such as Financial Conduct Authority (FCA) of the UK, major stock exchanges such as NASDAQ, global financial institutions and auditing firms are establishing blockchain labs to experiment on the new technology. Likewise, Hong Kong's higher education institutions have yet to follow global peers such as the Massachusetts Institute of Technology (MIT) or Harvard in opening blockchain labs on campus. These blockchain labs, initiated by private and public institutions with support from government and in collaboration with universities, have become the basic building blocks to attract and nurture talents, both locally and overseas, from which many new start-ups spring up to develop innovative applications.

As a 2015 report done jointly by KPMG, Thomas Reuters and DLA Piper

points out, crypto-currencies and data analytics are opportunities benefiting from Hong Kong's long traditions of business-friendly regulation and free exchange of goods and money. Moreover, the report suggests that many digital currency companies see Hong Kong as one of the world's most welcoming jurisdictions for the controversial Bitcoin businesses. Yet, they do not appear to share the enthusiasm on Hong Kong's potential of Bitcoin business with start-ups coming from outside Hong Kong.

As big data and artificial intelligence proliferates into the investment world, investment managers in the "quant" area are scouting for global talents in computer science and advanced mathematics to do investing modelling. These provide good job prospects for young Hong Kong scientists but are yet to be explored due to the weak linkages between universities and the financial world.

What is blockchain?

Blockchain is a distributed database that maintains a continuously growing list of data records that are hardened against tampering and revision, even by operators of the data store's nodes. The most widely known application of a block chain the public ledger of transactions for crypto-currencies used in bitcoin although its application is generally thought to extend far beyond bitcoin.

The blockchain architecture includes blocks of transaction records, which once completed, goes into the blockchain as permanent database. Each time a block gets completed, a new block is generated. There is a countless number of such blocks in the blockchain. The blockchain database is shared by all nodes (computers connected to the blockchain network using a client that performs the task of validating and relaying transactions) participating in a system.

The blockchain protocol lays the foundation that enables new innovations in transaction services, as well as providing new tools to financial regulatory bodies in regulating derivative contracts and monitoring of anti-money-laundering. Below are some examples of applications that are currently being explored.

Micropayments. The open architecture of blockchain allows transactions of very small size that are currently not feasible under current remittances or wire transfer systems.

Smart contracts. Smart contracts are programs that encode certain conditions and outcomes. When a transaction between two parties occurs, the program can verify if the product/service has been sent by the supplier. Only after verification is the sum transmitted to the suppliers account. Apart from financial transactions including derivatives, smart contracts are entering the legal system.

Digital trade finance. Blockchain, when combines with multi-signature technology can ensure delivery and payment as much as the traditional Letter of Credit. Electronic signatures are required from the buyer, seller and banks involved, who act as escrow service providers, to consent and release money if an agreement is reached. Should there be dispute with the trade, the technology can provide a "proof of existence" that authenticates legal documents and other critical international trade files such as invoice, packing list, bill of lading and airway bill.

Regulation vs. Innovation

As the Internet proliferates, the latest round of global innovations are centred on reinventing the way people organise their lives. This leads to many disruptive business models that challenge existing interest groups and industry practices. Very often, regulatory bodies are behind the curve in understanding and recognising such trends, and in coming up with appropriate regulatory measures that balance innovation/development and stability/consumer protection.

FinTech is one example. It took off after the financial crisis in 2008, with financial disintermediation caused by general risk aversion to lending by banks due to an increase in regulatory capital as well as a general public distrust towards financial institutions created an opportunity for new, alternative funding models. At the same time, a surge of compliance obligations for banks to meet new and stringent regulations diverted innovative resources from the traditional financial institutions (Arner and Barberis, 2015). These led to a ballooning of new start-ups, founded or co-managed by experts from the financial industry with deep domain knowledge. Many of these are direct consumer-to-consumer business models that blur the lines of who the service providers are, and what services can be provided.

In Hong Kong, however, an overly stringent regulatory regime is commonly cited by FinTech start-ups and incumbents as a hindering factor to the development of innovative solutions such as peer-to-peer lending and transactions, e-payment, crowdfunding, risk management and data security. Hong Kong regulatory bodies still adopt a reactive, rather than a proactive attitude towards FinTech start-ups. They are reticent to engage start-ups at the early stage of development, although this does now appear to be changing (Arner et al., 2015).

Hong Kong currently has no laws and regulations specifically for crowdfunding. The Securities and Futures Commission issued a Notice in May 2014, which warned of the risks and potential regulatory issues associated with crowdfunding. The Notice, for instance, highlighted that crowdfunding activities must comply to 'normal' and existing regulatory provisions (Charltons, 2015).

Crowdfunding activities in Hong Kong, as such, faces restrictions on multiple fronts, including on offers of shares or debentures to the public under the Companies Ordinance, with exemptions offered only to accredited investors or high net worth individuals; or to offers that do not exceed HK$5 million over a period of 12 months; or is subject to a ceiling of 50 persons in offer, among others.

In peer-to-peer lending, pure lending platforms matching borrowers and lenders face restrictions in Hong Kong that require the person to be a licensed money lender under the Money Lending Ordinance.

Additionally, operators of crowdfunding platforms are prohibited under the Securities and Future Ordinance to conduct "regulated activities" as defined in the Ordinance, as well as any unauthorised invitations to the public such as advertisements, with few exemptions.

In mobile payment, although recent regulation on stored value facilities (SVFs) and retail payment system is a welcoming development as it lays down clear rules and principles, the high $25 million capitalisation requirement leads some to question Hong Kong's commitment to internet entrepreneurship by not establishing a de minimums float value below

which the SVF regime will not apply (as is the case in Singapore) (Parsons, 2015). All these, and others, pose challenges and high regulatory compliance costs to FinTech start-ups.

Jurisdictions in the US, EU, UK and Asia are adjusting regulatory regimes to accommodate some of the new technologies. In the US, the Jump-start Our Business Start-up Act was introduced in 2012 to encourage funding of small-and medium-sized businesses by easing securities regulations, including regulatory exemptions of equity crowdfunding. The approval of Title III of JOBS Act in October 2015 marks the first time that every US citizens, regardless of their income, can invest in early stage companies.

In order to turn this financial hub into a technology hub of finance, Hong Kong's regulatory bodies need to review the balance between innovation and regulation.

Table 11. Regulation vs. Innovation: Comparison of Regulatory Frameworks on FinTech Elsewhere

Country/ Region	Status
United States	**Jump-start Our Business Start-up Act (JOBS)** introduced in 2012 to encourage funding of small medium businesses by easing securities regulations. Title III of JOBS Act was approved in October 2015, expanding equity crowdfunding to non-accredited investor participation. Investors making <US$100,000 per year can invest the greater of US$2,000 or 5% of annual income.
United Kingdom	FCA established in 2012; released **Policy Statement PS14/4**, which regulated and outlined rules for both investment-based crowdfunding and loan-based crowdfunding.
New Zealand	**Financial Markets Conduct Act 2013 (FMCA)** took effect in April 2014, enabling equity crowdfunding and peer-to-peer (P2P) lending.
Malaysia	**"Guidelines on Regulation of Markets Under Section 34 of CMSA"** issued by Securities Commission Malaysia in February 2015, outlining regulatory regime for equity crowdfunding.
Japan	**Amendments to the Financial Instruments and Exchange Act** enacted in May 2015 relaxing regulation of crowdfunding intermediaries and operators, and introducing of new regulations for fraud prevent.
Singapore	**Consultation paper on regulating securities-based crowdfunding** issued by the Monetary Authority of Singapore in February 2015; FinTech and Innovation Group created in July to formulate regulatory policies for the sector.
Mainland China	Trial implementation of **draft "Measures for the Administration of Private Equity Crowdfunding"** launched in December 2014.
Hong Kong	**Currently no regulatory framework specifically on Fintech;** Steering Group on Fintech said to be working on a policy blueprint outlining developments of the sector.

Sources: Securities and Exchange Commission (US), FCA (UK), SCMP, Monetary Authority of Singapore, KPMG

Regulation with Threshold Flexibility

Indeed, for the FinTech sector to capitalise on the strong foundation of Hong Kong's financial industry, regulations must be reviewed. According to KPMG's 2015 report, FinTech start-ups, often with limited compliance resources, are finding it hard to understand the legal requirements applicable to them (KPMG, Thomas Reuters & DLA Piper, 2015). Arner argues for the need for a dynamic approach in regulating start-ups that can adapt to the size and activity of a business as it grows and changes.

> "...the way forward may not necessarily lie in setting rules for financial products, but instead may lie in establishing threshold levels for when institutions need to comply with conduct rules for small actors or prudential rules for larger players"
> (Arner et al., 2015: 27).

Mark Branson, CEO of FINMA, echoes such view. He reckons that the Swiss' principles-based, rather than rules-based, regulation encourages the development of the digital business sector by providing more space for innovation. Principles-based regulation with threshold set to provide flexibility to start-ups, while provide a certain degree of protection to investors and the system. Besides Switzerland, Singapore's regulatory body is adopting similar approach to FinTech (Branson, 2015).

Table 12. Regulation vs. Innovation:

Examples of Threshold Arrangements of Regulatory Frameworks of FinTech

FinTech Application	Arrangements
E-payment	Switzerland's Financial Market Supervisory Authority set specific limit below which no formal client identification is required.
SVF	Singapore gives an exemption to SVF for the Payment Systems (Oversight) Act when the stored value outstanding (the float) are under US$30 million. When that level is exceeded, the operator is required to seek regulatory approval to be licensed as a Widely Accepted SVF.
FinTech (General)	The UK's FCA is exploring the feasibility of a "regulatory sandbox" which would enable FinTech business to experiment with innovative products and business models, without immediately incurring the normal regulatory consequences.

Sources: Swiss Financial Market Supervisory Authority, Monetary Authority of Singapore, FCA (UK)

Moreover, KPMG, Thomas Reuters and DLA Piper pointed out in 2015 that the nature of Hong Kong's financial regulations is an obstacle of the city's FinTech development. The existing financial regulations are broadly based on the activities undertaken by the relevant institutions, determining which laws and regulations it is subject to. Hong Kong's financial regulatory regime has four separate regulatory agencies that are divided along sectorial product lines, i.e. banking, insurance, pensions, securities and futures. Although this regulatory framework is rather common (with similar structures in the US and Mainland China), this structure does not dovetail with the increasing integration of financial services as well as new technology trends that break down traditional definitions and boundaries of products and services. In fact, it has drawn criticisms of under-integration (Melecky and Podpiera, 2012) and high regulatory costs (Michael, 2014). Countries including the UK, Australia and the Netherlands have moved to an objective-based regulatory framework, often called the "Twin Peaks Model", whereby regulatory bodies are organised along major objectives: financial stability and protection of consumer interests. While the Twin Peaks Model is still a subject of much debate, Michael argues that there is a trend towards higher regulatory integration as financial services become more integrated. (Michael, 2014). In the latest round of FinTech innovation, traditional boundary lines between financial services become even more blurred.

Hong Kong's Tax Incentives on R&D

A study done by Guellec and van Pottelsberghe (2003) confirms tax incentives' immediate and positive effect on business R&D. Considering the spillover effects of business R&D, it is not surprising that many countries turned to substantial tax incentives to promote business R&D (Griffith, 2000). The city's tax incentives on R&D do not have advantage over those of regional peers. For instance, Hong Kong does not offer any tax credits, especially

cash refundable ones that are more relevant to start-ups with none or little profits, or ones with a long enough carry forward period that may be helpful for small-and medium-sized firms. The tax deduction incentives for R&D that Hong Kong currently offers are lower than that of Mainland China and Singapore, which are competitors to Hong Kong on R&D investments. Moreover, unlike Mainland China, Hong Kong does not offer preferential profits tax treatment for corporates that are designated as "high tech" or "innovative technology" companies.

It must also be noted that tax incentives should be stable over time, as the business sector is less likely to invest in R&D if it is uncertain of the durability of the government support (Guellec and van Pottelsberghe, 2003).

Table 13. Comparison of Tax Incentives across Asia

Countries/ Regions		Government incentives
Hong Kong	R&D tax allowance	100% deduction for direct R&D expenditure or payments to approved research institutes. Does not include sub-contracted out research.
Singapore	R&D tax allowance	A standard 150% tax deduction on qualified R&D expenditure, and can increase to 200% for EDB approved projects. The allowance is further enhanced to 400% for the first S$400,000 with a cap of S$1.2 mn applied.
China	R&D tax allowance	150% tax deduction for eligible R&D activities. Certify High and New technology enterprises to pay 15% instead of 25% income tax rate.
Australia	Tax credit	40-45% tax offset on income tax payable for eligible R&D entities. Direct government grants and loans for projects in renewable energy, energy efficiency and clean coal technologies.
Korea	Tax credit	20% tax credit for R&D expenditure incurred by qualifying new, high-growth companies with original technology, and 30% tax credit for SMEs.
Japan	Tax credit	8-12% tax credit on qualified R&D expenditure, up to a maximum amount equal to 30% of the corporate tax due for the relevant fiscal year.

Source: Ernst and Young, 2013

Other Factors

MNCs Take Hong Kong as a Regional Sales Rather Than R&D or Product Development Centre

The European Chamber (2011) identified favourable legal, political, business and tax environments are among the top four selection criteria for MNCs to locate their Asia-Pacific (APAC) regional headquarters. No wonder with advantages in being a managing sales and management hub, legal framework, the transparency of the financial framework, and risk and governance provisions being well acknowledged by different MNCs, Hong Kong serves as a regional headquarter for 1,379 MNCs and housed 2,456 MNCs' regional offices in 2013 (KPMG, 2014).

Nevertheless, Hong Kong's performance on production facilities and operation cost is worse than that of Singapore and Shanghai (European Chamber, 2011). According to Russell Reynolds Associates' study (2015), Hong Kong has lost to Singapore in the race to attract global technology companies to set up regional APAC headquarters. Among the top 50 US-based technology companies, 40% have their APAC headquarters in Singapore versus 20% in Hong Kong. Among the top 50 European firms, 50% are based in Singapore versus 24% in Hong Kong (Arner et al., 2015: 27).

Executives also acknowledge a trend relocating from Hong Kong to Shanghai for lower cost (Russell Reynolds Associates, 2015). An example is Eaton, a global power management company with over 100,000 staff globally, which moved their APAC regional headquarters from Hong Kong to Shanghai in 2005 to shorten lead times, align cost points and localise research, development and application engineering (KPMG, 2014).

Moreover, Hong Kong is generally not on the radar of R&D centres for most MNCs, which are increasingly looking to Asia for R&D collaborations. One of the reasons cited is the lack of talents. As the FSDC's (2015) Report on Human Capital points out, there is a shortage in middle and back office operation across the financial industry in Hong Kong.

Absence of a Large Domestic Market Hinders E-commerce Development

Having a large and sophisticated domestic market, albeit not a necessity, is a major contributor to a country's technology development, since it is the natural destination of the products domestically produced. The US competitiveness in foreign markets, for example, partly results from its tremendous domestic demand for the latest technology products (NSF, 2002). Emerging markets, such as China and India, likewise, have ever increasing demands for technology. Innovations and technologies are critical for developing countries to be able to leapfrog incumbent legacy inefficiencies. For example, I&T adoptions such as the propitiation of internet use and online payment systems have enabled the resounding success of e-commerce in China against the backdrop of an inefficient retailing and internal trade system (KPMG, 2014). India, by contrast, has taken advantage of broadband technology to develop a thriving software outsourcing model that bypasses the many bureaucratic blockages that often come with brick-and-mortar industries (Nasscom, 2008).

Hong Kong has a relatively small domestic market. According to Census and Statistics Department (2014), only 4.3% and 14.9% of local business adopted e-commerce sales and purchases respectively. According to Euromonitor International (cited in HKMB, 2015), the sales value of internet retailing (excluding tax) of Hong Kong in 2014 was US$1.5 billion, compared to China's US$164.5 billion. To grow big, Hong Kong entrepreneurs need to tap the Mainland's market, which demands experience and knowledge of the local market.

Opportunities Abound but Yet to Fully Tap into

1. Strong Advantage to Develop as a Smart City

Despite the above disadvantages, Hong Kong has the attributes to make an ideal testing ground for a lot of smart city applications. To some extent, Hong Kong spearheaded the e-payment system via the Octopus Card in the 1990s, as discussed. In addition, the Immigration Department's e-channel system is also well ahead of many countries in offering fast and expedient services to local residents. However, there are also areas of obvious lags, such as informatics of many public transport services that provide real-time schedule updates for buses and trams, smart parking to enable monitoring of parking space availability, electronic health record for patients, online registration and appointment for outpatient clinical services

of hospitals, while Wi-Fi hot spots and many of the Government's existing online services have rooms for improvement. Finally, more accessible data is a very important part of the government drive to enable social innovation. More shall be discussed in the Government section.

2. Globalisation

An increasingly globalised and internet-centric world, geographical boundaries are no longer a major deterrent to scaling up. Sweden, a country of 9.7 million people, demonstrates how a small, open economy can thrive by using its home market as a test bed for innovative internet applications, and then leverage them up to the global market. The country boasts successful internet unicorns, such as Skype, MySQL, Klarna and Spotify, each having surpassed US$1 billion value marker.

As an international trading centre and financial hub, Hong Kong embraces global metropolitan culture and is attuned to the latest development of global trends. Hong Kong was ranked first among 60 major economies, in the 2011 and 2012 Globalization Indexes released by Ernst & Young. Some of the local start-ups are regionally or even globally oriented (Yoo, 2015). However, unlike Sweden, which houses several successful global companies, the limited number of indigenous technology companies with global operations in Hong Kong limits start-up executives the experience to manage operations at the global level.

While the Hong Kong Trade Development Council (HKTDC) helps SMEs to promote their products overseas and InvestHK helps attract foreign start-ups and MNCs to Hong Kong, more effort to help local start-ups to connect with overseas markets is required. Moreover, more students' overseas exchange programmes and internships may provide future business leaders with international exposure.

3. Open Collaboration Opens up R&D Opportunities from MNCs

As competition intensifies in an increasingly globalised and digitalised world and as global technology trends towards increasing integration that often requires inter-disciplinary collaboration, R&D is becoming more open and international in nature. According to the OECD, firms are increasingly offshoring R&D to other countries both to link R&D markets, but also to source technological capabilities, tap into centres of increasingly multidisciplinary knowledge, lower R&D costs and access highly skilled human capital (OECD, 2010). The number of international patents co-owned by business and public research institutes rose significantly from less than 30 in 1980 to around 200 in 2006. Martin Brudermueller, BASF SE Vice Chairman of the Board of Executive Directors, suggested in the 2015 International Forum on China's Economy and Policy that information technology will connect R&D and production facilities from around the world into global innovation value chains. Countries and cities can benefit from those opportunities only if they manage to integrate into those global value chains. MNCs will channel their investments to the most attractive nodes of these value chains.

Market research commissioned by BASF (2014) shows that by 2020, the top 180 globally leading companies will spend about €240 billion on R&D in Asia – more than in any other region. This means a massive potential for Hong Kong, but only if the right policies and investments to boost research capacity are introduced to attract these MNCs R&D businesses.

4. China's Huge Demand for Technology

Despite the relatively small domestic market, Hong Kong's proximity to Mainland China offers an advantage of tapping into the huge and fast-growing market. China's demand for advanced technology is insatiable. As stated by the State Council in its latest Made in China 2025 plan, one of the priorities is promoting breakthroughs in ten key sectors of new-generation information technology, including high-end numerically controlled machine tools, robots, biomedicine, and high-performance medical devices (Gov.cn, 2015). Foreseeing that the portion of the Chinese population aged 65 or above will increase from today's 8.87% to 11.92% by 2020, there is an increasing demand for pharmaceutical and biotech technologies (Deloitte, 2015). Moreover, environmental pollution and shortage of natural resources create strong demand for technologies in renewable energy, waste and water management, new materials and environmentally friendly vehicles (Zhang, 2011).

Currently, there are 16 Partner State Key Labs (SKLs) approved and managed by the Ministry of Science and Technology of China and Hong Kong's publicly funded universities and research centres (Table 14). However, owing to restrictions on cross-border funding, the Hong Kong's SKLs receive funding from the ITF, which is of much smaller scale (HK$2 million per year for five years) than their Mainland counterparts (RMB 1 billion per year). There are opinions from CUHK and HKU that such amount is too limited to create practical impacts (Yam & Fung, 2011). Similarly, research grants entitled to joint labs between the Chinese Academy of Sciences and universities in Hong Kong are also limited, ranging between HK$0.8 and 1 million (Croucher, 2015).

Table 14. Partner State Key Laboratories in Hong Kong

University	Year of Establishment	Research Area	Dimension
CityU, CUHK, HKBU, HKU, HKUST & PolyU	2009	Marine Pollution	Geology
	2008	Millimeter Waves	Engineering
CUHK	2005	Oncology in South China	Life Science
	2008	Agrobiotechnology	Life Science
	2009	Phytochemistry and Plant Resources in West China	Chemistry
	2013	Digestive Disease	Life Science
HKBU	2013	Environmental and Biological Analysis	Life Science
HKU	2005	Brain and Cognitive Sciences	Life Science
	2005	Emerging Infectious Diseases	Life Science
	2010	Liver Research	Life Science
	2010	Synthetic Chemistry	Chemistry
	2013	Pharmaceutical Biotechnology	Life Science
HKUST	2013	Advanced Displays and Opto-electronics Technologies	Signal
	2010	Molecular Neuroscience	Life Science
PolyU	1996	Ultraprecision Machining Technology	Advanced Materials
	2005	Chinese Medicine and Molecular Pharmacology (Incubation)	Life Science

Sources: Universities' websites

5. Emergence of Technology Hub Next Door

The emergence of Shenzhen as a high-tech cluster in China provides opportunities for technology collaboration that are currently under explored. After 30 years of strong growth, Shenzhen houses a number of globally competitive companies such as Huawei, which surpassed Ericsson as the world's largest telecommunication equipment provider in 2012 (Lee, 2012). The company spent more than US$6.5 billion on R&D last year, accounting for 14% of sales (Leung and Lee, 2015). Besides in-house R&D, Huawei has built a network of R&D labs to reach out for global talents in the US, Europe and India (Huawei, 2015). Many companies in Shenzhen have followed the footsteps of Huawei to adopt a 10% R&D expense practice, and have formed strong collaborations with universities outside Shenzhen. Examples include medical equipment supplier, Mindray; handset acoustic component manufacturer AAC Technologies; and internet giant, Tencent (Table 15).

Table 15: Major Technology Companies in Shenzhen

Name	Industry	Products	Markets	Sales (2014) US$Mn	Net profit (2014) US$Mn	R&D spending US$Mn	R&D % of sales
Huawei	Telecommunication	Telecommunication and network equipment, handset	Global	46,515	4,498	6,588	14%
Mindray	Medical equipment	Patient monitoring system, ultrasound, in-vitro diagnostics equipment & reagents	Global	1,323	199	147	11%
AAC Technology	Electronic components	Acoustic components and antenna	Global	1,109	372	106	10%
Inovance	Electronic components	Power inverters, automation	Local	362	111	33	9%
O-Film	Electronic components	Touch panels	Local	476	85	58	12%
Tencent	Internet	Online value-added service platform	Local	12,730	3,852	n/a	n/a

Source: Wenweipo, Mindray, AAC Technologies, Inovance, O-Film, Tencent

That Could Fill Hong Kong's Weak Downstream Industrial Gap

Despite its economic development and thriving private enterprises, Shenzhen historically lacks strong university compatible to its economic status (Li, cited in Yeung, 2011). Although Shenzhen is making great effort to strengthen this area, Hong Kong still excels in terms of innovation capabilities, particularly in its cost-effectiveness in adapting foreign technologies to the Mainland environment (HKTDC, 2012). Collaboration with Shenzhen industry provides Hong Kong researchers with applied or translational research opportunity, as well as allows them to tap into the huge R&D funding pool.

Over the past decade, there has been an increase in research collaboration between Hong Kong's universities/research centres and corporates in the Pearl River Delta (PRD) region. Mainland companies such as Huawei have set up R&D labs at the HKUST and the PolyU; while TCL has joint research project with ASTRI. In fact, six universities in Hong Kong have become members of the Shenzhen Virtual University Park. However, the level of cooperation remains quite small.

And Help Transform Hong Kong into a R&D Hub of International Talent Looking to Tap into the China Market

Besides local grooming, another way to boost Hong Kong's R&D capability is to attract overseas talents. As China's companies go global, they search for technologies abroad, as well as improve their R&D effort with global talents. Yet, cultural differences, communication barriers, and not doing things "by the book" are factors identified by foreigners making them reticent about moving to China (Anderson, 2012; Mendoza, 2015). Hong Kong has the potential to cater for those foreign R&D talents or multinational companies attracted by the Chinese market. BASF (2014), for instance, claims to locate 25% of its global R&D employees, a community of 3,500 professionals, to the APAC by 2020. Attracting more key multinational anchors and global research institutions to put down roots in Hong Kong would change its technology landscape.

Shenzhen and Hong Kong: Good Synergy to Enable Speedy Time-to-Market Commercialisation

Another synergy between Hong Kong and Shenzhen is the latter's prototyping and manufacturing hub advantage that complements Hong Kong's competitive strength in product design, testing, logistics management and marketing, thus enabling a unique time-to-market advantage. In a globalised world where competition is intense and information flow is 24/7, time-to-market is crucial to win, especially in many consumer devices. Ebersweiler (cited in Soo, 2015), the founder of a hardware start-up HAX based in Shenzhen, said the ability to move faster than big companies is a start-up's only advantage, and Shenzhen is flexible in delivering prototypes with very short turnaround times.

Shenzhen's hub of electronic components and devices helps drive commercialisation of Hong Kong's midstream research and designs. A good example is DJI, an entrepreneurial spinout from HKUST, which took advantage of Shenzhen's manufacturing hub to scale up, enabling it to become the industry leader in a short time span. Hong Kong can leverage on this to build global business networks with researchers and inventors around the world to help bring their prototypes into product samples before mass production.

Start-ups

Start-ups Are Catching Up

According to the Global Start-up Ecosystem Ranking 2015 conducted by the San Francisco-based research firm Compass, Hong Kong is among the top five fastest growing start-up ecosystems. Indeed, in the past two years, Hong Kong witnessed the birth of about 2000 early- to late-stage technology start-ups, and a mushrooming in the number of co-working spaces shared by entrepreneurs. The Government also recognises increasingly the importance of start-ups as InvestHK steps up marketing strategies to promote Hong Kong as a start-up hub, as well as introducing different new initiatives to promote start-ups springing from universities, Cyberport and Hong Kong Science Park. Together with a recent string of notable funding rounds for start-ups (See Table 16), the latest developments have fuelled optimism and anticipation that the Hong Kong start-up ecosystem may soon reach a tipping point and will be propelled into much faster growth.

But a Long Way to Go to Build a Sustainable Ecosystem

There are, however, many challenges for start-ups in Hong Kong. On the funding front, while the quantity of funding available has increased, Compass (2015) points out that the access to venture investments in Hong Kong is far lower than that of the other top-20 ecosystems. Hong Kong does not lack high net worth individuals (who are mostly in property sector or other traditional industries) and deep-pocketed financial institutions. But Compass (2015) believes that the small number of sizable tech exits causes angel and venture investors' discomfort with technology start-ups. And hence have less experience with these start-ups, resulting in the current "Funding and Start-up Experience gaps".

The lack of scale also hinders effective clustering and networking. Although there has been a surge in accelerator programmes and networking events from public and private incubators and universities in the past year or so, they are often fragmented and lack critical mass to make an impact. As suggested by stakeholders consulted, there is little interaction between various start-up clusters that exist among foreigners, who mostly locate in Sheung Wan, with the more local ones that are either incubated in the Hong Kong Science Park and Cyberport or in various private entities.

As discussed in the Human Resources section, the linkages between our universities and industry and entrepreneurship are weak, as the current system focuses on research output, mainly publications. Academics have fewer incentives and resources to promote technology diffusion, entrepreneurial spin-offs or university-industry collaboration.

According to the OECD (n.d.), barriers of innovative SMEs to access finance include asymmetric information and financing gaps between investors and entrepreneurs. They also suffer from resource constraints, insufficient collateral, and lack of track record. These potential market imperfections justify public intervention in entrepreneurial financing. In Hong Kong, the Government has indeed offered support, financial and non-financial, to selected start-ups. But there is still a lack of holistic policy to nurture the start-up ecosystem. For instance, CUHK's Centre for Entrepreneurship (2006) has criticised ITC's three-tier-funding of R&D centres as "picking winners" rather than "non-intervention", which hindered high growth entrepreneurship. Meanwhile, the CreateSmart Initiative was criticised for funding organisations which have the same activities every year and funding deep-pocketed organisations such as HKTDC (Apply Daily, 2014).

Support from large corporates and society is also weak. Very often, large corporates and start-ups see each other as competitive forces or potential threats (Zocco, cited in Mocker, Bielli and Haley, 2015), and can rarely find a mutually beneficial way to engage, such as allowing large corporates to benefit from start-ups' innovation, while giving funding and support to start-ups. Moreover, social attitudes and support towards failure are immature and weak. Among the younger generation in Hong Kong, the culture of risk averse still dampens entrepreneurship in general (Compass, 2015).

In short, the Hong Kong start-up ecosystem needs stronger and more meaningful participation from government, large corporates, the investment community, universities and the public in order to catalyse growth.

Figure 20. An Assessment of the Hong Kong Start-up Ecosystem

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Below are the highlights of key developments in the start-up scene of Hong Kong in the past year.

1. **Universities Supporting Start-ups**

Government's provision of cash for universities' support of student entrepreneurs. The Government is providing an annual HK$24 million to six universities for the next three years in what is known as the Technology Start-up Support Scheme for Universities (TSSSU). The six universities include the CUHK, HKU, HKUST, PolyU, CityU, and HKBU.

Google's partnership with CUHK. Google and the CUHK partnered to establish a high-profile incubation programme known as the Empowering Young Entrepreneurs (EYE) Programme. A total of 900 students competed for the opportunity to get training and mentorship over several months, and six finalists were selected and sent to Silicon Valley to "demo" their prototypes last October.

PolyU. Among the preceding six universities, PolyU currently offers the most complete set of funding programmes to support students at every stage of entrepreneurship and technology transfer of university R&D. Part of the TSSSU funding will be used to match private sector investments dollar-for-dollar, up to HK$1 million (US$129,000). We have not yet seen other universities using fund matching as their mechanism to award the TSSSU funding. PolyU also runs a micro fund offering HK$100,000 to start-ups at the

conceptual stage, and has additional funding schemes and partnerships with universities and government authorities in Shenzhen and Shanghai.

2. Corporate Engagement in Accelerator Programmes

"Blueprint" by Swire Properties. Blueprint is a business-to-business (B2B) accelerator and co-working space by Swire Properties. Officially opened in January 2015, it is the first accelerator in Hong Kong with a B2B focus. The accelerator programme runs for six months and does not take any equity– this "no strings attached" arrangement is rare in the start-up world.

AIA Accelerator and DBS Accelerator, powered by Nest VC. The AIA Accelerator aims to focus on healthcare technology and wearable. The new three-month programme is a joint effort between AIA and Nest VC, a local seed fund and incubator. The first batch comprises 10 start-ups that are all from Hong Kong, which may be a telltale sign, as the programme tried to recruit from all over Asia. Given that it was only launched in early March, it may be too early to evaluate its effect on the Hong Kong start-up ecosystem. For DBS Accelerator, with a focus on FinTech, this new programme is accepting applications and is set to launch in November. There is a consensus within the banking industry that a financial hub like Hong Kong could be doing more to develop FinTech. DBS is one among several banks that are positioning themselves to benefit from the new ideas and talents in this area.

Brinc IoT Hub by Brinc. The Brinc IoT (Internet of Things) Hub is Hong Kong's newest accelerator programme launched in April 2015. Brinc is a 24-week programme focused on supporting start-ups in the IoT space by providing them with a platform to help them move rapidly from the ideation to the commercialisation phase of their products.

3. Funding

Below is a quick overview of notable funding rounds for Hong Kong start-ups that have taken place between September 2014 and May 2015.

Table 16. Tech Start-up Funding Rounds (Sep 2014 to May 2015)

Series A–B–C		
Start-up	Funding	Nature of Business
8 Securities	US$9 million	Online brokerage
Boxful	US$6.6 million from a VC syndicate June 11, 2015 US$ 1.5 million seed (Q1)	Storage solutions
DemystData	US$5 million	Big Data analytics
GoGoVan	US$10 million from Renren (China's equivalent to Facebook) for expansion in the Chinese Mainland	Vans for hire
Insight Robotics	US$2 million	Robotics and data analytics
Tink Labs	US$25 million from institutional and private investors	Provides smartphones for daily rental to tourists, with unlimited calls to home countries and unlimited Internet access in Hong Kong, Singapore and Paris.
WeLab	US$20 million in Series A. Investors include Sequoia Capital and Li Ka-shing's TOM Group	Mobile and online lending services in Hong Kong and the Chinese Mainland
Vitargent	Undisclosed from WI Harper Group	Biotechnology

Source: StartupsHK; media reports

Table 17. Tech Start-up Funding Rounds (Sep 2014 to May 2015)

Seed Stage		
Start-up	Funding	Nature of Business
Ambi Labs	US$115,000 funded on Kickstarter within two days	Environmental control; smart device monitors room temperature and detects use patterns to ensure energy efficiency.
GRANA	US$1 million from local retail marketing and distribution company Bluebell Group	Online-only fashion brand; runs its own sourcing, warehousing and distribution to keep costs down.
Gowell	US$1 million from Fresco Capital and Nest Investments	Online education
Klook	Estimated US$300,000 to $500,000 US$1.5 million from Shuren Hu and Wu Xiaoguang, 6/1/2015	Local tour booking
MailTime	US$850,000	Founded by PolyU graduate students; email productivity app.
Sensbeat	US$500,000	Founded by HKUST students; the app analyses users' emotions by the music they listen to, allowing better recommendations and forming a social network of users based on their emotions.
Shopline	US$1.2 million from five VC firms, one of which (SXE Ventures) is from Hong Kong	E-commerce solution; allows non-tech-savvy merchants to open an online shop on mobile and Web platforms.
Spottly	US$850,000 from Silicon Valley-based incubator 500 Start-ups and other VC	Social travel app

Source: StartupsHK; media reports

More Room for Improvement: Student Entrepreneurship Practices and Culture

Graham (2013) suggested that powerful student-led entrepreneurship is one of the most powerful factors underpinning the success of university-based technology innovation. Universities in Hong Kong are expanding their efforts in innovation-based entrepreneurship among their students at varying degrees. Furthermore, universities organise a range of entrepreneurial programmes with the business sector to assist students at different stages of entrepreneurship to establish their start-ups (Table 18). The formats, however, are largely limited to networking platforms, business competitions and pre-incubation supports.

Table 18. Highlights of Hong Kong Universities' On-campus I&T Student Entrepreneurship Strategies

University	Highlights
HKBU	The Business Entrepreneurship Support & Training (BEST) cultivates entrepreneurial culture via training and incubation support for students. In 2014, a sum of 10 bootcamps, innovation laps and seminars were held with about 250 student attended. E-Challenge, a series of business plan competitions, allows students to share business ideas or plans with industry experts, whereas E-space provides financial and non-financial supports to winners of business competitions to start businesses.
CityU	The Discovery-enriched Curriculum, incorporated since 2012 and managed now by the Innovation Commons, gather cross-disciplinary students in activities related to innovation, intellectual property and entrepreneurial spirit. The course "Innovation and Technology Entrepreneurship" is offered by the Department of Information Systems to students to acquire knowledge in gathering resources and managing risks for technology-intensive businesses.
CUHK	The Centre for Entrepreneurship (CfE) launches annually the Vice-Chancellor's Cup of Student Entrepreneurship (VCCE) where students teams enter their start-up business plans. It offers courses in entrepreneurship such as workshops in Design & Creative Business and minor programme in entrepreneurship. The Empowering Young Entrepreneurs (EYE) Programme, a thematic year-long entrepreneurship programme, is launched with Google since 2013 to encourage innovation and facilitate networking through activities like mentorship and pitching.
HKU	The Entrepreneurship Academy is held since 2010 by the Technology Transfer Office (TTO), under which workshops, trainings, sharing and networking opportunities targeting at research staff and research postgraduate (RPG) students are offered. Info sessions on innovation competitions and start-ups open to all students are held occasionally.
HKUST	The Entrepreneurship Centre organises the Innovation & Entrepreneurship Training Camp in which student business ideas are shaped into executable and fundable plans with systematic training assistance. Venture Mentor Service Programme (VMS) and Entrepreneurship Programme prepare students to get venture capitals for their entrepreneurial dreams and help establish technology-based start-up companies. TechLink, in the format of bi-monthly forums, serves as a platform for cross-disciplinary technology networking among like-minded individuals on campus and the wider community.
The Hong Kong Institute of Education	The Student Affairs Office (SAO) organised in March 2015 the "Turn your Passion into Success" – iBosses Entrepreneurship Conference in which success stories of different start-up companies were shared with students.
Lingnan University	The Department of Marketing and International Business (MIB) offers the course "Be Your Own Boss - Entrepreneurship" that trains up students' entrepreneurial skills.
PolyU	The Institute for Entrepreneurship (IfE) has various funding programmes such as the Micro Fund Scheme to promote student-driven start-ups and facilitate knowledge transfer. The one-month training programme, "From Research to Business: Nurturing Techno-preneurs", targets at research students to commercialise their research outcome. Alumni clustering events such as "Poly-preneurs" facilitate alumni entrepreneurs' knowledge transfer for the commercialisation of PolyU technologies.

Source: Universities' websites

On the other hand, venture capital companies registered in Hong Kong, such as Nest, prefer to invest in promising and scalable start-ups. Although there are successful start-ups springing from university campuses, like Editgrid and Vitargent, their founders explained initial capitalisation often came only at a later stage, after gaining recognition via business competitions (Tse, 2012) There indeed remains a large gap to bridge in building academic and industry collaboration. The government need to expand its effort in linking start-ups with mentors, angel and venture investors.

Recommendations

Clear Policy Supports Local and Foreign Start-ups to Prime a Sustainable Ecosystem

In supporting start-ups, most stakeholders agree that the Government should focus on building a market-based ecosystem of innovation and entrepreneurship and that the Government should avoid picking winners. Although there is general concern about a shortage of seed and early stage funding, some caution against flooding the ecosystem with cash, as "easy money could ruin a start-up". The majority however agree that a drastic change in social mind-set towards entrepreneurship and acceptance towards failures is of primal importance.

We agree that a thriving and sustainable start-up environment constitutes a crucial ingredient in a country's drive towards innovation and technology and recommend that a policy of start-up support should focus on fostering the growth of the venture capital and incubator industry, attracting non-local start-ups, promoting start-ups inside universities and nurturing the pool of local talent.

It is however important to note that fostering start-ups is a long process. It takes time to build critical mass to generate sufficient deal flow enough to make the system self-sustaining and that it requires most of all, a strengthening of the foundation of human capital to improve the quantity and quality of potential start-ups.

1. **Facilitate the Development of Venture Capital Market.**

Before the venture capital market takes shape and operates by itself, the Government may want to facilitate and offer incentives to venture capital firms, angel investors, and private incubators to step in, particularly in areas where market fails. Strategies include the following:

- **Financial Incentives**. To leverage private resources and, if need be, offer help to share risk with private sectors. This could take the form of co-investment schemes such as matching funds for financing seed and early stage ventures. We are pleased to learn that the Government is actively exploring the possibility of Government co-investment strategies.
- **Alternative funding.** To develop regulatory frameworks that will facilitate start-ups and small companies to raise seed capital and venture funding via the Internet, such as crowdfunding, while at the same time ensuring

due protection to investors. Venture capitalists are encouraged to act as sponsors to the capital raising.

- **Facilitate globalisation.** To help promote local start-ups outside of Hong Kong, and facilitate local incubators and investors with fewer global resources to reach out to potential investors, customers and business partnership for the start-ups. InvestHK could consider widening its scope to support local start-ups to attend overseas start-up events.
- **Enhance clustering.** To maximise the impact of catalytic events to enhance connections and networking that are deemed useful for start-ups, and thereby to enable self-learning via experience sharing. Consolidate events of Hong Kong Science Park and Cyberport into bigger ones where there are overlaps or synergies. Government could also consider organising or sponsoring large-scale catalytic events back-to-back against key regional industry conferences held in Hong Kong.

2. Supporting Start-ups

Given the challenges start-ups face, the Government should offer direct and indirect entrepreneurial financing support. Options include tax incentives on R&D, grants and loan guarantees or subsidies.

Grant allocation mechanism. To review the grant allocation mechanism of ITC to ensure that the process is efficient with minimal bureaucracy, to avoid rent-seeking activities and support non-mainstream challengers. Composition of the expert panel should be reviewed to ensure that people with relevant industry and/or investment expertise are invited.

3. Attract Non-local Start-ups

To develop and promote Hong Kong as a hub of global talents by highlighting its unique advantage of geographical proximity to Mainland China and Asia, its openness and cross-cultural diversities, sound legal system, strong basic and digital infrastructure and its competitive advantage as an international financial hub of Asia. Strategies include:

- **Start-up visas for Mainland Chinese**. Mainland Chinese to be offered the same start-up visa status as foreigners in order to enable those studying or staying in Hong Kong to venture into start-up activities.
- **Quality professionals.** The Government to look into relaxing the requirements for quality migrants under the current Quality Migrant Admission Scheme to allow entrants of more high-achieving professionals.
- **Holistic approach.** The Government to take a holistic approach to address housing, education, environmental and other problems that are essential to make Hong Kong an attractive place to live for non-locals.

4. Promoting University-Based Innovation and Entrepreneurship

To foster innovation and entrepreneurship among students and faculties through various incentives and support, facilitate university-industry collaboration and engaging local economic and community development efforts into collaborative research and commercialisation.

- **Technology transfer offices.** The role of universities' technology transfer

offices no longer confines to commercialisation of individual technologies. More resources would obviously be required to take on additional tasks of bridging students, faculty, and alumni with investors, entrepreneurs, industry, non-government agencies, and other relevant stakeholders.

- **Student entrepreneurship.** Universities are encouraged to enhance student innovation and entrepreneurship by further promoting cross-disciplinary studies and perhaps offering formal degree programmes. Extra-curricular activities such as student entrepreneurship clubs, business plan contests, start-up internships, on-campus accelerators and student venture funds could also be enhanced.
- **Faculty entrepreneurship.** Universities are urged to promote faculty entrepreneurship by giving greater recognition of faculty entrepreneurs, creating flexible work place policies, and making seed funding available to faculty, researchers and graduate students, increasing faculty connections with outside partners.
- **University-industry collaboration.** Universities to open up their facilities, faculty and students to businesses to encourage more strategic collaboration. Could consider internships and externships with companies, start-up facilities with accelerators and start-ups, and creating venture funds and incentive programmes funded by industry.

Foster Business Dynamism and Leverage on Existing Competitive Advantage to Create Strategic Niches

Given the importance of business in driving and supporting a country's technology development and, given the significant lag of Hong Kong in this area, there is strong consensus that the government needs to offer more attractive incentives to encourage industry to move up the value chain. Moreover, instead of leapfrogging into new frontiers of technologies with no local expertise, most participants agree that Hong Kong should leverage on existing infrastructure and areas where it commands globally competitive advantages to drive technology demand and to strengthen basic and applied research capacity.

We recommend the Government to boost existing tax and grant incentives to encourage industry to move up the value-add and to perform a comprehensive review of all areas of public services, private business and non-profit sector to see where advanced technologies can be applied and localised as well as areas where more industry-university collaboration in research can be supported. The following policy areas can be considered: 1) fostering R&D culture among business and encouraging technology localisation; 2) boosting the technology level of the public sector, 3) reforming the regulatory regime to ensure that regulations are responsive to changes in the social, economic and technological environments; and 4) encouraging the creation of thematic-based research centres to take research initiatives that are aligned with competitive advantages of Hong Kong.

1. Foster R&D Culture among Business

To boost existing tax incentives to make them competitive viz. regional neighbours to attract both local and non-local companies and start-ups to invest in R&D in order to move up the value chain and to encourage technological innovation.

- **Support start-ups and SMEs.** To provide generous tax incentives to lure and support local and non-local start-ups and SMEs to invest in R&D. Could consider providing refundable tax credits to start-ups for qualifying R&D spending and if need be, a ceiling rule also be set on credit allowed. For SMEs, the tax credits could be non-refundable but be allowed to carry forward for a reasonable period of time. In this regard, the tax credit granted could be based on a certain percentage of relevant R&D expenditure incurred for a year.
- **General business.** To allow for super deduction of qualified R&D spending to at least match that of regional peers such as Singapore and Mainland China of 150%, from the current 100%. Ideally, the tax deduction should be raised to 200% given Hong Kong's significant lag in business sector R&D spending. In order to promote industry and university collaboration, the Government should review if that should receive more generous tax incentives.
- **Concessionary profits tax rate for qualifying innovative technology companies.** Companies meeting certain criteria such as headcount requirement for R&D personnel, minimum R&D expenses requirement and minimum revenue requirement for innovative technology products or services, would be eligible for a reduced profits tax rate, say 50% of normal tax rate, over a defined period of time.
- **Scope expansion.** To expand the scope of qualified R&D to allow "contract out" research conducted locally, besides universities and research institutes, to be eligible to claim R&D tax benefits, given their spillover effect on the overall economy as well as on the innovation and technology ecosystem.
- **Targeted areas.** Government to offer tax incentives to encourage R&D investment in selected priority areas that are deemed critical to the social and economic development of Hong Kong or where Hong Kong has globally competitive advantages and research excellence. Options include tax credit, direct government grants and loans.
- **Industry-university collaboration.** Offer incentives, such as tax benefits, grants or loans, to companies conduct research collaboration with local universities or selected research institutions. Government to host technology symposiums and conferences to promote exchanges and collaborations between academics and business sector.
- **Alternative subsidy option.** Should the Government not want to complicate the tax regime, it could consider setting up a new endowment fund or through the Innovative Technology Fund, to refund part of the qualified R&D expenditure (could consider a ceiling) of all companies to achieve similar financial effect as the tax measures mentioned above.

2. **Reforming Regulatory Regime to Ensure that Regulations are Responsive to Socio-Economic and Technological Changes**

In the face of rapidly changing industry environment brought about by new technologies, regulators should stay vigilant of latest technology trend to understand the linkages between technology and regulation and to foster competition without compromising its original regulatory duty.

- **Engage start-ups.** To adopt an open-minded attitude and a forward-looking, rather than retrospective approach to innovations in order to engage start-ups and technology companies at the early stage of development.

- **Balancing regulation and innovation.** Regulatory institutions should strike a balance between the innovation and competition needs of the society with its duty of keeping social and economic stability. Relevant government departments should review their mandates to include "fostering competition and innovation" in the interests of consumers.
- **Clear principle-based policy with flexibility for start-ups.** Develop and publish a policy on regulatory requirements that start-ups can rely on, if certain regulatory principles or conditions are met. Establish threshold levels when companies need to comply with tighter regulatory rules. To help minimise legal and compliance costs, solutions-based guidance should be offered to help start-ups find practical and low-cost way to meet regulatory expectations.
- **Financial regulatory frameworks.** To conduct a comprehensive review of the competitiveness and innovation-friendliness of the overall financial regulatory framework to ensure the regulatory bodies can cope efficiently with the increasing integration, novelty and granularity of new services brought about by new technologies.

3. Government to Set an Example in Technology Procurement

It is encouraging to learn that the Government has placed promoting procurement of local innovation and technology products and services as a priority. Moving forward, we recommend the Government to conduct a 360-degree review of all public institutions and regulated entities to evaluate and strengthen their technology intensity in order to boost Hong Kong's technology readiness and enhance its image as a smart city. That could in turn attract foreign companies or start-ups to come use Hong Kong as a test bed for innovation.

- **Technology requirement for public utilities' license**. To require a competitive technology roadmap as a condition for the issuance and renewal of licenses for public institutions and regulated utility companies. Ideally, these roadmaps should be consistent and complementary to the government blueprint on technology development.
- **Technology advancement of government departments.** To evaluate and revamp existing e-Government platforms to ensure that services are state of the art, user-friendly, efficient and competitive viz. private sectors and overseas public sectors.
- **Procurement policy.** To evaluate and review procurement policy. To expand innovation and technology promoting procurement policy where possible.

4. Leverage on Existing Competitive Advantages to Develop Technology Niches

Government should set priorities to leverage on Hong Kong's financial hub, logistics and other infrastructure advantages to create research collaboration platforms to galvanise local and non-local talents from business, government and academia to come use Hong Kong as an experimental ground for advanced technologies.

- **FinTech hub of Asia.** A multi-prone strategy to develop Hong Kong as a FinTech hub via measures such as incentivising regulators and financial firms, and to experiment and adopt on the new technologies and to offer accelerator programmes to FinTech (including blockchain) start-ups, and government to launch promotion campaigns to attract

non-local FinTech talents while universities to consider offering degree programmes.

- **Engage key stakeholders to promote smart city.** To engage major domestic I&T spenders, public utilities, business organisations, government departments, regulatory agencies, universities, local and non-local start-ups to collaborate to develop smart city technologies to ensure Hong Kong can maintain its world leading infrastructure advantage and to boost innovative and technological capacity in this area.

Strengthen Ties to Pearl River Delta, Especially Shenzhen, to Drive Hong Kong's Applied Research

There is a strong consensus among stakeholders that Hong Kong needs to cooperate more closely with the PRD, especially Shenzhen, to foster the development of applied research in Hong Kong and to create synergies as a "super-connector". In many ways, Shenzhen and Hong Kong are natural partners. Some however highlighted that Hong Kong should broaden its scope to go global.

We recommend that, whilst Hong Kong entrepreneurs should keep an eye on overseas business co-operations, they should leverage on their proximity to the manufacturing juggernaut in PRD, especially Shenzhen. Policies should focus on driving synergies in the following areas. First, to encourage the major technology companies in Shenzhen to cooperate with Hong Kong universities in their R&D activities. Second, to utilise the manufacturing base in PRD to drive product commercialisation of Hong Kong's translational research. Third, to liaise with overseas translational research centres to promote Hong Kong as a hub to convert their prototypes into real samples and final products.

1. Co-operation Between Shenzhen/PRD Companies and Hong Kong Universities

To leverage on the PRD, especially Shenzhen's technology hub, to drive applied research in Hong Kong in order to fill the missing gap in Hong Kong's downstream, industrial-led applied research.

- Universities-Shenzhen industry. Universities are encouraged to review KPIs and incentives to drive deeper and broader collaboration with companies in the PRD region, especially Shenzhen to foster the growth of downstream applied research of Hong Kong.
- Funding mechanism. To review current funding mechanism of ITC to ensure efficient and fair allocation of funding to successful applicants and that adequate resources and incentives are given to both corporate as well as to research organisations.
- Joint Technology Conferences. Regular technology conferences could be hosted by both Hong Kong and PRD local governments in Hong Kong and Mainland China to promote R&D collaboration.

2. **Build on the Manufacturing Base of the PRD to Facilitate the Commercialisation of Hong Kong's Translational Research**

Hong Kong should continue to take advantage of its location in the PRD, especially Shenzhen's electronics manufacturing hub advantage, to drive product commercialisation of Hong Kong's translational research in areas such as consumer IoTs and robotics.

- Information support for start-ups. Survey the supply chain network in the PRD area and maintain an updated database for Hong Kong start-ups to facilitate their commercialisation process.

3. **Promote Hong Kong as a Hub to Enable Time-to-Market Design-Prototype-Sampling Services for Overseas Research Centre and Start-ups**

Due to the superior industrial design capability, efficient logistics management and network, global marketing expertise and the large manufacturing base across the border, Hong Kong is in a highly competitive position to act as a "super-connector" of translational research and product commercialisation for products such as consumer IoTs and other electronics devices.

- Promotion of Hong Kong's capability to overseas research centre/start-ups. InvestHK should be encouraged to strengthen its marketing ties with foreign universities, private and public research centres to entice students and faculty members engaging in translational research and to use Hong Kong as a hub for time-to-market design, prototype manufacturing and sampling services.

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Government

Background and Current Landscape

The HKSAR Government has taken initiatives to foster the development of innovation and technology. It has established government bodies and infrastructure to support the science and technology community. The following is the major government and statutory bodies involved in the promotion of innovation and technology. In addition, the HKSAR Government has just set up an Innovation and Technology Bureau.

- Innovation and Technology Commission
- 5 research centres
- InvestHK
- Hong Kong Science and Technology Park
- Cyberport
- Hong Kong Productivity Council

Innovation and Technology Commission

The ITC was established in 2000 as a government department under the Commercial and Economic Development Bureau. Its mission is to promote applied research and development and facilitate the development of Hong Kong's technology infrastructure. It administers the ITF, which was established in 1999. Under the ITF, there are three major funding programmes.

- The **Innovation and Technology Support Programme** supports midstream/downstream applied R&D projects mainly undertaken by the five government R&D centres, local universities and other local public research institutions.
- The **University-Industry Collaboration Programme** provides matching grants to projects undertaken by private companies in collaboration with local universities.
- The **Enterprise Support Scheme**, a new scheme launched in 2015 to replace the **Small Entrepreneur Research Assistance Programme**, provides 50:50 matching grants of up to HK$10 million for R&D projects undertaken by enterprises in Hong Kong. In addition, companies can get a 30% cash rebate on their invested sum on completion of the project.

As of August 31, 2015, the ITF had funded a total of 4,739 projects with total funds approved at HK$9.6 billion.

Table 19. Innovation and Technology Fund—Statistics of Approved Projects (as of August 31, 2015)

Programme	Approved Projects	Funds Approved (HKD Mil.)
Innovation and Technology Support Programme	1,939	7,837.1
General Support Programme	2,109	815.6
University-Industry Collaboration Programme	277	322.2
Small Entrepreneur Research Assistance Programme	414	505.9
Total:	**4,739**	**9,667.7**

Source: ITF

In 2006, the ITC set up five research centres to drive and coordinate applied R&D, as shown in the Table below. As of the end of September 2014, the five R&D centres had conducted 707 projects with a total funding of HK$3.3 billion.

Table 20. New Projects Undertaken by R&D Centres

R&D Centre	No. of New Projects Approved	Approved Funding (HKD Mil.)
Automotive Parts & Accessory Systems R&D Centre	77 (18)	208.1 (57.9)
Hong Kong Applied Science Technology Research Institute	322 (21)	2,222.2 (128.0)
Hong Kong Research Institute of Textiles and Apparel	116 (19)	286.5 (32.4)
Hong Kong R&D Centre for Logistics and Supply Chain Management Enabling Technologies	64 (8)	317.3 (6.2)
Nano and Advanced Materials Institute	128 (44)	292.9 (99.8)
Total	**707 (110)**	**3,327.0 (324.3)**

Note: Figures in parentheses denote figures for collaborative projects.
Source: ITC

In 2011, the ITC launched the Public Sector Trial Scheme, which helps fund the production of tools/prototypes/samples and the conducting of trials in the public sector of R&D projects by the ITF. The ceiling of funding was later raised from 50% to 100%. Finally, to help reinvigorate the start-ups in Hong Kong, ITC launched a new TSSSU in 2014 that provides an annual funding of HK$24 million to six local universities, initially for three years, to encourage students and professors to start technology businesses and to commercialise their R&D results.

InvestHK

InvestHK is a department under the Commercial and Economic Development Bureau of the HKSAR Government. It was established in 2000, and its objective is to attract foreign direct investment to Hong Kong. InvestHK has formed a start-up team to support foreign entrepreneurs planning to set up in Hong Kong. This new focus follows a relatively high-profile StartmeupHK

competition in November 2014. The competition recruited start-ups from all over the world to compete with their business ideas and pitches. The final pitch competition was part of a week of 45 events that gathered global entrepreneurs to mingle with local ones.

InvestHK works with overseas and Mainland entrepreneurs, including SMEs and MNCs that wish to set up an office, or expand their existing business, in Hong Kong. The agency offers free advice and services to support companies from the planning stage right through to the launch and expansion of their business.

Hong Kong Science and Technology Parks

Hong Kong Science and Technology Parks Corporation (HKSTPC), established in 2001, aims to transform innovation and technological advancement into value creation that benefits Hong Kong, the Mainland and the world. The HKSTPC is a statutory body, with the Hong Kong Government as its sole shareholder, and is governed by its board of directors. It is dedicated to building a vibrant innovation and technology ecosystem to connect stakeholders, nurture technology talent, facilitate collaboration, and catalyse innovations to deliver social and economic benefits to Hong Kong and the region. The HKSTPC runs the Hong Kong Science Park, the InnoCentre and three industrial estates. The Hong Kong Science Park provides world-class infrastructure for companies with innovation and technology initiatives. Located in Pak Shek Kok, it contatins 330,000 square metres of R&D office and ancillary Space. The Science Park has 335 tenants and 183 incubatees, employing 11,000 people, comprising 10,300 tenant workers and 776 incubatee workers. The Science Park is clustered into five areas: biomedical technology, electronics, green technology, ICT, and material and precision engineering. In 2014, 20 incubatees received a total of HK$200 million in funding.

Hong Kong Cyperport

Cyberport is a cluster of Information and Technology companies. Located at Telegraph Bay in Pok Fu Lam, it was developed to create an information and communications technology node. It provides 990,000-square-feet office complex. With four separate grade-A intelligent office buildings and world-class IT&T infrastructure, Cyberport currently is the cluster of 660 community members. Cyberport has established five interdependent centres: Entrepreneurship Centre, Knowledge Centre, Technology Centre, Collaboration Centre and Campus Development Centre. These five centres aim to drive collaboration, nurture ICT entrepreneurs and accelerate ICT adoption.

Table 21. Sector Breakdown of Companies at the Hong Kong Science Park

Cluster	Number of Companies
Information Communications &Technology	112
Electronics	82
Biomedical Technology	45
Green Technology	42
Material and Precision Engineering	30
Professional Services	15
Total	**326**

Source: HKSTP

Some success stories are as follow.

Biomedical Technology

Founded by Professor QY MA, Time Medical aims to pursue global technological and clinical excellence in medical imaging devices, including Magnetic Resonance Imaging (MRI), Digital Radiography (DR) and Computed Tomography (CT) systems. Its core technology is a patented High Temperature Superconducting (HTS) coil that significantly improves the signal-to-noise ratio, spatial resolution and clinical image quality.

The breakthrough MICA Whole-body MRI System can achieve 3T image quality with 2T magnet integrated with the HTS coils. The technologies are transferred from Columbia University and the University of Hong Kong. It has been installed in world renowned medical schools for research and education purpose. The systems target a worldwide market which Time Medical has already established direct sales teams in China, the US, India and Indonesia; and distribution channels in other 8 countries.

Time Medical has its major research team of 30 engineers working in the Science Park, involving in product design, system engineering, technical documentation, regulatory and compliance, and software development.

Future Development: Time Medical will focus on development of neonatal MRI systems and explore advanced manufacturing of its products in Hong Kong.

Master Dynamic Ltd

Master Dynamic came up with high-precision silicon balance spring and watch escapement products with their advanced nano-fabrication and laser-induced breakdown spectroscopy technology. Master Dynamic worked with universities and research institutes worldwide for R&D, including HKU, CUHK, China Academy of Engineering Physics, Tsinghua University, Sun Yat-Sen University, University of California San Francisco and University of Lyon. The core technology has filed over 20 patents, 5 have been granted.

The products have high potential in horological, supercapacitor and medical industries, and can be applied to watches, medical devices, smart devices and material analysis businesses. All the technologies and products were researched and developed in Science Park facilities.

Future Development: Master Dynamic will further strengthen its leading edge in advanced material analysis technology, and work on R&D of techniques for material analysis, food and drug analysis and inspection.

SenseTime Group Ltd

SenseTime is founded by a team of experienced IT professionals and PhD graduates from local universities. Its key technology is advanced computer vision technology powered by deep learning, especially in face recognition, object recognition, image search, image/video processing and intelligent surveillance.

SenseTime's technologies have shown superior performance in a broad range of vision tasks, in which the achievement is primarily rooted in their unparalleled expertise in deep learning. The key applications include: (i) Face recognition for surveillance or access control; (ii) Image recognition for identifying components in images and videos; (iii) Image processing such as deblurring and distortion correction; and (iv) Intelligent surveillance technology.

SenseTime works closely with both local and international organisations to expand R&D and business. Its system targets Hong Kong and Mainland China markets. SenseTime was connected to potential clients like Hong Kong Airport Authority and various property developers via the Science Park's "Technologies from Science Park" programme; and was connected to InvestHK to facilitate working visa applications.

Future Development: SenseTime plans to expand its company by doubling the number of researchers at the Science Park. It will focus on developing unique applications that incorporate the four key technologies above.

Hong Kong Productivity Council

The Hong Kong Productivity Council (HKPC) is a statutory body inaugurated in 1967. Its objective is to promote productivity excellence for industry to enhance competitiveness and sustainability. It provides many technology-related services to Hong Kong's innovation ecosystem, with around two-thirds of its services related to technology development with regard to intellectual property, patent, product design and engineering, and material technology. HKPC is the host for the Automotive Parts & Accessory Systems R&D Centre, which was set up by the ITC.

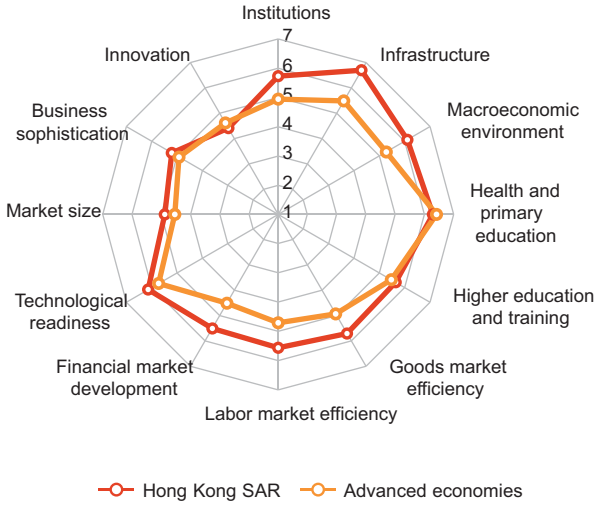
Strengths and Challenges

Strengths

Leadership in Infrastructure and Public Institutions

Hong Kong is ranked seventh in the World Economic Forum's Global Competitiveness Report 2015-2016 (Schwab, 2015), with the quality of its infrastructure, specifically transportation, telecommunications and energy are among the very best in the world. In addition to high-quality public utilities, Hong Kong's public competitive advantages include internationally renowned market, rule of law, protection of intellectual property rights, logistics and supply chains, free flow of information, low tax rates, and relatively flexible immigration policy.

Figure 21. Radar Diagram of Hong Kong's Competitiveness Versus Other Advanced Economies



Source: The Global Competitiveness Report 2015–2016, World Economic Forum, Switzerland, 2015.

Strong Basic Infrastructure

The development of Hong Kong's technology sector has been facilitated by the advanced technology infrastructure of the territory. In the World Economic Forum's Global Competitiveness Report 2015-2016, Hong Kong ranks third in infrastructure, and ranks in the top ten in eight of the nine infrastructure metrics. Indeed, Hong Kong possesses notable competitive advantages in infrastructure in the quality of its roads, railways, ports, air transport, electricity supply, and mobile-phone penetration.

Table 22. Hong Kong's Infrastructure Rankings

Indicator	Value	Rank
Quality of overall infrastructure	6.4	**3**
Quality of roads	6.2	**5**
Quality of railroad infrastructure	6.4	3
Quality of port infrastructure	6.4	**5**
Quality of air transport infrastructure	6.6	**3**
Available airline seat km/week, millions*	2,643.2	17
Quality of electricity supply	6.8	**2**
Mobile telephone subscriptions/100 pop.*	239.3	1
Fixed telephone lines/100 pop.*	61.1	1

Note: In the rank column, notable competitive advantages are marked in **bold**. Values are on a 1-to-7 scale unless otherwise annotated with an asterisk (*).
Source: The Global Competitiveness Report 2015–2016, World Economic Forum

According to the 2014 report of the Institute for Management Development (cited in HKTDC, 2015) in Lausanne, Switzerland, Hong Kong is ranked number one globally in terms of technological infrastructure. Global rankings of related areas are included in Table 23.

Table 23. Hong Kong's Rankings for Infrastructure

Criterion	Rank
Fixed telephone lines/1,000 inhabitants	4 (after Taiwan, France and South Korea)
Fixed telephone tariffs/local calls	2 (after Canada)
Mobile phone subscribers/1,000 inhabitants	1
Mobile phone costs/local calls	2 (after India)
Internet bandwidth speed	1

Source: Institute for Management Development

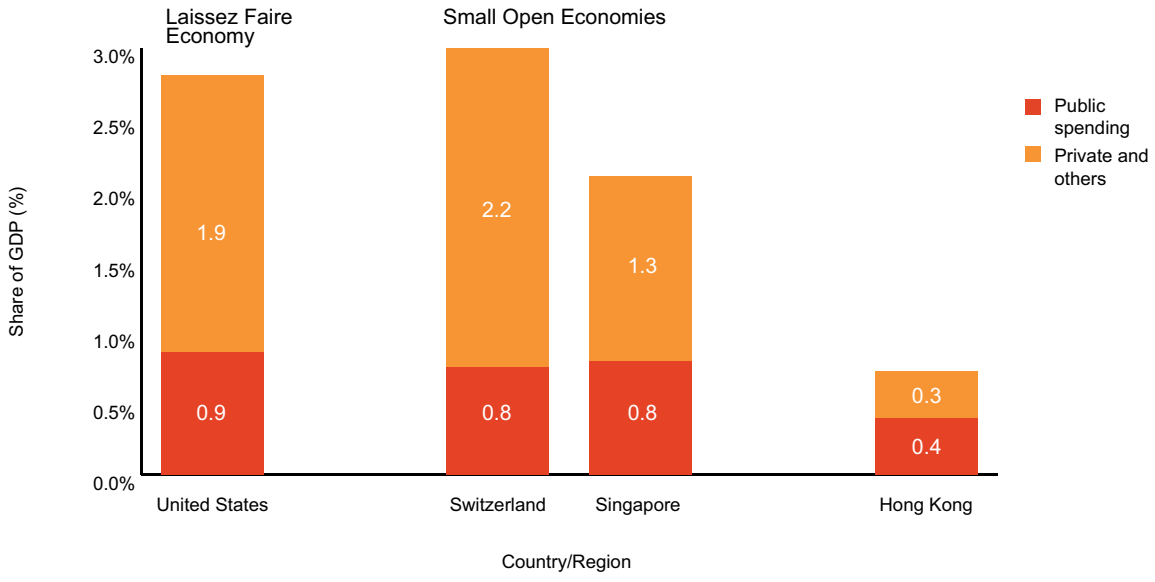
Challenges

The Constrain of "Small State"

As a staunch believer of laissez-faire, the HKSAR Government often boasts its "small state" and minimal intervention in the market (Tsang, 2008). Since the colonial time, Hong Kong has not seen any major industrial policy or blueprint on R&D. Moreover, fiscal prudence has been the dominant theme of budget planning (Chan, 2003). Yet when we compare Hong Kong to other countries with similarly "small open economies", such as Singapore and Switzerland, or to the similarly liberal economic system of the US, it still lags far behind in government spending, as well as total spending, on R&D. This in turn affects the private sector's incentive to invest in R&D (Levy and Terleckyj, 1983). The lack of commitment from the Government highlights its unwillingness to recognise that adequate investment in basic and applied research is important to facilitating a sustainable development of our economy.

While we recognise Hong Kong does not have a defence budget and military industry as one of the factors that leads to its low R&D investment, it is not an excuse for the Government not to commit more resources on R&D.

Figure 22. R&D Spending by Countries with Similarly Liberal Economic System



Source: Agency for Science, Technology and Research (Singapore), OECD, Census and Statistics Department (Hong Kong)

No Holistic Approach

As innovation and technology takes centre stage in a country's economic development, many governments are adjusting their strategies and organisations to cope with the rapidly changing technology landscape as well as the intense competition for global talent. This involves taking a holistic, inter-departmental and inter-disciplinary approach to tackle three main objectives: 1) promoting world-leading research excellence; 2) focusing on priorities; and 3) fostering partnerships among various stakeholders that includes academics, business, start-ups and international partners. Money alone does not provide the full answer to the current problem. As Mowery noted, a country's innovation performance is directly linked to the willingness of both academic centres and businesses to develop, implement and share new ideas (Mowery et al., 2004).

Since the late 1980s, the Government has taken piecemeal steps to improve Hong Kong's R&D competitiveness (Sharif and Baark, 2005). These include ITC setting up the HK$5 billion ITF in 1990, the establishment of the HKUST in 1991, the establishment of the ASTRI in 2000, the opening of the Science Park in 2002, and the opening of Cyberport in 2003. However, Hong Kong has yet to devise an all-encompassing blueprint for the development of innovation and technology, the promotion of industry-research collaboration in Hong Kong, and cross-border cooperation with the Mainland. The establishment of the Innovation and Technology Bureau is another significant step to enable a strategic, coordinated approach.

Direct Government Funding of Midstream and Downstream Applied Research by ITC

The ITC has been instrumental in providing financial support to applied research to universities, the five research centres, as well as corporates. However, it faces implementation challenges that are shared by many similar public funding schemes. From our focus group, stakeholders have expressed concerns over the complexity and duration of the application process, as well as the suitability of the personnel of review panellists. In general, the inherent nature of riskiness, funding of research and start-ups may not be compatible with the risk-aversive nature of public governance, and risks diverting attention away from more important priorities including technology diffusion and the creation of R&D jobs to foster sustainable growth of the economy. According to the OECD, although direct government grants/subsidies remain an important part of public support of business R&D, recent developments among OECD countries have aimed at applying more market-friendly approaches that would avoid "picking winners". They also encourage investments that are likely to see the highest social returns. This has been accompanied by a move away from unspecific, single-firm, project-based grants, to more sophisticated designs, leaving basic public support to tax incentives for R&D, and towards consolidation and streamlining of public support schemes (OECD, 2011).

Government Should be the Champion of High Technology Products

According to the Global Competitiveness Report 2015-2016, Hong Kong is ranked 38 in the government's procurement of advanced technology

products. Procurement is an important strategy to promote the development of the technology and innovation industry (Dalpe, 1994).

The HKSAR Government has started a gradual launch of the E-Procurement System, which enables electronic transaction between suppliers and the participating government bureaux and departments. As of June 2015, a total of eight bureaux and departments have joined the programme.

Table 24. List of Participating Bureaux/ Departments (B/Ds)

The Auxiliary Medical Service (AMS)
The Environmental Protection Department (EPD)
The Independent Commission Against Corruption (ICAC)
The Immigration Department (ImmD)
The Joint Secretariat for the Advisory Bodies on Civil Service and Judicial Salaries and Conditions of Service (JSSCS)
The Office of the Government Chief Information Officer (OGCIO)
The Official Receiver's Office (ORO)
The Working Family and Student Financial Assistance Agency (Working Family Allowance Office) (WFAO)

Source: GovProcurement

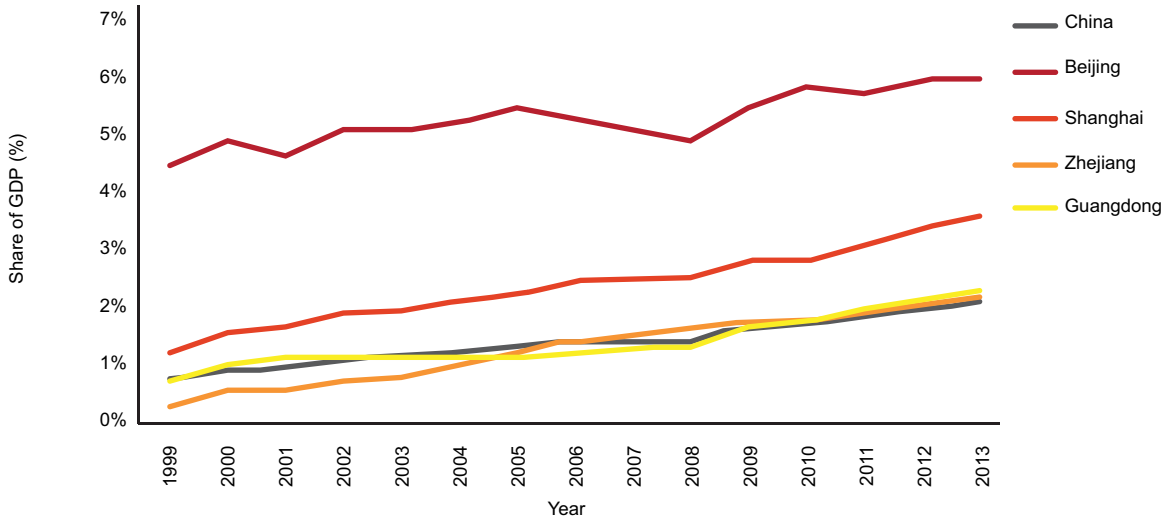
However, the degree of participation is far from satisfactory: the number accounted for only 11% of the 75 bureaux and departments in the government. As the Central Policy Unit points out, government departments lack a clear policy of procurement on R&D products or other high-tech products invented by local businesses (Central Policy Unit, 2015). The Government should encourage its bureaux and departments to join the programme.

Hong Kong in the Context of Mainland China

In comparison with the Mainland, Hong Kong lags behind in its effort to drive higher R&D intensity. The Chinese Government has been emphasising the importance of science and technology improvement as a key variable in its economic restructuring and development. In the 12th Five-Year Plan (2011-2015), the Chinese Government set the R&D expenditure target at 2.2% of GDP, up from 1.76% in 2010. This is in line with the international average, but higher than in most emerging markets. The recently announced 13th Five-Year Plan (2016-2020) blueprint highlights the priorities of green energy, biotechnology, information technology, industrial automation and advanced equipment. It also highlights the promotion and support of new incubation models and venture funding platforms including crowdfunding and reform of ChiNext (a capital platform for SMEs).

Figure 23 shows R&D as a percentage of GDP for China and selected Chinese provinces for selected dates from 1991 to 2013. The Figure includes the major cities Beijing and Shanghai, as well as Zhejiang province (home to Alibaba and a cluster of technology start-ups in Hangzhou), and Guangdong province, which is home to China's high-tech industry in Shenzhen. Cities such as Beijing and Shanghai have ratios of R&D-to-GDP well above the national average. In Shenzhen, the ratio is over 4% of GDP.

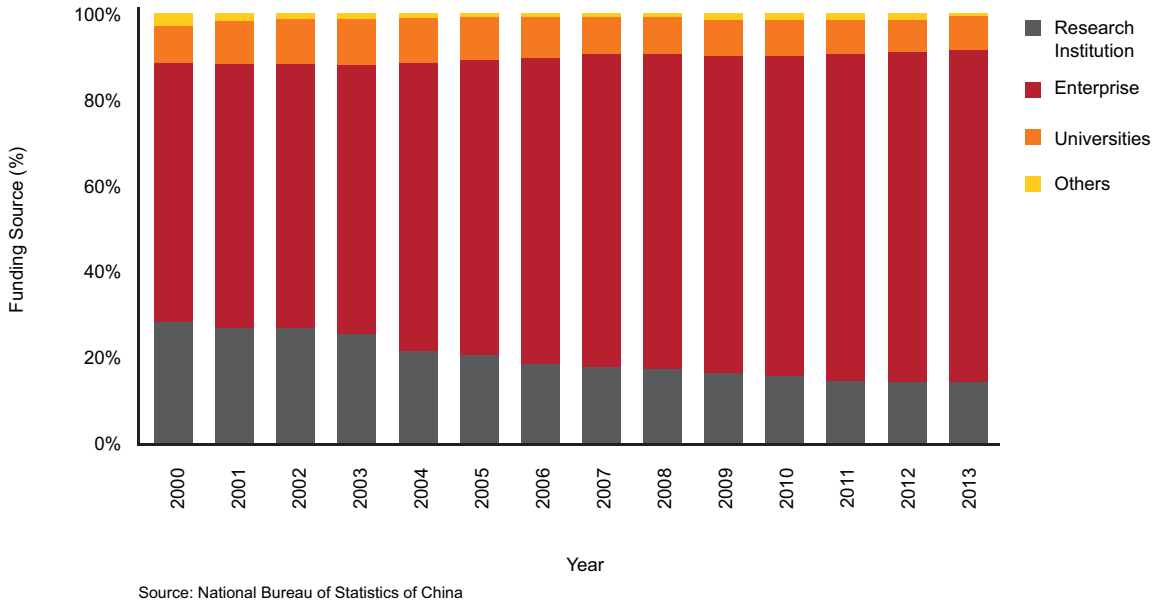
Figure 23. R&D Spending as a Percentage of GDP



Source: National Bureau of Statistics of China

Unlike Hong Kong, the role of business sector as a major source of R&D is highlighted in the 12th Five-Year Plan. With R&D spending tax-deductible, while cooperation between enterprises, universities and research institutions are also strongly encouraged. Also, to strengthen basic research, a number of new national R&D centres on specific topics were established in the 12th Five-Year Plan period. Currently, R&D spending in China is mostly from the business sector, though it must be noted that the makeup of the Chinese business sector consists of many state-owned enterprises.

Figure 24. China R&D by Funding Source



Source: National Bureau of Statistics of China

Smart City

Background

We have discussed the strengths and weaknesses of Hong Kong's innovation and technology ecosystem. It is clear that more investment, from both the public and private sector, are required. But some of the challenges will not disappear overnight. Entrepreneurship culture among the young people and academics' desire to engage with businesses will take time to nurture. Longer still would be any attempt to reindustrialise of Hong Kong.

There are, however, other opportunities arising to drive the technology sector. And government could be the key advocate of such opportunities. As IBM (2012) points out, urban citizens are expecting more and more from their cities. They want a higher quality of life, optimal conditions for business and professional development, and more efficient transportation and energy systems. Hong Kong very much shares the same demand to be a "smart city".

The concept of a "smart city" is understood differently by different people and sectors. Accenture (cited in United Nation, 2015) understands a smart city as a physical place where services to citizen and businesses are delivered in an integrated and resource-efficient way, in order to improve inhabitants' quality of life and support growth. In contrast, the UK Department of Business, Innovation and Skills (2013) considers the smart city as a process consisting of citizen engagement, hard infrastructure, social capital and digital technologies.

IBM (2012) focuses on the strategic use of new technology and innovative approaches to enhance the efficiencies and competitiveness of cities. It identifies three areas of expertise that most advanced cities focus on.

- **Leveraging information for better decision-making.** The right information is given to the right people at the right time, so that they make good decisions and monitor the ongoing impact of those decisions.
- **Anticipating and resolving problems proactively.** City leaders discover patterns and trends in structured or unstructured data with the help of advanced analytics solutions.
- **Coordinating resources to operate more efficiently.** This is achieved by sharing information across agencies like metrics, events and processes, and by collaborating in real time to optimise resources.

This section shall discuss how the HKSAR Government can strengthen the foundation of smart city applications in Hong Kong, and add another dimension to its innovation and technology ecosystem.

With ICT rapidly advancing, it is becoming much easier for the public to obtain data and materials. The same applies to information exchange between the government and the society.

The following parts will discuss the data sharing initiatives in other places and the possibility to boost innovative web application using the shared data, with a focus on how Hong Kong can leverage on the standardisation and exchange of government geospatial data by building a SDI.

Open Data and Creative Commons - a Global Trend of Distribution and Sharing of Resources

In the US, the importance of government openness and improvements on the open data policy have been highlighted since the government issued two memorandums in 2012 and an executive order in 2013 about commencing a project of establishing an 'open government' and an open data project. The US Government (n.d.) launched a website, data.gov, based on two open source projects, to provide a comprehensive database for public use, with the number of datasets reaching 140,000.

In the UK, the launch of open data commenced in 2010, followed by the first National Action Plan of an open government in 2011. A second National Action Plan was published in 2013 which continued to improve on the existing policy. The online database contains more than 26,000 datasets. One of Hong Kong's main competitors, Singapore, also started the project of open data in 2011, launching the website data.gov.sg. There are more than 11,000 datasets from 70 government ministries and agencies (Singapore Government, 2015). As for the EU, an EU Open Data Portal (n.d.) has been established for public acquirement of data, and this database provides more than 8,700 datasets.

In contrast, Hong Kong started the project on open data relatively late. Although open data is part of the Digital 21 Strategy initiated since 2008, the updated comprehensive web database that allows public reference, data.gov.hk, was not launched until March 2015 by the OGCIO which provides over 4,000 datasets under 18 categories.

Nevertheless, the vision and progress the HKSAR Government demonstrated in the past couple of years are encouraging. Besides the increasing willingness to provide more data, the government is also showing initiative on public engagement in policy formulation and community projects. Central Policy Unit (2015) highlights the Barcelona case, in which citizens can share their ideas and experiences on different points of the city to explain their environmental and social values, which can be further consolidated as consultation materials on conservation measures. In addition, a central platform to gather and publish information on public work programmes allows stakeholders to monitor, follow up and coordinate work progress more easily. As a result, everyone becomes a co-creator of the community and there is a more closely collaborative relationship between the government and citizens. Central Policy Unit (2015) acknowledges that Hong Kong needs further development in a public participation system for e-submission of opinions in public consultations.

Beyond the front of government open data policy, Creative Commons (CC) is another initiative that encourages the sharing and use of resources. Copyrights of work are traditionally understood at two extremes, namely "all right reserved" and "no right reserved". The notion of a CC license, originated from a non-profit organisation called Creative Commons in the US in 2001, gives the work creator an ability to declare explicitly that his work may be used and shared by others on conditions of the creator's choice without needing the comers to request permission again and again. In other words, CC licenses identify copyright terms from the default of "all rights reserved" to "some rights reserved". As an extension of copyright law, CC licenses meanwhile are enshrined in the legal frameworks of various jurisdictions internationally (Miller, Styles and Heath, 2008).

According to Creative Commons, as at March 2015, governments of 31 regions such as those of the US, the UK and Taiwan as well as various intergovernmental organisations such as the United Nation and the World Bank are using CC licenses to provide public access to their census data, geo-scientific information and knowledge. In Hong Kong, the Journalism and Media Studies Centre of HKU in 2008 initiated a project called Creative Commons Hong Kong which has prepared CC licenses for everyone's use for free.

Application Programming Interfaces

By making data collected by governments, organisations and private companies available to everyone, preferably at no cost, would fuel innovations of the wider community, especially the entrepreneurs and technologists. This could made to happen with Application Programming Interfaces (APIs), which refer to a set of standardised routines, protocols, and tools such as HTTP, JSON and XML for programmers to incorporate a program's functionality into their program without understanding all software codes of the program written by others (Proffitt, 2013). Examples of API applications are logging in a website using one's Facebook login account, and allowing Slideshare viewed on LinkedIn.

Lensmar (2013) drew an analogy of building LEGO to the relationship between data and APIs. Data are like pre-molded LEGO pieces. On the other hand, similar to the identical small plastic "bumps and holes" on LEGO pieces that provide an universal way of adhering one to each other, APIs provide a standardised and relatively simple way for people to integrate data sources to build web applications for the what is right for them or what businesses will adapt.

APIs facilitate creativity and innovation by changing data sources and usage scenarios. Improving the availability of such data would benefit innovative start-ups, and better meet the public demand for a smarter city.

Indeed, API is especially useful in disseminating and distributing geospatial information in SDI due to its inherent complicated data structure. Use of API on geospatial information can save a lot of efforts and costs in pre-processing raw geospatial data before it can be used in a software application. Easier access and use can certainly further facilitate much wider use of geospatial information in different smart city apps by independent developers and start-ups.

SDIs in Other Parts of the World

The Committee of Experts on Global Geospatial Information Management of the United Nation stressed the importance of geospatial information with which governments can use to "answer those questions and understand better the condition of their populations, or the condition of their economy, or the condition of their natural resources and environment and so forth" (UN News Centre, 2015). In many places, the geospatial information is systematically managed and exchanged within a SDI, defined by Global Spatial Data Infrastructure Association as

> "the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data" (Nebert,2004:8).

In the US, the National Spatial Data Infrastructure (NSDI) was called by the Executive Order 12906 in 2003. Coordinated by the Federal Geographic Data Committee (FGDC), the NSDI assembles trusted and standardised geographic data from public and private sector through an online portal GeoPlatform.gov. Data users, including federal agencies, state, local, tribal governments, private sector, academia, and the general public, can quickly retrieve, build, publish and share geographic data among themselves on the portal. In May 2014, some federal agencies placed their datasets into the worldwide public domain using the CC0 Public Domain Dedication so that they can be used by anyone for any purpose anywhere in the world (Vollmer, 2014). At the city level, SDIs are built to cater city-wide development needs. For example, governments and citizens use the Los Angeles GIS Hub to improve living by reducing blight, tracking and responding to citizen requests as well as boosting new business development (Esri, 2015). In order to bring all standards into a single database in the NSDI, when there were no equivalent voluntary consensus standards, FGDC develops geospatial data standards by consulting and cooperating with the relevant stakeholders or the international community. The data producers must follow FGDC's reference source, standards, and guidance when creating geographic data (FGDC, 2015).

In Europe, the 28 EU member states put forward the INSPIRE Directive in 2007, which is based on collaborative establishment, operation and sharing of infrastructures for 34 themes of spatial information in Europe to support policies or activities which may have an impact on the environment, through the EU geoportal (or INSPIRE geoportal) and other self-managed access points. To ensure the geographic datasets and services are understood, compatible and usable in a trans-boundary context, common Implementing Rules are adopted in a number of specific areas. For instance, the initiative ISO/TC 211 Geographic Information/ Geomatics specifies the methods, tools and services for geo-referencing, acquisition and analysing (Soares & Martins, 2012).

In 2008, the Singapore Land Authority and the Infocomm Development Authority launched the Singapore's NSDI initiative called Singapore Geospatial Collaboration Environment (SG-SPACE). It provides a platform

and mechanism for government agencies to share and use interoperable geospatial data for sustainable policy, decision-making via GeoSpace and OneMap. By 2012, 29 public agencies contributed 371 layers of spatial data. SG-SPACE also reaches out enterprises to adopt geospatial applications by awarding projects that create new business opportunities and improve workforce productivity.

SDI in HK

In 2004, the Housing, Planning and Land Bureau launched the Data Alignment Measures (DAM) Project, as the first step towards the establishment of the SDI. The Project facilitated agreement of 14 participating departments on the standard units and identifiers in exchange of geospatial data and aligned the definition of five Common Spatial Units. Hong Kong Institute of Land Administration (2009:20) acknowledged that the Project has "facilitated exchanges of spatial data in the planning, lands and public works areas".

In 2004, the Survey and Mapping Office (SMO) in the Lands Department developed the Hong Kong SAR Geospatial Information Hub (GIH), a government-to-government service initially served as service to systematically convert and integrate the isolated and scattered geographic data collected from different departments, for their convenient and rapid access to improve their operation and decision-making processes. According to Lands Department's reply to Legco in 2015, SMO's GIH service has had over 7,500 registered accounts across 66 government bureaux and departments for the first 11 months in 2014-15 financial year. Since 2010, public access to over 180 types of spatial data provided by 26 departments via GeoInfo Map became available. Other access platforms include Data.One web portal and a mobile application "GeoMobile Map HK" since 2011, followed by another mobile application "MyMapHK" since 2014.

Many government departments have built their own GIS systems for handling the geospatial information related to their own businesses, works and assets. For example, the Highways Department has one for the asset management and road maintenance needs. They are also using the latest surveying and GIS technology known as Mobile Mapping System to take the specialised and measurable Street View videos for all public roads for their asset management needs (Highways Department, 2013). The Centre for Health Protection (2010) of the Department of Health is building a large scale Communicable Disease Information System (CDIS) for surveillance and control of communicable diseases. The Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department has been using GIS since early 1990s (e.g. the Slope Information System and the Geological Modelling System) to manage the landslide risks in Hong Kong (Cheung, n.d.).

However, a majority of this information are only for internal use. Compared to other places, Hong Kong is lagging behind in allowing access to government data sources which could fuel creativity and innovation in the community with a robust growth of web applications.

In fact, opening these geospatial data to the public would significantly improve people's everyday living. Taking transport information as an example, in its centralised data warehouse named the Transport Information System (ITS), the Transport Department collects, processes and disseminates a wide range of transportation information, including special traffic news, traffic

speed, time, distance and toll of driving routes, traffic directions, turning restrictions at road junctions and stopping restrictions. If city wide real-time traffic speed information is available, more advanced intelligent transport applications can be developed. For instance, bus companies, tunnel operators and commercial vehicle fleet operators can develop real-time apps to adjust their operations readily to cope with changes in the traffic conditions, such as KMB's recently launched mobile app in which passengers can check estimated time of bus arrival. Apart from passenger information system, parking management systems and pedestrian/cyclist guidance systems are possible initiatives to be explored.

Room for Improvement

Despite a wide spectrum of geospatial data at hand in many government departments, most GIS systems are for internal use only. Although GIH and GeoInfo Map of the Lands Department, plus the Statutory Planning Portal of Planning Department share geospatial data across government departments and among the public, the amount and data shared is small and their functions are limited to browsing and querying only.

Meanwhile, aligning the standards and definitions of geospatial data is necessary to facilitate their development, sharing and use.

The DAM Project did some pioneer standardisation work but it only covered 5 categories of geospatial data across 15 departments which are a very small portion of geospatial data in a SDI. According to Lands Department Environmental Report 2013, the Lite version of GIH without password protection has been provided to all civil servants who can access Government Intranet since 2013. This underpins the usage and exchange of geospatial data are of huge demand within the government. Hence, there is urgency for the Government to put in place relevant policies and institutional arrangements for setting up and implementing a SDI of Hong Kong by extending the foundation works which have been done by the Development Bureau and the Lands Department, before the robust of innovative web applications in the wider community comes.

Expand Free Wi-Fi Hotspot Programme

In order to build a healthier ecosystem of information society, Van der Meer and Van Winden identified access to ICT as a vital element. They suggested more local ICT users (more access) attract more companies to develop more and better electronic services, and vice versa.

"more local users and electronic services demand ICT infrastructure of higher quality and better quality of ICT infrastructure also evokes the improvement of electronic services and attracts more users" (Meer and Winden 2003, cited in Huang, 2012:5).

To enhance the technology ecosystem, policy makers must increase users' access to services and content. Comprehensive internet access facilitates local development of the innovation and technology sector. For such access, Wi-Fi has become the preferred technology for wireless local area networking in both business and home environments. Wi-Fi is also being increasingly deployed in public places to create so-called hotspots. More hotspots provide better internet connectivity, which could lead to an improved quality of life. Public Wi-Fi available for everyone can bridge the digital divide between those who have access and those who do not.

In fact, Potts (2014), from the perspective of market failure, agrees the public sector should offer public Wi-Fi. Moreover, such service could be a discovery process that yields market information about entrepreneurial opportunities as a public good, which could be taken up by private businesses. In Kansas, wireless connections power smart city applications using internet technologies so that they could be deployed, tested and validated in a full-scale industrial user environment (Kansas City Living Lab, 2015).

The implication for private network providers, and the economy in general, goes beyond this. Wi-Fi offloading is a technology to reduce data congestion on cellular bands through allocating part of the bandwidth to a separate Wi-Fi network. Besides, there are data users not requiring full mobility, hence Wi-Fi provision can retain this type of customer by offering them a high-speed alternative. In fact, according to Cisco (cited in Gaskell, Berard and Zehle, 2014), Wi-Fi offloading yields a win-win situation for both end-users and mobile operators.

Using unused or underutilised bandwidth more effectively for Wi-Fi has an economic benefit that can be estimated. A study initiated by Ericsson demonstrated that doubling the broadband speed for an economy increases GDP by 0.3% (Ericsson, Arthur D. Little and Chalmers University of Technology, 2011). Furthermore, in a survey conducted by Craig Settles (2012), most economic development experts believe broadband speeds above 100 Mbps are required to impact economic development, with over a quarter concurring that 1 Gigabit minimum is a must-have to attract new businesses.

Free Public Wi-Fi in HK: GovWiFi and Wi-Fi.HK

Besides the HKSAR Government GovWiFi scheme, which covers around 550 premises as at August 2015 (Gov.HK, 2015), the "City-wide Wi-Fi for the Public and Visitors" under the 2014 Digital 21 Strategy saw collaborations between the government and other public and private institutions since 2014. Under the Wi-Fi brand, 'Wi-Fi.HK', the total number of hotspots surged to 12,000 as at February 2015, including Wi-Fi hotspots under the GovWiFi scheme. Wi-Fi.HK provides free Wi-Fi service across the city covering Hong Kong International Airport, tourist attractions, public telephone booths, shopping centres, cafés, restaurants, convenience stores, Cyberport and the Science Park.

Comparison of Public Wi-Fi Download Speed across Countries

Based on data collected from public Wi-Fi hotspots across 172 countries by Rotten Wi-Fi (cited in Zaliauskiene, 2014), a public Wi-Fi and 3G/4G watchdog, the 20 countries with the highest average speed of public Wi-Fi networks are mostly from Europe. Lithuania, Croatia and Estonia are top three with 13.75 to 15.40 Mbps. The first non-European nation to make the list is Singapore with an average download speed of 9.49 Mbps over its public Wi-Fi networks.

Table 25. Comparison of Countries'/ Regions' Public Wi-Fi Download Speeds

Country	Rank	Public Wi-Fi download speed (Mbps)
Lithuania	1	15.40
Croatia	2	14.05
Estonia	3	13.75
Ireland	4	11.43
Romania	5	11.32
United Kingdom	6	10.97
Denmark	7	10.52
Hungary	8	10.37
Belgium	9	10.07
Slovenia	10	9.72
Bulgaria	11	9.67
Singapore	12	9.49

Source: Rotten WiFi, 2014

Hong Kong is significantly lagging behind in terms of connection speed. There is a connection speed and bandwidth limit set for each user to ensure that GovWiFi provides reasonable service level. In general, the average uploading and downloading speed for each user is about 1 to 2 Mbps, with maximum up to 3 Mbps. The bandwidth allocated to each user is about 1 to 2 Mbps (Gov.HK, 2014). Recalling the review results on free public Wi-Fi by Audit Commission (2013), it is not surprising that the GovWiFi service average download speed, in 1.32 Mbps only, was far lower than those of other countries. Even with the more recently launched Wi-Fi.HK, informal experiments carried out by several Hong Kong technology sites demonstrate that the new scheme's download speed remains relatively slow compared with those of other countries (Unwire.hk, 2014; E-zone, 2014; RingHK.com, 2014).

Moreover, according to data between 2010 and 2012 from the OGCIO, GovWiFi was not cost-effective (Audit Commission, 2013). 108 (27%) out of around 400 government premises experienced low usage with an average number of daily users below 15. This implied the average cost on some premises could be as expensive as over HK$50 to HK$ 100 per Wi-Fi connection.

Table 26. Sample of Common Applications and the Speeds Required to Successfully Run Them

Download Speed	Application
768K-1.5Mbps	Email, Web Browsing, Voice Over IP (Vonage)
1.5-3Mbps	Streaming Music, Standard Definition Video, Remote Surveillance, Telecommuting
3-6Mbps	File Sharing, Internet Protocol Television (IPTV)
6-10Mbps	Online Gaming, Streaming Video
10-25Mbps	Telemedicine, Remote Education, IPTV High Definition
25-50Mbps	HD Video Surveillance
50-100Mbps	Video Conferencing, Remote Super Computing
>100Mbps	Real-Time Data Collection, Real-Time Medical Image Consultation, Research

Source: New York State Broadband Program Office, 2013

In fact, the Hong Kong Wireless Technology Industry Association provides explanations of such low usage. Its studied of Wi-Fi adoption in Hong Kong in 2013 point out users of GovWiFi were most unsatisfied with inadequate Wi-Fi access points (72.1%), inadequate bandwidth (50.0%), and unstable service quality (47.1%) (Wong, 2013).

High subscription rate to mobile data internet services is another possible reason of the low usage of public free Wi-Fi. As of May 2015, mobile subscriber penetration rate stroked 228.4% in Hong Kong. Among the 16.59 million mobile subscribers, 12.1 million (73%) also subscribed to 2.5G/3G/4G mobile data services (Office of the Communications Authority, 2015). Nevertheless, it is worth noting the public are demanding more and more mobile data. As at March 2015, local mobile data usage recorded a remarkable surge to 17,472 Terabytes (i.e. 17,472,476 Gigabytes), which is equivalent to an average of 1,417.9 Mbytes (or 1.38Gbyts) per data subscriber. This represents a growth of 1.35 times and 1.95 times in the mobile data usage respectively over the same period in 2014 and in 2013 (Office of the Communications Authority, 2015). Not only does it highlight the demand for data, it underlines the importance of free Wi-Fi service to reduce the digital gap.

Looking ahead, in order to increase the number of hotspots and to maintain high-quality service such as speed, the government should consider other Public-Private Partnership (PPP) models, including those implemented in other cities. In doing so, more suppliers will be encouraged to provide complimentary public Wi-Fi service, and current participating organisations of Wi-Fi.HK will be incentivised to provide additional hotspots. Table 27 illustrates some alternative PPP models adopted in other countries and cities to provide complimentary public Wi-Fi.

Table 27. PPP Models Adopted in HK and Elsewhere to Provide Public Wi-Fi

Location	Method	Results
Singapore	• "Wireless@SG" launched in 2006, infocomm companies invited to offer low- or no-price plan with certain minimum requirements • Selected companies to provide free public Wi-Fi service for three years, in return are issued license to provide commercial service, are offered government funding and access to government resources (e.g. spectrum licenses) • Government paid for hotspot installations until April 2013. After which, installation costs were covered by the selected service providers	• The scheme functioned well initially (over 6200 hotspots in 2010) but obstacles appeared once government stopped paying for hotspot installations • With an overall higher operation cost, service providers now have less incentive to offer free public Wi-Fi service, leading to less competition among telecom providers bidding for the service • Fewer hotspots also benefit telecom companies that charge people for internet access
Taipei	• First in the world to introduce city-wide free public Wi-Fi network in 2004 by forming a nine-year partnership with private company • Company responsible for network planning, installation and operation, in return given opportunity to attract paid users	• Estimated total of 5000 access points installed, reaching 90% of the city population by mid-2006 • Government not required to make investment or transfer ownership of property • Difficult for suppliers to attract users to pay for premium service
New York City	• Government implemented several PPP initiatives to make public Wi-Fi available across the city • Highlight is "LinkNYC", a 12-year partnership between NYC and CityBridge (formed by four companies) to create a communications network • Partnering companies can profit from advertising revenues on the kiosks	• Incentive for service providers to expand "LinkNYC" network (Target: Install 10000 kiosks, each able to support up to 256 devices) • Government not required to invest in installation of kiosks • New ad spaces said to damage cityscape and bring disturbance to public • Gives CityBridge monopoly over other payphone operators
Guangdong & Province	• Provincial government announced the "i-Guangdong" in 2015 to provide free Wi-Fi in public areas throughout the whole province within three years • Users allowed internet access for unlimited time • Service provider profits from Big Data obtained from public Wi-Fi users	• Government not required to invest • Incentive for providers to maintain high-quality service • Operator not relying on ads • Privacy concerns may arise
Hong Kong	• Government initiated Wi-Fi.HK scheme, encouraging major organisations and payphone operators to provide complimentary Wi-Fi service for at least 30 minutes per day	• Government not required to invest • Little incentive to improve service or download speed • Little incentive for payphone operators to increase hotspot numbers or for non-participating organisations to join the scheme

Source: King, International Business Times, Infocomm Development Authority of Singapore, Gigaom, Wi-Fi Planet, IDA International, Techgoondu, Lital Shenzhen, PCOnline

Successful Stories

The experience of most successful ecosystems centre on the activities of universities, either in terms of accepting and pursuing government research projects, as well as partnerships with industry, such as technology spin-outs and commercialisation of intellectual property (Jackson, 2011). These partnerships benefit all parties, as the universities can receive substantial funds from government research contracts, which help cover overhead and teaching activities, as well as income from licensing intellectual property and upside from equity stakes in spin-off companies.

In the Successful Stories Section (see Appendix III), we discuss how universities such as Stanford University in Silicon Valley and Technion in Israel have become hubs for the intersection of academic research and commerce. We further provide examples of other university-industry models in Finland, Belgium, and Mainland China.

Recommendations

A Holistic and Long-term Policy on Innovation and Technology and Smart City with Effective Implementation

Stakeholders are unanimous that the government need to take the lead to change the social mind-set towards technology and entrepreneurship and that it should play a key role in fostering a sound environment for innovation, in investing in the foundations for innovation, in overcoming certain barriers to innovation and in ensuring that innovation and technology contributes to key goals of public policy.

- **Long-term plan.** To deliver a clear and credible roadmap for the long-term development of innovation and technology in Hong Kong to identify strategic focus of development, for instance smart city, and to lay down concrete policy initiatives with timeline on implementation.
- **A holistic approach.** Policies relating to innovation and technology touches on many areas including land and housing, education, immigration, labour importation and economic development. Government needs a high-level organisation to coordinate with other departments to tackle issues and problems and to ensure that policies are well aligned.
- **Engage stakeholders.** To engage stakeholders involving business, academia, investors and start-up accelerators, social partners and relevant government and public agencies into the process at the early stage to ensure support of stakeholders for policy actions.
- **Cooperation with Mainland China.** Government to liaise and negotiate with Mainland Chinese authorities including the Ministry of Science and Technology, the State Council and the Ministry of Education as well as with regional authorities for collaboration opportunities with mainland companies and academic institutions for the promotion of innovation and technology and to explore the role of Hong Kong in the Central Government's Five-Year Plan.

- **Innovation and Technology Fund.** To review of the funding mechanisms of the ITC to ensure efficient allocation of resources, that adequate support and incentives are given to researchers and start-ups and to enhance the role of the Government as a facilitator rather than a winner picker. Consider adding macro metrics such as "number of R&D jobs created" to the KPIs of the ITC in order to capture the societal benefits of its investments, rather than giving undue emphasis on success or failures of its projects.
- **E-Procurement.** The Government can speed up the adoption of e-procurement to its departments. It can start from the Government Logistics Department, the central government procurement agent. It can later expand the size of e-procurement to larger projects such as public works which involve departments such as Buildings Department, Highways Department and Water Supplies Department.
- **Open government data.** To expand open government data in order to spur new research and development of new products, the Government can consider improving the existing information system. It should also review how to modify and expand the use of RSS Feed and Web API service to provide more personalised and convenient updates of new information to citizens and users. Blogs could also be introduced on the data.gov.hk. This system can add more interaction and convenience for the end-users.
- **Machine readable data.** Government should introduce standards for government departments in the release of their data and statistics online. Such data should come in computer-friendly formats, such as JSON (JavaScript Object Notation), Atom, XML (eXtensible Markup Language) and CSV (Comma Separated Values).
- **Standardise SDI.** Since most Smart City applications are location-based, the establishment of a SDI of Hong Kong lays an important foundation for further development of Smart City applications. The Development Bureau and the Lands Department should take the lead to standardise the geospatial data and establish the SDI.
- **Extensive High-speed Free Wi-Fi.** There is an increased demand for internet connection. However, the free Wi-Fi service provided by the Government are currently at a low speed. Moreover, as more and more people subscribe to private 3G/4G mobile data service, the digital gap of those who cannot afford such service is getting wider. We hope the Government will do more than merely increasing the number of hotspots, as there remains much room for the quality of these hotspots to be improved. To achieve this, the Government could review the PPP model it currently adopts.

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Concluding Remarks

This report has attempted to assess the current state of Hong Kong's innovation and technology ecosystem. In doing so, we have set out the strengths of Hong Kong, and the challenges it faces. While we recognise that some issues have not been thoroughly discussed in this report, including privacy and cybersecurity, and high operation cost, particularly the city's expensive office rent, we hope this report has sufficiently demonstrated the role of innovation in driving economic growth and development. As such, there are enormous benefits for Hong Kong to develop its innovation and technology ecosystem. Addressing the policy implications of Hong Kong's obstacles to innovation and technology development, we recommend a number of measures, as summarised in the next section.

Summary of Recommendations

1. **Substantial increase in public research funding**

- Government to target a public research-spending ratio of 1% of GDP over the next decade.
- To inject HK$2 billion recurring funding per annum by increasing RGC's endowment by HK$50 billion.
- To put more focus on applied research.
- Universities to form research centres, preferably inter-institutional joint centres, in order to compete for the necessary resources to appoint full-time research-intensive staff, such as postdoctoral fellows and research associates.
- To conduct further research and to engage stakeholders in finding the best inter-institutional collaboration model suitable to Hong Kong.
- Government to support the development and maintenance of infrastructure such as specialist facilities that can be shared across sectors or centres where universities, researchers and industry can come together to undertake innovation and research activities.
- To adopt a holistic approach to take into account and ensure that housing and family education needs of the new research recruits are met.

2. **Reform public research funding mechanisms**

- To increase the relative share of competitive, project-based research grants over discretionary institutional funding by channelling new research investments in the future to RGC.
- To build up the critical mass of research capacity by reducing fragmentation.
- RGC to encourage more inter-disciplinary, inter-university research collaboration through funding programmes. A review of the current Areas of Excellence and Theme-based Research programmes may be conducted to evaluate their effectiveness in driving excellence through collaboration.
- RGC to be separated from UGC and be the coordinating body of all basic and applied research of universities, as well as research centres.
- RGC may be separated into three distinctive agencies accordingly, in order to adopt disciplinary perspectives in allocating funding.

- Governance boards of the respective research funding agencies to include representatives from government and business, as well as local and international expertise from the academia.
- RGC could create two separate arms within its structure; one to serve the universities and other research organisations; and another to drive technology transfer and research collaboration between business and universities along strategic areas of priority. If two separate agencies are required to handle funding allocation to business and start-ups and to academics and researchers due to different sources of funding, then there must be strong cooperation between the two.
- RGC funding should be broadened to include all academics in universities as well as other pre-qualified research entities or individuals.

3. **Enhance evaluation and transparency of discretionary institutional funding**

- To review UGC's evaluation system. To consider reducing the weighting of RAE in calculation of the Research Portion in UGC's Block Grant to the institutions, while adding those of competitive grant successes as well as other impact metrics. In the long run, UGC could consider phasing out RAE and replacing it with other performance and impact metrics.
- UGC to commission an independent study of the indirect (infrastructure and administrative) costs related to competitive research grants and to make arrangement with RGC to ensure sustainability of research to complement the proposed increase in competitive research funding via RGC.
- UGC's reform initiatives to inject competition in block grant allocation should be continued. According to the current plan, 12.5% of total UGC funding or 50% of the Research Portion will be progressively allocated, over a period of nine years by 2020, on a competitive basis with reference to successes in obtaining RGC grants.
- Universities to offer incentives to encourage academics to think beyond basic research to consider socio-economic impact of their research.

4. **Facilitate collaborations between Mainland China and overseas institutions in research and talent training activities**

- RGC to expand the scope and depth of cooperation agreement and joint programmes with partners in Mainland China and other countries.
- Government to negotiate with mainland authorities for special treatment to allow Mainland government research fund to come into Hong Kong.
- To arrange tax harmonisation for Hong Kong's researchers working on Mainland funded research projects in the Mainland, to deal with the huge income tax rate gap between Mainland China and Hong Kong.
- Universities to provide flexible work schedule arrangements to encourage university researchers to work in Mainland-based projects.
- Government to encourage mainland companies to establish research facilities in Hong Kong by offering taxation and other incentives.
- To expand ITC's student internship programme to overseas and mainland corporations.

5. **Clear policy support to local and foreign start-ups to prime a sustainable ecosystem**

- To facilitate the development of venture capital market through incentives, in particular risk sharing in the form of co-investment schemes such as matching fund for financing seed and early stage ventures.
- To develop regulatory frameworks that will facilitate start-ups and small companies to raise seed capital and venture funding via the Internet, such as crowdfunding, while at the same time ensuring due protection to investors.
- To review the grant allocation mechanism of Innovation and Technology Fund to ensure that the process is efficient with minimal bureaucracy, to avoid rent-seeking activities and support non-mainstream challengers. Composition of the expert panel should be reviewed to ensure that people with relevant industry and/or investment expertise are invited.
- Mainland Chinese to be offered the same start-up visa status as foreigners in order to enable those studying or staying in Hong Kong to venture into start-up activities.
- Government looks into relaxing the requirements for quality migrants under the current Quality Migrant Admission Scheme to allow entrants of more high-achieving professionals.
- Government takes a holistic approach to address housing, education, environmental and other problems that are essential to make Hong Kong an attractive place to live for non-locals.
- Universities' technology transfers offices to be given more resources to take on additional tasks of bridging students, faculty, alumni with investors, entrepreneurs, industry, non-government agencies other relevant stakeholders.
- Universities enhance student innovation and entrepreneurship by further promoting cross-disciplinary studies and perhaps offering formal degree programmes.
- Universities promote faculty entrepreneurship by giving greater recognition of faculty entrepreneurs, creating flexible work place policies, making seed funding available to faculty, researchers and graduate students, and increasing faculty connections with outside partners.
- Universities open up their facilities, faculty and students to businesses to encourage more strategic collaboration such as internships and externships with companies, start-up facilities with accelerators and start-ups and venture funds and incentive programmes funded by industry.

6. **Foster business dynamism and leverage on existing competitive advantage to create strategic niches**

- To provide generous tax incentives or R&D subsidies to lure and support local and non-local start-ups and SMEs to invest in R&D.
- To allow for super deduction of qualified R&D spending to at least match that of regional peers such as Singapore and Mainland China of 150%, or the equivalent in the form of R&D subsidies.
- To offer a reduced profits tax rate over a defined period of time to companies meeting certain criteria such as headcount requirement for R&D personnel.

- To expand the scope of qualified R&D to allow "contract out" research conducted locally, besides universities and research institutes, to claim R&D tax benefits.
- To offer tax incentives or R&D subsidies to encourage R&D investment in selected priority areas that are deemed critical to the social and economic development of Hong Kong or where Hong Kong has globally competitive advantages and research excellence.
- To offer incentives, such as tax benefits, grants or loans, to companies that conduct research collaboration with local universities or selected research institutions. Government to host technology symposiums and conferences to promote exchanges and collaborations between academics and business sector.
- Government to consider Alternative subsidy option, such as setting up a new endowment fund or refunding qualified R&D expenditure through the ITF, should it not want to complicate the tax regime.
- To require a competitive technology roadmap as a condition for the issuance and renewal of licenses for public institutions and regulated utility companies.
- To evaluate and revamp existing e-Government platforms to ensure that services are state of the art, user-friendly, efficient and competitive viz. private sectors and overseas public sectors.
- To evaluate and review procurement policy and where possible expand innovation and technology promoting procurement policy.
- To help develop Hong Kong as a FinTech hub via a multi-prong strategy by driving regulators on FinTech adoption and incentivising businesses to offer accelerator programmes to local and non-local FinTech start-ups while universities to consider offering degree programmes.
- To engage major domestic I&T spenders, public utilities, business organisations, government departments, regulatory agencies, universities, local and non-local start-ups to collaborate to develop smart city technologies.
- Government to pump up its effort to attract more MNCs to Hong Kong for R&D.

7. **Remove regulatory hurdles to open up space for innovation.**

- Regulatory bodies to adopt an open-minded attitude and a forward-looking, rather than retrospective approach to innovations in order to engage start-ups and technology companies at the early stage of development.
- Regulatory institutions should strike a balance between the innovation and competition needs of the society with its duty of keeping social and economic stability. For instance the gate of equity crowdfunding could first be opened to professional investors.
- To develop and publish a policy on regulatory requirements that start-ups can rely on, if certain regulatory principles or conditions are met. Establish threshold levels when companies need to comply with tighter regulatory rules. Offer solutions-based guidance to help start-ups find practical and low-cost way to meet regulatory expectations.

- To conduct a comprehensive review of the competitiveness and innovation-friendliness of the overall financial regulatory framework to ensure the regulatory bodies can cope efficiently with the increasing integration, novelty and granularity of new services brought about by new technologies.

8. **Strengthen ties with the PRD, especially Shenzhen, to drive Hong Kong's applied research and boost role as a "super-connector"**

- To encourage the major technology companies in Shenzhen to cooperate with Hong Kong universities in their R&D activities; to utilise the manufacturing base in the PRD to drive product commercialisation of Hong Kong's translational research, and to liaise with overseas translational research centres to promote Hong Kong as a hub to convert their prototypes to real samples and final products.
- University research funding to review KPIs and incentives to drive deeper and broader collaboration with companies in the PRD region, especially Shenzhen to foster the growth of downstream applied research of Hong Kong.
- Government to review current funding mechanism of ITC to ensure efficient and fair allocation of funding to successful applicants and that adequate resources and incentives are given to both corporate as well as to research organisations.
- Hong Kong and the PRD local governments to host regular technology conferences in Hong Kong and Mainland China to promote R&D collaboration.
- To survey the supply chain network in the PRD area and maintain an updated database for Hong Kong start-ups to facilitate their commercialisation process.
- InvestHK encouraged to strengthen its marketing ties with foreign universities, private and public research centres to entice students and faculty members engaging in translational research and to use Hong Kong as a hub for time-to-market design, prototype manufacturing and sampling services.

9. **A holistic and long-term policy on innovation and technology, and smart city**

- To deliver a clear and credible roadmap for the long-term development of innovation and technology to identify strategic focus of development and to lay down concrete policy initiatives with timeline on implementation.
- Government establishes a high-level organisation to coordinate with other departments to ensure that policies are well aligned.
- To engage stakeholders involving business, academia, investors and start-up accelerators, social partners and relevant government and public agencies into the process at the early stage.
- Government liaises and negotiates with Mainland Chinese authorities and regional authorities to explore collaboration opportunities and the role of Hong Kong in the Central Government's Five-Year Plan.
- To review of the funding mechanisms of the ITC with consideration of adding macro metrics to the KPIs of the ITC.
- Government speeds up the adoption of e-procurement to its

departments and to expand the size of e-procurement to larger projects.

- To expand open government data with consideration of improving the existing information system, reviewing how to modify and expand the use of RSS Feed and Web API service and introducing blogs on the data.gov.hk.
- Government introduces standards for government departments in the release of their data and statistics online in computer-friendly formats.
- The Development Bureau and the Lands Department to take the lead to standardise the geospatial data and establish the SDI.
- Government increases the quantity of free Wi-Fi hotspots, improve their service quality and to review the PPP model it currently adopts.
- EDB conducts a thorough review of the DSE syllabus to give students a comprehensive exposure to all science subjects to ensure a smooth transition to university education.

Appendix
Appendix I: Stakeholders Consulted

Table 28. Stakeholders Consulted

Name	Company	Title
Douglas Arner	Faculty of Law, HKU	Professor
Kevin Au	Centre for Entrepreneurship, CUHK	Director
Lawrence Beck	Credit Suisse	Managing Director of the Information Technology Division
Laura Cha	HKSAR Government Executive Council	Member
Tony F.C. Chan	HKUST	President
Paul Y.S. Cheung	Department of Electrical and Electronic Engineering, HKU	Professor
Jason Chiu	Cherrypick	CEO
Paul Chow	Hong Kong Cyberport	Chairman
David Chung	Hong Kong Cyberport	Chief Technology Officer
Victor Fung	The Fung Group	Group Chairman
Simon Galpin	InvestHK	Director-General of Investment Promotion
Melissa Guzy	Arbor Ventures	Managing Partner
Jason Ho	HKFYG Youth Service Advisory Committee	Member
Herman Lam	Hong Kong Cyberport	CEO
Fanny Law	HKSAR Government Executive Council	Member
Lee Wai-Kwong	ASM Pacific Technology Limited	Chief Executive Officer
Antony Leung	Nan Fung Group	Chief Executive
Humphrey Leung	Solomon Systech	Chairman and Group CEO
Michael Leung	China CITIC Bank International	Chief Information and Operations Officer
Nisa Leung	Qiming Venture Partners	Managing Partner
Richard Leung	Hong Kong Exchanges and Clearing Limited	Co-head of Information Technology
Dennis Lo	Department of Chemical Pathology, CUHK	Professor
Sara Lo	HKU	Director of Finance
Vincent Lo	Shui On Land Limited	Chairman
Lu Aiping	School of Chinese Medicine, HKBU	Dean and Chair Professor
Allen Ma	HKSTP	Chief Executive Officer

Table 28. Stakeholders Consulted

Name	Company	Title
Theodore Ma	Cocoon	Co-Founder
Deepak Madnani	Papercliphk	CEO/Founder/Catalyst
Charles Ng	InvestHK	Associate Director-General of Investment Promotion
Stanley Ng	Hong Kong Federation of Trade Unions	Chairman
Lawrence Shum	NewOcean Energy Holdings Limited	Managing Director
Simon Squibb	Nest	CEO
Ted Suen	MTR	Head of Information Technology
Tai Hay-Lap	Tin Ka Ping Foundation	Vice Chairman
Grace Tang	Ernst & Young	Partner
Paul To	Hang Seng Bank	Head of Digital Banking
Frank Tong	ASTRI	CEO
Timothy Tong	PolyU	President
Paul Tsui	Esri China (Hong Kong) Limited	Managing Director
Benjamin Wah	Research Grants Council	Chairman
Leonhard Weese	Bitcoin Association Hong Kong	President
Alwin Wong	Institute for Entrepreneurship, PolyU	Director
Janet Wong	Innovation and Technology Commission	Former Commissioner
Johann Wong	Innovation and Technology Commission	Deputy Commissioner
Jolly Wong	The Institution of Engineering and Technology	Trustee and Vice President
Wong Suk-Ying	C.W. Chu College, CUHK	Dean of Students
Henry N. C. Wong	Department of Chemistry, CUHK	Professor
Claudia Xu	Technology Transfer Center, HKUST	Director
Yang Qiang	Department of Computer Science and Engineering, HKUST	Head
Nicholas Yang	Innovation and Technology Bureau	Secretary for Innovation and Technology
Allen Yeung	HKSAR Government	Chief Information Officer
Shero Yip	Hong Kong Cyberport	Manager of Collaboration Centre
Jenny Yiu	Nano and Advanced Materials Institute Limited	Director of Public Affairs and Development
Joseph Yu	Roseville Group of Companies	Chairman

Appendix II: Acronyms and Abbreviations

Table 30. Acronyms and Abbreviations Used in this Report

Acronym/ Abbreviation	Meaning
APAC	Asia-Pacific
API	Application Programming Interface
ASTRI	Applied Science and Technology Research Institute
B2B	Business-to-Business
CC	Creative Commons
CityU	City University of Hong Kong
CUHK	The Chinese University of Hong Kong
DAM	Data Alignment Measures
DSE	Diploma of Secondary Education
EU	European Union
FCA	Financial Conduct Authority
FGDC	Federal Geographic Data Committee
FinTech	Financial Technology
GDP	Gross Domestic Product
GIH	Geospatial Information Hub
HKBU	Hong Kong Baptist University
HKPC	Hong Kong Productivity Council
HKSTPC	Hong Kong Science and Technology Park Corporation
HKTDC	Hong Kong Trade Development Council
HKU	The University of Hong Kong
HKUST	The Hong Kong University of Science and Technology
I&T	Innovation and Technology
ICT	Information and Communications Technology
IoT	Internet of Things
IP	Intellectual Property
IPO	Initial Public Offering
IT	Information and Technology
ITC	Innovation and Technology Commission
ITF	Innovation and Technology Fund
KPI	Key Performance Indicator
LegCo	Legislative Council

Table 30. Acronyms and Abbreviations Used in this Report

Acronym/ Abbreviation	Meaning
London AIM	London Alternative Investment Market
MIT	Massachusetts Institute of Technology
MNC	Multinational Corporation
NASDAQ	National Association of Securities Dealers Automated Quotations
NIH	National Institute of Health
NSDI	National Spatial Data Infrastructure
NSF	National Science Foundation
NYSE	New York Stock Exchange
OECD	Organisation for Economic Co-operation and Development
OGCIO	Office of the Government Chief Information Officer
OSC	Office of the Chief Scientist
OTL	Stanford Union's Office of Technology Licensing
PolyU	The Hong Kong Polytechnic University
PPP	Public-Private Partnership
PRD	Pearl River Delta
R&D	Research and Development
RAE	Research Assessment Exercise
REF	Review Excellence Framework
RGC	Research Grants Council
RMB	Renminbi
SAR	Special Administration Region
SDI	Spatial Data Infrastructure
SG-SPACE	Singapore Geospatial Collaboration Environment
SKLs	State Key Labs
SME	Small-and Medium-sized Enterprises
SMO	Survey and Mapping Office
STEM	Science, Technology, Engineering and Mathematics
SVF	Stored Value Facility
Tekes	Finland's Funding Agency for Technology and Innovation
TSSSU	Technology Start-up Support Scheme for Universities
TTB	Technology-to-Business
UGC	University Grants Committee
UK	United Kingdom
UN	United Nations
US	United States

Appendix III: Successful Stories

Successful Stories

Two detailed case studies on the innovation ecosystems of the Silicon Valley and Israel are presented, which aim to show the present state of these two leading locations for innovation. Background factors which have enabled innovation to flourish in Silicon Valley and Israel are illustrated and discussed. The case studies highlight best practices in the government, university, and commercial sectors. Furthermore, additional initiatives and practices, which have been undertaken to build regional clusters and ecosystems by other developing innovation hotspots are listed.

Silicon Valley

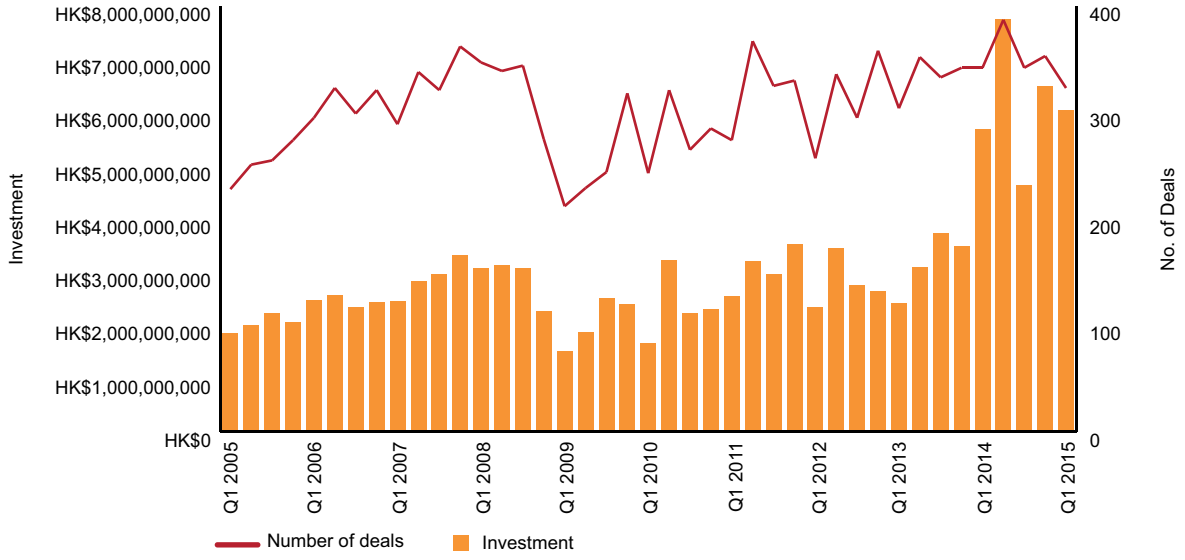
Silicon Valley has the world's greatest number of innovation and start-ups . It has the highest concentration of high-tech workers, the most high-tech manufacturing activities and the largest number of millionaires and billionaires on a per capita basis of any major metropolitan area in the US. Silicon Valley is home to a significant number of the world's high-tech companies, including Apple, Cisco Systems, eBay, Google, Hewlett-Packard Co., Intuit, LinkedIn, Oracle, Sun Microsystems and Yahoo.

Start-up Activity at a Glance

2014 was the strongest year in terms of investment activity for start-ups in the Valley since the Tech Boom of 1999. During 2014, a total of 1,424 deals were made representing US$24.5 billion being invested. The year-on-year growth in the number of deals from 2013 to 2014 was 7%, but the amount of capital invested was up a staggering 93%. The average deal size in 2014 was US$17.2 million compared to US$9.6 million in 2013, accounting for an 80% increase. It is evident from the numbers that the Silicon Valley remains the go-to hotspot for venture capital investments.

In 2015 the Valley continued where it left off, registering another 6.2% year-on-year increase in capital put to work in Q1 2015, even though the number of deals decreased slightly from 342 in Q1 2014 to 323 in Q1 2015.

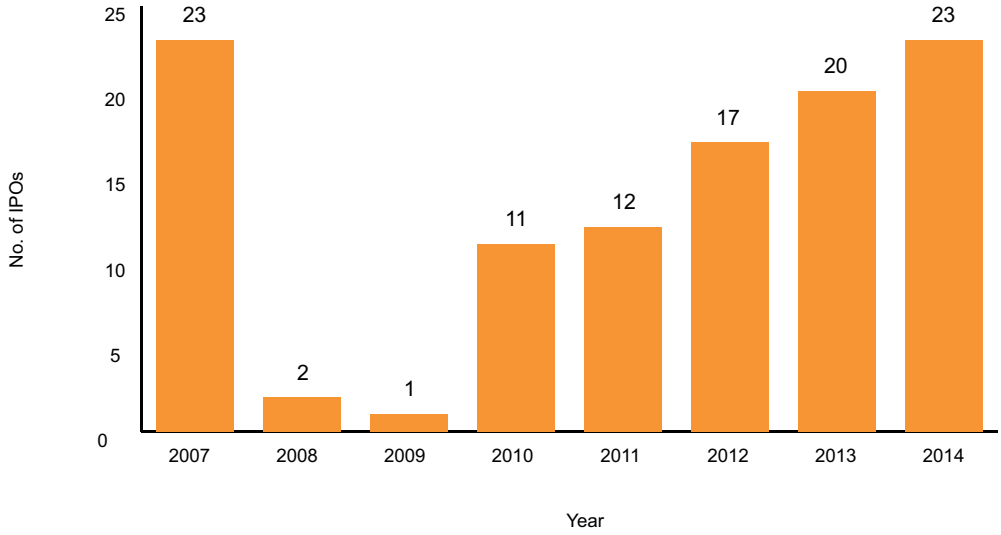
Figure 25. Silicon Valley Investment Statistics



Source: PricewaterhouseCoopers Moneytree

The number of Silicon Valley IPOs has also grown steadily since the financial crisis returning to its pre-2008 levels. 23 companies in Silicon Valley were floated in 2014 but the number was 20 in 2013 and 17 in 2012.

Figure 26. Number of Silicon Valley IPOs



Source: PricewaterhouseCoopers Moneytree

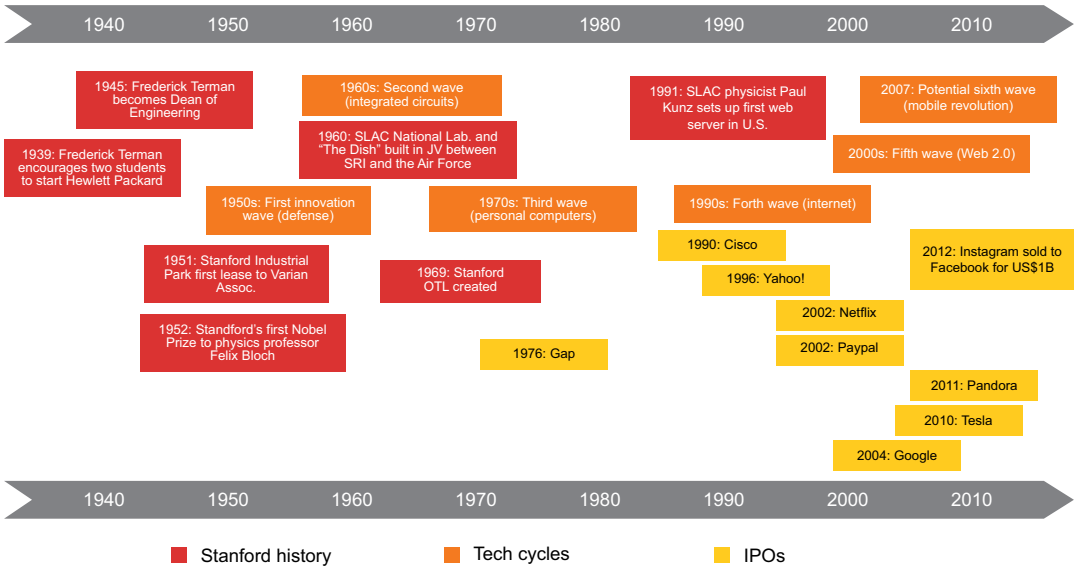
Background

After World War II, Frederick Terman who was the Dean of the School of Engineering at Stanford University began establishing critical links between the university and the high-tech industry through programs that enabled engineers at nearby companies to take classes on the Stanford campus. Terman was the driver in positioning Stanford as the frontier of innovation, encouraging students to start and build their businesses locally. Faculty members joined the program through consulting, investing, and in some cases, founding new companies. Thus, it creates a vibrant young entrepreneurial community in technology.

Terman helped establish the Stanford Industrial Park, in which nowadays, it provides real estate to technology companies, such as Hewlett-Packard, General Electric, Lockheed and Facebook. Terman is also credited for convincing William Hewlett and David Packard to work out of a Palo Alto garage and ultimately establish Hewlett-Packard, often considered the birth of innovation ecosystem.

As a result of Terman's efforts and vision, Silicon Valley has established itself as the premier location for innovation over the past 60 years, becoming a model for innovation around the world. The Figure below illustrates the development of the Silicon Valley innovation ecosystem between 1939 and 2012.

Figure 27. Development of the Silicon Valley Ecosystem, 1939–2012



Source: kauffmanfellows.org

Culture

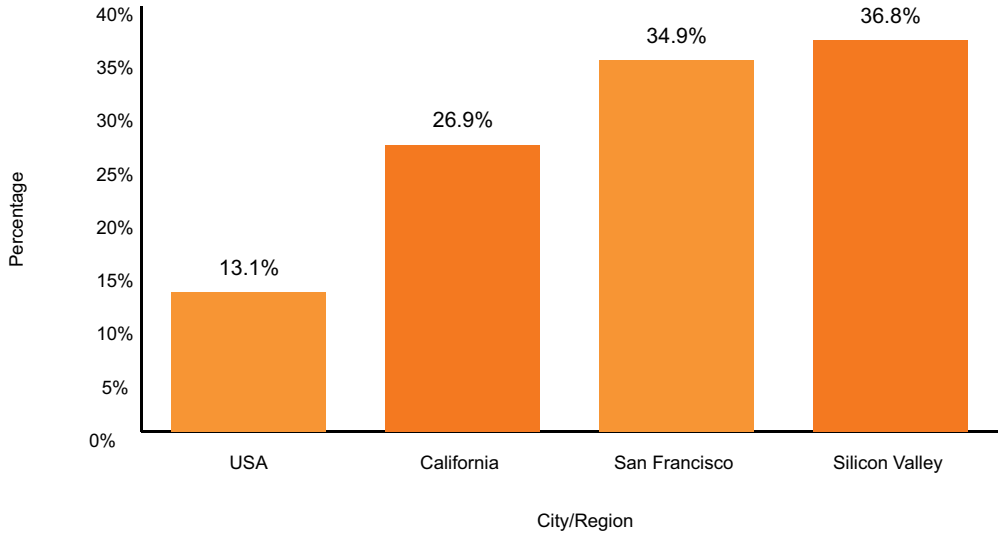
Many people credit the unique culture of the Silicon Valley for its success as an innovation ecosystem. An Accenture report titled, Decoding the Contradictory Culture of the Silicon Valley published in 2013, describes the Silicon Valley culture using five contradictions:

- **Laid back** – yet driven for speed
- **Committed** – yet independent
- **Competitive** – yet cooperative
- **Pragmatic** – yet optimistic
- **Extrinsically motivated** – yet intrinsically fulfilled

In addition, authors such as University of California, Berkeley Professor AnnaLee Saxenian, offered that, "Silicon Valley's high rates of job-hopping and company formation, its professional networks and easy information exchange, lent its advantage". The whole innovation ecosystem has supported experimentation, risk-taking, and sharing the lessons of success and failure.

A large part of the culture is also the diversity of the talent pool. According to data from the US Census Bureau and the American Community Survey, 36.8% of Silicon Valley inhabitants are foreign born, which is 13.1% on a national basis.

Figure 28. Percent of Foreign-Born Inhabitants



Source: U.S. Census Bureau, American Community Survey

Research co-authored by Saxenian stated that from 1995 to 2005, 52.4% of engineering and technology start-ups in Silicon Valley had one or more people born outside the US as founders, which was twice the rate seen in the US as a whole. Immigration could be an essential piece of the puzzle that has made the Silicon Valley's culture what it is today and a key source of the Valley's sustained competitive advantage.

The section below examines the Silicon Valley by looking at the sectors of government, universities, and industry.

University

Stanford University is a significant driver of the Silicon Valley innovation ecosystem. The university is an incubator of new technologies and attracts major high-tech companies.

Stanford's Office of Technology Licensing (OTL), established in 1969, has commercialised faculty and students' research into profitable companies. Since its founding, over 200 companies (including Google) have started technology licensed through OTL. Today there are over 18,000 invention disclosures, more than 10,000 patents filed and more than 5,000 licenses granted (Source: www.kauffmanfellows.org).

Government

The US government also plays a key role in Silicon Valley's evolution, by supporting Stanford University's cutting-edge research. "Stanford is fundamentally a research university. The primary, almost exclusive source of its research budget is the federal government, particularly the NIH, the NSF, the Defense Departments and various other federal agencies" (Source: OTL, "Innovation Farm Teams: Benefits and Incentives" (2013), para. 4). Other government's involvements, for examples, through the US military and space exploration efforts following World War II are important in the development of the Silicon Valley innovation ecosystem by grooming talent and providing research funding.

Industry

Multinational corporate efforts coming from different industries have contributed to the rise of the Silicon Valley as an innovation ecosystem. Different models of the domestic and international companies are examined. The goals of the businesses are to tap into the talent of the Valley and being a source of innovation of the Silicon Valley community.

Table 31. Major Industry Research Centres and Investment Arms in Silicon Valley

Type	Company	Description
Research Centre	Xerox	Xerox founded the Palo Alto Research Centre in 1970, which became legendary due to the high quality of R&D.
Research Centre and Venture Capital Fund	General Electric	As part of General Electric's US$1 billion initiative using software to transform the industries, General Electric has expanded its footprint in the Silicon Valley significantly since 2011, including building a software centre in San Ramon. The software and analytics centre employed close to 1,000 engineers by end of 2014. In addition, General Electric has a venture capital operation located in the Valley.
Research Centre	Ford	Ford Silicon Valley Lab was set up in 2013, focusing on big data and open-source programming. In January, 2015, Ford opened the new Research and Innovation Centre Palo Alto to accelerate its development of technologies and experiments in connectivity, mobility, autonomous vehicles, customer experience and big data. The new centre will have a team of 125 professionals.
Research Centre	Amazon	The company's research operating in Silicon Valley, known as Lab126, has grown from a very small team in a shared space in Palo Alto law library in 2004 to a large operation in Sunnyvale. According to a Reuters News Service report in September, 2014, "Amazon will pour an additional US$55 million into funding and staffing its Lab126 division". The company expects that by 2019 it will employ 3,757 full-time workers at the Lab126 facilities in Sunnyvale and Cupertino.
Research Centre	Walmart	The company's innovation centre and "skunk works", Wal-Mart Labs, with 6 labs around the world, has had a presence in Silicon Valley for about a decade, and has its headquarters in San Bruno (south of San Francisco). The innovation centre has worked on projects related to current and emerging technology in mobile, website and social media. Wal-Mart Labs has been aggressively hiring engineers and developers in Silicon Valley, but has also acquired many start-ups in technology areas of interest.
Research Centre and Venture Capital	Siemens	Siemens established its presence in Silicon Valley in 1999 through its Technology-to-Business (TTB) unit in Berkeley. According to the report *Europe and the Bay Area*, "TTB scouts emerging, disruptive technologies that could impact Siemens' position in the market, with university partnerships and start-ups as the medium. Eighty percent of its projects involve start-ups (roughly one-third located in the Bay Area and two-thirds elsewhere in the US) and 20 percent involve universities." Siemens leverages its TTB, Siemens Venture Capital, and Corporate Technology units to find, fund and forge the breakthroughs that will harness the power of data to make things real.
Multiple	Samsung	With over 4,000 employers in Silicon Valley, Samsung has run research and development as well as sales operations for displays and semiconductors out of San Francisco Bay Area for over three decades. The company plans to increase significantly its commitment to Silicon Valley. A major new Samsung campus will open in north San Jose, and four businesses have been created to tap into the resources and expertise of Silicon Valley: (1) Strategy & Innovation Centre, searching for new technology, investments and partnerships for the company; (2) Samsung Design America, which has hired leading designers from top Silicon Valley design firms; (3) Open Innovation Centre, which runs an accelerator, forms partnerships and makes acquisitions and investments in start-ups focused on software and services—two areas where Samsung has had major weakness in the past; and (4) Media Solutions Centre America, which creates its own software and services for the company's devices and works with developers makings apps for its products.
Multiple	Baidu	After raising a US$1.2 million in seed capital in Silicon Valley at the beginning of 2000 and returned nine months later to raise another US$10 million, Baidu returned to Silicon Valley in 2014 to start a US business operation and to build a research centre. Baidu Research intends to bring together global research talent to work on technologies in areas such as image recognition and image-based search, voice recognition, natural language processing and semantic intelligence. Baidu Research comprises three labs: the Silicon Valley AI Lab, the Institute of Deep Learning and the Big Data Lab (The latter are based in Beijing, China). The company has said it will invest US$300 million in the Silicon Valley lab over the next five years.

Source: Adopted from research performed by Eilif Trondsen

Table 31. Major Industry Research Centres and Investment Arms in Silicon Valley

Type	Company	Description
Multiple	Alibaba	The largest e-commerce company in China has stepped up activities in Silicon Valley after its successful IPO. There is a data centre and cloud-development centre, launch of 11 Main, an online retail market (with facilities in San Mateo, CA), and making numerous investments in and acquisitions of early-stage tech companies in Silicon Valley. These investments include gaming company Kabam Inc., mobile deep-linking company Quixey Inc., mobile messaging platform TangoMe Inc., ride-sharing app developer Lyft Inc., and smartphone remote-control company Peel Technologies Inc.

Source: Adopted from research performed by Eilif Trondsen

Accelerators

As one might expect in the Silicon Valley, there is an abundant number of accelerators that serve as a launch platform for start-ups. The accelerator programs in the valley offer mentorship and capital to new companies supporting the companies in their early stage of development. The most prominent accelerator is Y Combinator, which has grown to be an institution in itself.

The Table below contains a selected group of leading 30 accelerators that are active in the Valley today.

Table 32. Leading Silicon-Valley Incubators

500 Start-ups	ImagineK12 (Education)	RockHealth
AngelPad	Innovation Endeavors	SSE Labs
Blackbox.vc	Inveneo	StartL (Education)
Blue Print	Kauffman Labs	Sunfire Office
Dogpatch Labs	KickLabs	swissnex
First Floor Labs (AOL Ventures)	Matter.	Techstars
Founder Institute	Microsoft BizSpark	Teens in Tech Incubator
German Silicon Valley Accelerator	MissionSocial	Upwest Labs
Greenstart	Palo Alto Research Center	Y Combinator
i/o Ventures	PARISOMA	YouWeb Incubator

Source: Quora

Summary

Silicon Valley is the best example of a successful innovation ecosystem. The convergence of government, university, and industry factors has brought about a unique culture and innovation mentality. Once in place, the culture nurtures entrepreneurship and innovation in a virtuous cycle that feeds on the success of the entrepreneurs and companies of the Valley.

In terms of best that we take away from observing this thriving environment, we can identify the following:

Initial government funded research performed by commercial entities (lack of government involvement in the mature stage of the ecosystem):

- Strong university external drive in research, commercialisation, and industry partnerships
- Pro-active industry which is open to partnership with universities and other private entities
- Talent diversity mainly due to the immigration
- Flexible job market, where it is expected that people change companies frequently adding on to their skillsets in the process

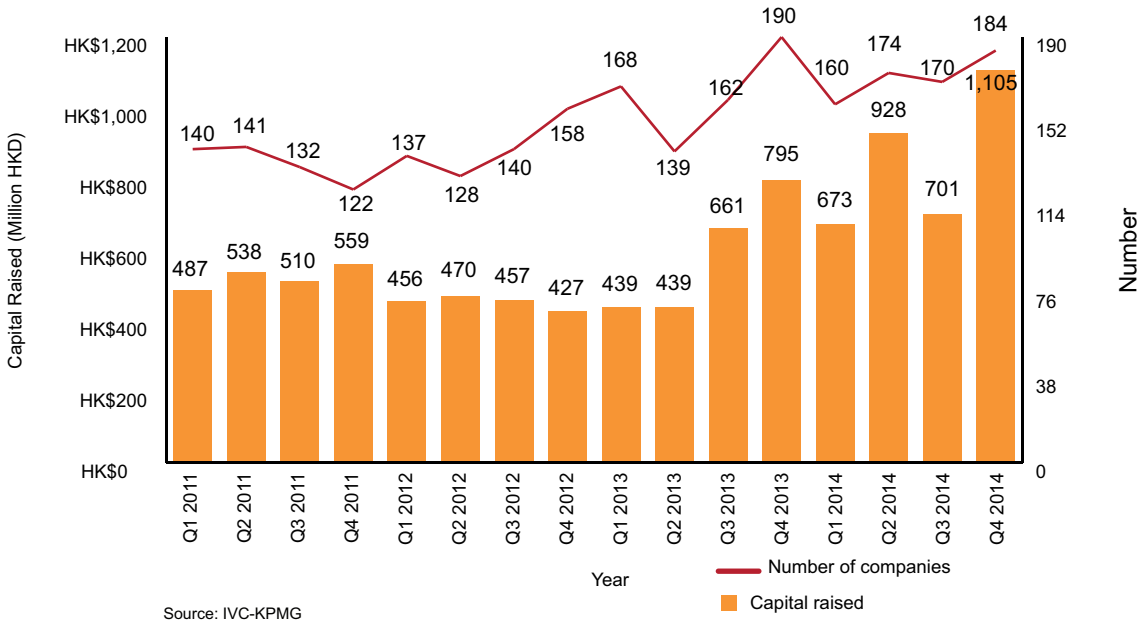
Israel

The most vibrant start-up ecosystem after the Silicon Valley is located in Israel. Below is an overview based on data from IVC Research Centre, an information provider on Israel's high-tech start-up scene and NoCamels.com, an online media outlet focused on innovation in Israel.

In 2014, 688 companies raised a total of US$3.4 billion. This Figure was 46% higher than in 2013, when 659 companies raised US$2.3 billion. The overall trend also shows that the average size of deals is increasing.

In Q4 2014 alone, 184 Israeli high-tech companies raised US$1.1 billion. This was much higher than the quarterly average of US$470 million over the past decade, and highest in a quarter since 1999.

Figure 29. Israeli High-Tech Capital Raises, 2011 - 2014



Source: IVC-KPMG

The number of IPOs and amounts raised in 2014 were highest in 10 years. There were 17 IPOs accounted for US$2.1 billion. However, there was eight IPOs which raised US$0.36 billion in 2013. The NASDAQ had 11 Israeli high-tech IPOs in 2014, in amounts ranging from US$35 million to US$150 million.

The two largest IPOs in 2014 were:

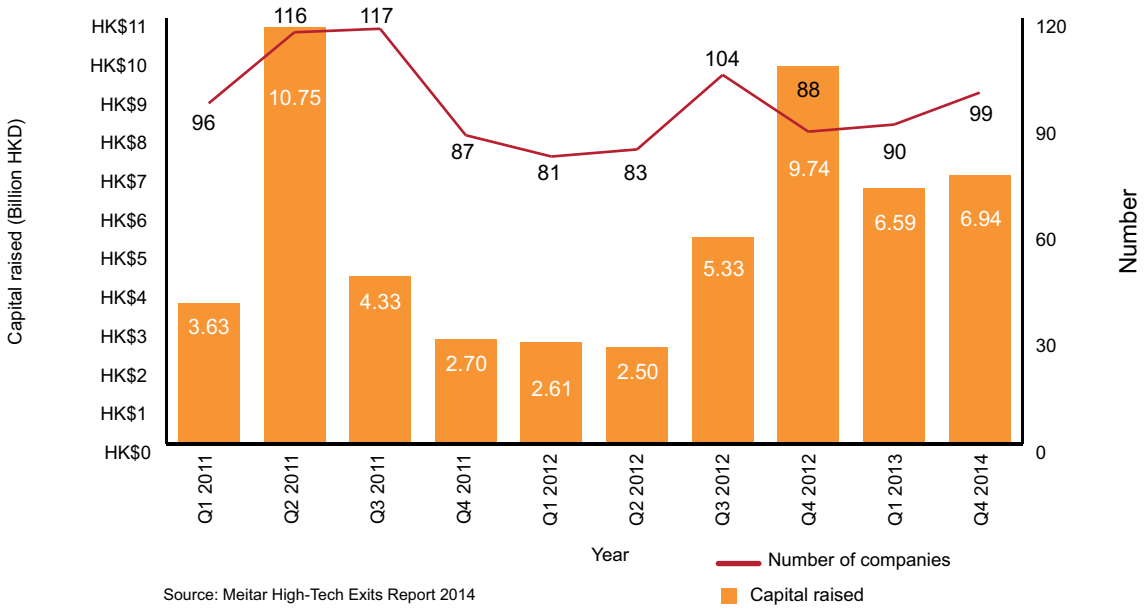
- **MobilEye,** a vision system that can prevent vehicle collision, was the largest IPO of an Israeli high-tech company in 2014, at US$890 million. It was listed on the NYSE.
- **SafeCharge,** an online payments solution provider, listed on London's AIM at US$125 million.

(Source: IVC-Meitar High-Tech Exits Report 2014)

In 2014, 99 Israeli companies sold for a total of US$6.94 billion, up 5% from US$6.59 billion in 2013.

There was also an increase in deals ranging from US$100 million to US$500 million. In 2014, there were 18 such exits, compared to 12 in 2013. This may indicate that more Israeli start-ups are able to scale, instead of selling their technology early on.

Figure 30. Israeli High-Tech Exits, 2011–2014



Source: Meitar High-Tech Exits Report 2014

Background

Israel is a place where citizens want to improve and succeed as a nation. The size of Israel–with a population of only 8.3 million–is such a small domestic market that start-ups start seeking international markets from day one.

As in the book Start-Up Nation (Senor and Singer, 2009) pointed out, cultural and historical conditions of Israel create a suitable environment for a start-up ecosystem to grow and thrive. Two factors were highlighted in particular:

A culture of assertiveness and flat hierarchies

The Israeli culture is one of doubt, argument and independent thinking, encouraging the questioning of authority in a reasonable manner. There is a perception of equal status, so hierarchies in most social settings, such as in a university or in the military, are very flat. These cultural traits align very well to the culture within start-ups.

1. Military training

Military conscription for all 18-year-old Israeli citizens has been credited as one of the most important contributors in the development of the start-up ecosystem. After the initial years of service, draftees become part of the military reserves and return once a year to the same unit for training. The system creates lifelong camaraderie and a meritorious culture. The military unit in which one served is an important fact on the resume that a recruiter would look at when recruiting for talents in Israel.

For elite units such as 8200, the Israeli Intelligence Corps' unit responsible for code decryption and cyber intelligence, it is a valuable lifelong alumni network. The EISP Start-up Accelerator is run by 8200 alumni using their network and resources to help early-stage start-ups.

2. Talent, Education and the Role of Universities

Israel has robust and prestigious university education and research institutions, and is especially strong in mathematics and the sciences. The top universities all have well-established technology transfer companies, the first one of which was founded as early as 1959. They are responsible for commercializing academic intellectual property into marketable products.

One successful story is MobilEye, a vision system that can detect obstacles around a vehicle and provide warnings to prevent collision, was first developed in 1999 by a professor at Hebrew University and was commercialised by Yissum, the university's tech transfer company. In August 2014, this company went for an IPO in the NYSE, raising US$890 million.

The achievements of Israeli technology transfer companies are quantified as:

- Each year, Israeli technology transfer companies generate US$250 million in royalties.
- 15 new companies are started each year based on academic inventions in Israel.

- US$25 million are invested by industrial companies each year in scientific research collaboration with Israeli universities.
- The technology transfer companies of Hebrew University (Yissum) and of Weizmann Institute (Yeda) are ranked top 10 tech transfer companies worldwide in terms of revenues.

(Source: Yissum 2011 presentation)

Today, top universities in Israel are creating entrepreneurship education and its science R&D leadership as a cultural export. Technion, the Israel Institute of Technology, has a partnership with Cornell University, set up in 2013, forming the Jacobs Technion-Cornell Institute located in New York City. Hong Kong's Hutchison Group companies also funded Technion to open a R&D centre at Shantou University, Guangdong Province.

Talents have also come from Israel's melting pot of immigrants. Entrepreneurs are risk takers, problem solvers and have to value persistence - all of which are part and parcel to the immigrant experience. More specifically, the fall of the Soviet Union brought an influx of immigrants, of whom one in three were engineers, scientists or technicians. The government's earliest incubator programs in the 1990s were started to stimulate the technology sector in order to provide jobs for these highly qualified immigrants.

The 2014 survey of entrepreneurs, co-authored by innovation scholars at Technion, Israel's Institute of Technology, also found that family played a significant role in cultivating talent in an indirect way (Source: Kon, Fabio and Cukier, Daniel and Melo, Claudia and Hazzan, Orit and Yuklea, Harry, A Panorama of the Israeli Software Start-up Ecosystem). Entrepreneurs reported that they imitated family members who were entrepreneurs, whether they were small business owners or tech entrepreneurs.

Incubators and Accelerators

Israel's tech incubators has its roots in the Yozma program of the 1990s, under which the government co-invested to create new funds, nurturing 300 projects that still exist and employ over 1,500 scientists today. Technology incubators are licensed through a competitive process and financially supported by the Office of the Chief Scientist (OSC). The licensed incubators can take pay only 15% of the approved budget for start-up funding. The other 85% is funded by the government.

This almost 6:1 ratio has been criticised as a high-risk program with questionable returns. However, there are success stories such as Waze, OSC lent US$1 million to the company and got US$3 million back. Other critics have even argued that the private venture capital industry no longer needs government support.

Meanwhile, several accelerator programs in Israel attempt to address the need for Israeli start-ups to reach global markets. Over one-third of US-based entrepreneurs are from India. In comparison, only less than 5% are Israeli. This is taken as an indication that Israeli entrepreneurs either do not found their start-ups in the US, or do not scale to the point where it makes sense for them to expand or relocate to the US.

- **UpWest Labs** is an accelerator program that runs for three months in Silicon Valley. At least one of the co-founders should be Israeli

- **IDC Elevator** features three months in Israel and one month in New York
- **DreamIt Ventures,** the Philadelphia-headquartered accelerator, runs a program in Israel, which features one month in Israel and three in New York

The above accelerators are general programs that accept tech start-ups in any industries. There are also vertical accelerators run by Microsoft Azure and Plarium Labs (focused on gaming).

Start-ups

This section features start-up exits through IPOs and through mergers and acquisitions. Start-ups are selected here to show their diversity and global nature. We also highlight early-stage start-ups in retail and other industries.

As Yaron Carni, founder of two Israeli VC funds told TechCrunch in January 2015:

"While there seems to be a general hype around IoT, security and fintech, I find Israel to be a very unique place in the fact that entrepreneurs don't tend to have group think and as such, we are seeing ventures tackling a very wide array of industries".

Table 33. Selected Start-up Exits via IPO and M&A

Category	Start-ups	Funding or Exit	Product, service and company background
Exits by IPO			
Automotive, vision, motion detection	Mobileye	US$890 million IPO on New York Stock Exchange, the largest ever for an Israeli company in a US stock market (Aug 2014) Goldman Sachs was involved in two previous funding rounds in 2007 and 2010, totaling $137 million.	A vision-based driver assistance system that gives warnings for collision prevention and mitigation. Founded in 1999 by Amnon Shashua, professor at Hebrew University, and businessman Ziv Aviram. Mobileye technology is already used in BMW, Hyundai, Kia and General Motors cars.
E-commerce	Borderfree	IPO on Nasdaq (Mar 2014)	Serves US retailers' global expansion by e-commerce. Operates a platform that takes care of international order lifecycle, including multi-currency pricing and payment processing, landed-cost calculation, customs clearance, global logistics and fraud management. Founded in 1999 by Israeli entrepreneur Yuval Tal.
Fintech	SafeCharge	US$120 million IPO on London AIM (Apr 2014)	Payment solutions for European betting companies.
Robotics	ReWalk Robotics	US$36 million IPO on Nasdaq (Sep 2014)	Robotic exoskeletons for paraplegics. Software included in the form of a backpack enables users to control robotic legs for walking, standing and sitting motions.

Table 33. Selected Start-up Exits via IPO and M&A

Category	Start-ups	Funding or Exit	Product, service and company background
Data management	Varonis	US$106 million IPO on Nasdaq (Mar 2014)	Founded in 2005. Data crunching, data protection and management software.
Exits by Merger or Acquisition			
Navigation	Waze	Acquired by Google for US$966 million in cash consideration (Jun 2013)	A community-based traffic and navigation app.
Security	Trusteer	Acquired by IBM for close to US$1 billion. (Aug 2013)	Founded in 2006. Technology investigates source of malware attack incidents to predict future attacks.
Mobile	Onavo	Acquired by Facebook for US$120 million. The start-up's Tel Aviv office became Facebook's first office in Israel. (Oct 2013)	Founded in 2010, Onavo provides analytics that enable mobile publishers to track how their own apps are performing, and compare against competitors. Also provides consumer-facing apps optimizing device performance and battery life.
Internet of Things, Connected Car	Red Bend Software	Acquired by HARMAN International Industries, the American audio and infotainment equipment company, for US$200 million (Jan 2015).	Founded in 1999, entered the automotive market in 2010. Leader in over-the-air programming and cyber security. Technology hooks cars up to the Internet.
Mobile messaging	Viber	Acquired by Rakuten, the Japanese e-commerce giant, for US$900 million.	Founded in Cyprus by Israeli entrepreneur Talmon Marco, who had served as chief information officer in Israeli Defense Forces central command in the 1990s. The app had 300 million users at the time of acquisition.
Early-stage Start-ups: Retail-related			
Augmented reality	Cimagine	US$2 million funded by OurCrowd, Plus Ventures, Titanium and 2B-Angels	A virtual fitting room for furniture and interior design. Augmented reality software allows users to see how a piece of furniture would fit into a room. User can move around the virtual furniture or change the color of the furniture. Currently piloting in the e-commerce site of UK retailer Shop Direct.
Retail—Gifts	Jifiti	Raised US$3.5 million so far	Users can capture tangible products in stores and turn them into digitally transmittable gift cards. Recipients of the digital gift card have the option to visit the store to select size or other customization. Customers include Sears, Ikea and Kmart.

Table 33. Selected Start-up Exits via IPO and M&A

Category	Start-ups	Funding or Exit	Product, service and company background
Retail – Pricing intelligence	Wiser	Undisclosed funding rounds. Backed by 500 Start-ups, an early stage seed fund and incubator.	Founded in 2012 by Israeli entrepreneurs in San Francisco. Technology that crawls the world's pricing databases (15 million price points) to provide intelligence and pricing tools. Brands using Wiser's pricing engine can adjust their listings based on demand and competitor pricing.
Early-stage Start-ups: Other Industries			
Navigation, Crowd-sourcing	Moovit	Series C funded for US$81 million.	Free local public transit planner. Uses GPS navigation, provides live arrival and departure times for buses, trains, ferries and rapid transit. Available in 500 cities around the world.
Security, FinTech	BioCatch	Series A funded for US$10 million. Investors include OurCrowd.	Biometric authentication and threat detection. Tracks 400 biometric indicators and psycho-social behaviors to enable banks and ecommerce companies to stop online frauds before they happen. (IBM Trusteer mentioned above is a competitor.)
Electric cars, mobile, nano-biology	StoreDot	Series B funded for US$42 million. Raised US$58 million so far. Investors include Israeli VC Singulariteam and Russian businessman Roman Abramovich.	Uses bio-organic peptide molecules to create batteries that recharge in minutes and retain their power many times longer than currently available technology. Founded in 2012.

Summary

The Israel ecosystem has developed based on the culture of values and vision that was brought about by the convergence of government, university, and industry.

In terms of best that we take away from observing this environment, we can identify the following:

- Clear government vision and strategy in support of the innovation ecosystem
- Active university drive to partner with industry and government programs
- Cultural idiosyncrasies such as military training and upbringing can be key tools to support the building of an innovation culture

Other Success Stories

Other successful international models include the following.

Strategic partnerships between fast-growing companies and R&D institutions, universities, anchor companies, and other growing companies.

- In **Finland**, large companies applying for funding from the Funding Agency for Technology and Innovation (Tekes) must acquire research services from universities, research institutions or SMEs. As a result, Tekes funding requires the formation of concrete collaborative processes and strategic partnerships between large companies, SMEs and/or research institutions
- **Belgium's** strategic research centres bear the responsibility for initiating

joint R&D platforms with academia and industry in specific sectors. Mechanisms to encourage collaboration include joint R&D projects and the exchange of researchers across organisations

- **Taiwan** features a network of Core-Satellite development centres that involves MNCs ("core" manufacturers) in supporting SMEs ("satellites") in increasing their capacity and to connect them to global markets. Both core and satellites receive incentives from the government to encourage cooperation

Public sector mechanisms to attract large companies and encourage their participation the development of the ecosystem

- **Finland's** strategic centres for Science, Technology and Innovation recruit leading companies within various industries to cooperate on a common research agenda and programs, and they then ask the public funding agencies to carry a portion of the cost.
- The **South Korean** government has attracted large companies by offering large investments to create national flagship infrastructure (e.g., "science towns"). These anchors provide technology development resources for private industry, with the aim of creating the critical mass in I&T activities at certain locations, supported by sizable public investment.
- **Singapore's** government has held an open dialogue with foreign MNCs and asked them to relocate their Asian business subsidiaries in Singapore. The government further launched several incentive programs (e.g. tax cuts and investment credits) to attract investors.

Mechanisms to encourage long-term cooperation between universities and industry in creating ideas for innovative products and services and to develop and execute applied research plans

- **Finnish** universities and enterprises have launched co-working environments called "factories," which based on domestic research products to coordinate the creation of generation of ideas in order to solve real business problems and effect social change.
- Strategic centres in **Finland** for Science, Technology and Innovation create platforms for companies, universities and research institutes to create common research goals, in order to meet the needs of industries over a five-to-ten year timeframe. The groups find a consensus on common research themes and then ask the Finish funding agency, Tekes, to cover funding level of up to 60% of the project's needs.
- The **Belgian** government has improved its "bridging institutions" (science parks, incubators, and other facilities) which aims to create better results at higher education institutions and at research groups. These groups focus on providing tangible support to companies in order to solve technical problems, develop new products and services, and assimilate new technologies and train knowledge workers.
- Strategic research centres in **Belgium** are holding "industry affiliation programs" to include MNCs in areas of advanced research that have been identified to run three to ten years ahead. Four centres receive have received more nearly US$200 million in annual public funding. IMEC is the largest, with Europe's largest R&D field R&D centre, with more than over 2,000 employees, with a budget of approximately US$360 million, of which more than 80% derives from contract research.
- **Chinese** government encourages universities and research institutes to commercialise intellectual property rights by allowing universities to launch for-profit equity ventures. Universities have the right to open

office for technology transfer using their own resources and treat the entities as businesses.

Cooperation and synergy with other countries' R&D efforts

- **Israel's** Bi-national Industrial R&D Foundation program provides funds to R&D cooperation between US and Israeli firms
- **Taiwan's** government has created links between Hsinchu Science Park and Silicon Valley in order to encourage skilled technology workers to resettle in Taiwan

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