



Innovation and government intervention: A comparison of Singapore and Hong Kong

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ABSTRACT

Government is one of the determinants for innovation capacity although its role and degree of involvement in innovation is debatable. Government intervention can be vital in supporting R&D and innovation as market alone cannot provide adequate incentives for knowledge production. Degrees of government intervention, however, vary in different economies and range from directive intervention by actively advising industrial policy and investing in selected areas, to facilitative intervention by creating positive environment and providing public goods for industry. This study uses Singapore and Hong Kong as two cases to explore the influence of government intervention on innovation performance. Singapore is known for strong government intervention while Hong Kong is famous for its positive non-intervention policy that minimizes the power of government in influencing the market. The comparison shows that innovation activities in Singapore are largely policy driven and dominated by big players, while in Hong Kong industry innovation is less active but the local industry has a dynamic innovation base contributed by small firms. Using a difference-in-differences analysis of USPTO patents filed by Singapore and Hong Kong, we find evidence for the effectiveness of government intervention on enhancing the technological significance and scope of innovation. The findings could shed light on the implication of government involvement in innovation.

1. Introduction

Government is one of the determinants for innovation capacity according to the National Innovation System theory (Nelson, 1993) and the Triple Helix theory (Etzkowitz and Leydesdorff, 2000). While it is generally agreed that a capable government is important, how government should function is still debatable, especially the role it should play and the way it could get involved in innovation. The debate has been going on for decades with no consensus in sight, partly due to the difficulties in assessing the impact of government intervention on innovation performance given the presence of various confounding factors. The study intends to move the discussion forward by using Singapore and Hong Kong as two cases for comparison and probe the relationship between government intervention and innovation performance. Singapore is known for high level of government intervention in various aspects of society (Mok, 2005). By contrast, Hong Kong adopts a “positive non-intervention” policy that favors free economy and minimizes the power of government in influencing the market. They represent two streams of the views on the role of the government and are perfect examples for illustration. The comparison of innovation activities and performance could shed light on the implication of government involvement in innovation.

2. Role of the government

The debate over the ideal role of government in economy seems to be polarized between neoliberalism favoring market-led development and statism favoring government intervention (Yeung, 2000). The free market neo-classical theory argues that the state should refrain from intervening in the market and let Adam Smith’s invisible hand solve economic problems. Government interventions will distort the market and lead to deadweight loss because of inefficient resource allocation and possible corruption. By contrast, state-centered theory argues that the state should play a more strategic role in “taming market forces and harnessing them to a national economic interest” (White and Wade, 1988). The economic success in Asian Newly Industrialized Countries (NICs) is often cited as evidence of the contribution of direct state intervention (Appelbaum et al., 1992; Wade, 1990). In the arena of innovation policy, the market failure concept is also applied to justify government support for science and technology (Arrow, 1962; Nelson, 1959). It is argued that the market alone fails to provide enough incentives for knowledge production. The knowledge inappropriability and uncertainty in obtaining returns for long-term commitment often lead to firms’ under-investment in R&D, which calls for impetus from the public sector (Martin and Scott, 2000). In addition, the

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Table 1
R&D activities in the business sector in 2012.
Source: Data are compiled by the author (ASTAR, 2013; C&SD, 2014, 2015a,2015b; DOS 2015).

Industry	HK			SG		
	GDP (in USD)	R&D expenditure (in USD)	R&D exp/GDP	GDP (in USD)	R&D expenditure (in USD)	R&D exp/GDP
Manufacturing	\$3.9B (1.5%)	\$43.5 M (5.1%)	1.1%	\$55.2B (19.4%)	\$2,214.8 M (60.2%)	4.0%
Import/export, wholesale and retail trades, accommodation and food services	\$7.6B (29%)	\$321.2 M (37.7%)	0.4%	\$60.3B (21.2%)	\$448.8 M (12.2%)	0.7%
Information and communications service	\$9.1B (3.5%)	\$265.0 M (31.1%)	2.9%	\$11.1B (3.9%)	\$125.1 M (3.4%)	1.1%
Financing, insurance, real estate, professional services	\$7.2B (27.4%)	\$170.0 M (19.9%)	0.2%	\$74.5B (26.2%)	\$853.5 M (23.2%)	1.1%
Others	\$100.8B (38.6%)	\$52.8 M (6.2%)	0.1%	\$83.3B (29.3%)	\$36.8 M (1.0%)	0.0%
Total	\$261.2 B (100%)	\$852 M (100.0%)	0.3%	\$284.4 B (100%)	\$3679 M (100%)	1.3%

development of some technology involves high cost that is beyond the financial and technical capability of most private firms and requires government assistance (Link and Siegel, 2007). By contrast, critics of market failure theory argue that there is no clear cut standard to identify market failure and assess when the government should intervene (Demsetz, 1969). The cost of corrective government action may be higher than the potential gains. In addition, it is warned that bureaucrats are less capable to identify opportunities and pick the winners if they are not familiar with the industry. Government allocating resources to selectively support some industries and enterprises is likely to put other industries and enterprises at a disadvantage (Joseph and Johnston 1985).

Along with the debate, other suggestions were made to lay aside the dichotomy of markets and states. Instead, there should be multiple forms and organizations of economy, where state intervention is only a matter of degree (Yeung, 2000). Most government intervention takes on two types: directive intervention – which aims to achieve pre-determined results by making changes in investment and production patterns in selected industries; and facilitative intervention – which aims at creating positive environments for private enterprises by providing public goods such as infrastructure and education (Luedde-Neurath, 1988). The directive government participates in picking winners as they believe some industries and products are more important than others and therefore strategically concentrate capital in these industries. For example, in promoting high tech economy, government provides R&D funding, sets up public research facilities, and assists transfer of the result to private sectors. The facilitative government attempts to promote innovation by constructing institutions conducive to fostering a healthy culture and by aiming policies at overcoming obstacles to private investment in innovation instead of directly influencing the innovation behavior through highly interventionist measures (Sharif and Baark, 2009).

Despite the ample discussions on the role of government, empirical studies testing the relationship between the level of government intervention and innovation are still scarce. Existing studies are generally focused on particular policy instruments ranging from fiscal interventions such as R&D subsidies, R&D contracts, tax incentives and public procurement, to non-fiscal intervention such as infrastructure, professional service, and regulations. The most studied instrument is direct R&D subsidy and tax credit (Aerts et al., 2004; Almus and Czarnitzki, 2003; David et al., 2000; Hall and van Reenen, 2000; Martin and Scott, 2000) as it is easily quantifiable and is expected to have the most straightforward contribution to the output. Scholars have also looked into other innovative outputs such as patents, new products or process, and sales of new products, or long term outcomes on firm performance, such as sales, employment, productivity and profitability (Chudnovsky et al., 2006). However, very few studies have taken government intervention as a whole and assessed its overall impact on innovation, which is difficult because of the complexity of national innovation system, the variance across regions in the country, and the mixed roles of government at different levels. Singapore and Hong Kong, both being

city economies with a single government and no regional disparity, make them ideal cases for the purpose to examine the overarching impact of government intervention. Therefore, this study intends to fill in the gap in the literature by exploring the relationship between the level of government intervention and innovation performance.

3. Methodology and data

The study uses Singapore and Hong Kong as two cases to compare the role of government and innovation. Singapore and Hong Kong are often compared with each other due to their similarities in history, size, population, the lack of natural resources, as well as their economic performance and competitiveness (Young, 1992). However, the differences in these two city-states are also noticeable, one of which is the role of the government. Singapore is well known for its strong government and long history of government intervention in economy. The government has directed the economic upgrade from labor intensive industry to technology intensive industry. In the recent decade, the government is actively promoting R&D and innovation activities and tries to transform Singapore into an innovation-led economy. By contrast, Hong Kong is known for the laissez-faire capitalism with the characteristics of non-interventionism and later positive non-interventionism. The government keeps a low public budget and has a limited role in the market. While Hong Kong also intends to stimulate innovation by setting up innovation fund, the effort is rather small in both scope and scale. For example, the Singapore government provided US\$2.3 billion (S\$2.7 billion) for R&D in 2012, accounting for 0.8% of GDP (Table 1.6 in ASTAR, 2013).¹ In the same year, the Hong Kong government financed US\$0.9 billion (HK\$ 6.8 billion) for R&D, which was only 0.3% of GDP (C&SD 2013; Chart 1.1). Given the similarities and differences, Singapore and Hong Kong are interesting cases for comparison.

The two cases are compared using two approaches. The first approach is to profile the innovation activities in these two regions, including innovation output, research areas, and innovation performers. The second approach uses a natural experiment design and takes the local industry in Singapore as a focal point to analyze the impact of government intervention, with foreign companies and Hong Kong as counterfactuals. The pre- and post-intervention comparison of the local industry performance in Singapore is only valid when compared with the foreign industry (less influenced by the intervention) and the industry in Hong Kong (with minimal government intervention). As elaborated below, the national strategy of development moves from relying on MNCs in the 1980s, to encouraging R&D activities starting

¹ The currency Singapore Dollar was converted to US Dollar based on the Foreign Exchange Rates in the respective years published by the Monetary Authority of Singapore (<http://www.federalreserve.gov/releases/h10/hist/>). The currency Hong Kong Dollar was converted to US Dollar based on the fixed exchange rate of US\$1 = HK\$7.8 as published by the Hong Kong Monetary Authority (<http://www.hkma.gov.hk/eng/key-functions/monetary-stability/history-hong-kongs-exchange-rate-system.shtml>).

from the 1990s and to emphasizing local R&D capacity since mid-2000s. During the latter two periods, various policy instruments appeared that target local businesses. The fact that only local firms are eligible for most R&D support allows us to test the impact of government intervention in a natural experiment setting, where the local industry in Singapore is the treatment group while the foreign firms in Singapore and Hong Kong industry are used as two control groups.

This paper uses patents granted by the United States Patent and Trademark Office (USPTO) as a measure of innovation output. As both Singapore and Hong Kong are small economies with limited domestic markets, the US is the major targeted overseas market and USPTO is the largest patent filing office. We retrieved the USPTO patent data from PATSTAT database in July 2015 for both Singapore and Hong Kong by searching the inventor country field. Inventor country is used as the location of innovation as it reflects where the innovation occurs. For patents with multiple inventors, every country is counted, with a higher sum of patents by country than the total tally. For example, if the patent has inventors from Singapore and Hong Kong, it is counted as one patent for Singapore and one patent for Hong Kong. The data was then manually checked for accuracy and the fields for inventors and applicants cleaned, including names, sector, and country. For the field of inventor/applicant name, we looked into the relationship between firms with similar names and grouped the subsidiaries under the parent company. For example, patents filed under different names, such as ExxonMobil Chemical Company, ExxonMobil Chemical Patents Inc, Exxon Research and Engineering Company, and ExxonMobil Oil Corporation, were all assigned to the parent company ExxonMobil Chemical Company. Typos such as “Exxonmoil” and other variations in spelling were also corrected. The field of inventor/applicant country was updated to reflect the location of headquarter for MNCs. Despite the fact that patents may be filed by the local office in either Singapore or Hong Kong, we still use the headquarter country to reflect the fact that it is a foreign company, so as to better differentiate with local domestic firms. For example, patents filed by GE Aviation General Operations in Singapore were grouped to its parent company General Electric in the US and the applicant country was changed from Singapore to the US. In addition, some companies registered in Cayman Islands, Virgin Island and Bermuda with their applicant country as KY, VI and BM in the PATSTAT database were reassigned to the country out of which they operate. For example, Marvell Technology Group was founded in Hamilton, Bermuda and has office locations in over ten countries/regions. Since its operation headquarter is based in Santa Clara California, we replace KY with US in the applicant country field.

4. Role of government in Singapore and Hong Kong

The Singapore government has been actively involved in the economic development of the nation. In the 1980s and 1990s, foreign investment was a top government priority and great efforts were made to attract multinational companies (MNCs) to set-up their R&D centers in Singapore to facilitate technology transfer and diffusion to local enterprises (Wong, 2001). In the late 1990s, to overcome the vulnerability of over-reliance on foreign capital and lack of indigenous entrepreneurship and innovation (Yeung, 2000), the government started a series of five-year national plans on science and technology, and set up a Technopreneurship Innovation Fund to promote high tech entrepreneurship by co-investing in new businesses with venture capitalists (NRF, 2015) (Fig. 1). A cabinet-level organization Research, Innovation and Enterprise Council (RIEC) was launched in 2006 to advise Singapore's R&D strategies and policies. In 2008, the National Research Foundation (NRF), founded to support RIEC and encourage greater innovation, launched the National Framework for Research, Innovation and Enterprise to encourage technology commercialization. The Science and Technology 2010 Plan aimed to strengthen the foundation for R&D with a budgeted US\$9 billion (S\$13.55 billion) and this commitment in R&D was bolstered by another five-year RIE 2015 Plan with US

\$12.4 billion (S\$16.1 billion). A series of support schemes have been introduced by various agencies to promote the innovation capabilities and development of local firms (See Appendix A). The support schemes range from financial assistance directly to the local companies or indirectly through incubators, to initiatives promoting collaboration and talent development. All the initiatives clearly require the target companies to be local establishments. Some schemes were discontinued in 2017, but are likely to be re-designed under the new RIE2020 plan in the next five years, which will continue to selectively support some priority areas for national needs, and assist local firms in R&D (Teo, 2015).

In comparison, Hong Kong sees less active industrial policy. State intervention varies in different periods of time. In the 1960s and 1970s, due to the limited financial resources and conservative nature of the state, Hong Kong was regarded as laissez-faire capitalism with non-interventionist economic philosophy and low public expenditure. Starting from the 1980s, Hong Kong government, while making no resource allocation, responded to industries with regulations. After sovereignty change in 1997, the government, under pressure to perform, became more interventionist oriented (Cheung Anthony, 2000) and proactive in promoting innovation and technology commercialization (Yam et al., 2011). In 2000, the Innovation and Technology Commission (ITC) was set up to encourage innovation and technology development (Fig. 1). It established up five R&D centers in 2006 to drive industry-oriented R&D and facilitate commercialization. A similar cabinet-level organization – the Steering Committee on Innovation and Technology was founded in 2004 to coordinate innovation policies and activities. Financial support for innovation comes from the Innovation and Technology Fund (ITF) that was set up in 1999 with US\$0.6 billion (HK\$5 billion) and is managed by ITC (ITC, 2015). These initial efforts, however, were not further supplemented by other initiatives and resources. Government investment in R&D remains modest with the majority of government funding going to universities and research institutes, while the business sector is largely left to itself for R&D financing (Fig. 2).

5. Innovation in Singapore and Hong Kong

The size of R&D activities in Singapore is much bigger than that in Hong Kong. Not only are there more R&D personnel in Singapore in 2011, its R&D expenditure in 2012 was US\$4.1 billion more than Hong Kong's, accounting for 2.1% of GDP (ASTAR 2013) compared to Hong Kong's 0.73% (C&SD, 2013). In Singapore, 61% of R&D was performed by the industry, mainly manufacturing, followed by universities and research institutes (29%), and government institutions (10%). In Hong Kong, universities and research institutes outperformed the industry, accounting for 51% of R&D expenditure. Industry and the government sector (mainly public technology support organization) contributed 45% and 4% respectively. Trade, accommodation and food service, and finance dominated Hong Kong's industry sector, accounting for 88% of R&D personnel in the industry and 89% of business R&D expenditure. The role of manufacturing industry in innovation is quite minimal with 5.7% of R&D personnel and 5.1% of R&D expenditures (C&SD, 2014). This can be attributed to the difference in the industrial structure in these two regions. In Singapore, manufacturing, retail/trade and financial services have similar contributions to the GDP, accounting for 20–26% each (Table 1). By contrast, the economy in Hong Kong is dominated by the service industry, with a negligible role for manufacturing (1.5%). The high cost in labor and land in the 1980s had resulted in the relocation of a huge portion of the manufacturing industry to mainland China, especially in the Pearl River Delta area adjacent to Hong Kong (Yam et al., 2011), threatening the development of Hong Kong's manufacturing industry and transferring much of the R&D activities to mainland China (Huang and Sharif, 2009).

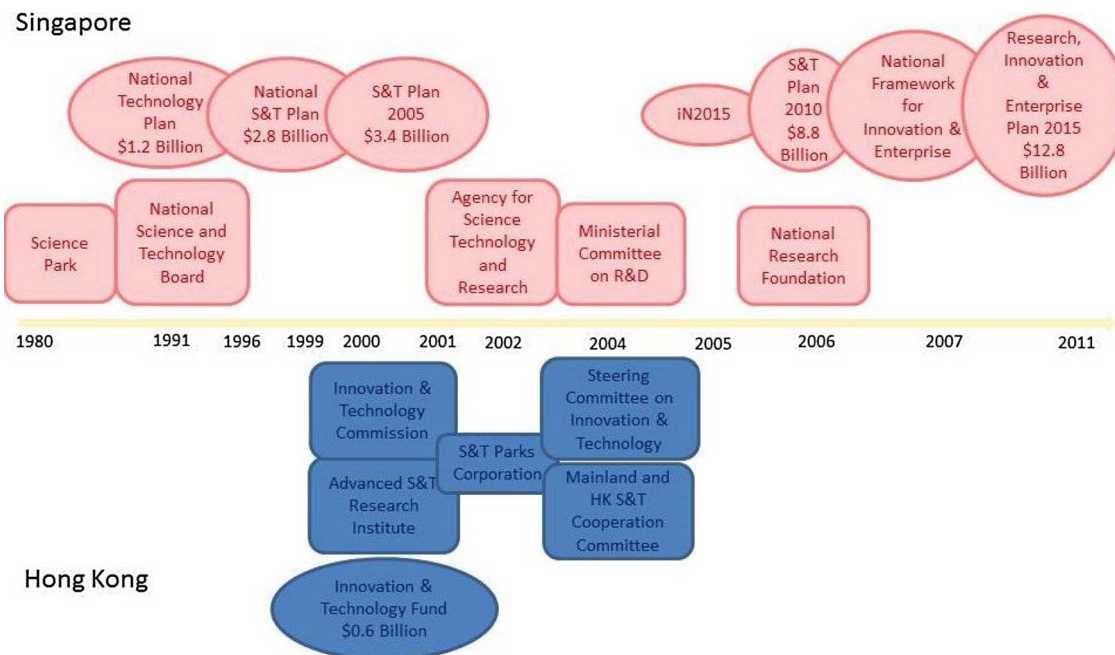


Fig. 1. Innovation initiatives in Singapore and Hong Kong.

5.1. Patent counts

The number of patent applications at USPTO increased for both Singapore and Hong Kong, but at a different pace. The number of USPTO patent applications was comparable until the mid-1990s, with Singapore lagging a bit behind. Starting from 1995, Singapore overtook Hong Kong and the gap has been particularly enlarged since 2004. With an annual increase of 8% on average, patent applications in Singapore reached 1636 in 2012. Patenting activities seemed stagnated in the same period for Hong Kong, with 752 applications in 2012, less than half the number in Singapore. While the same trend is observed for patent grants, with Singapore surpassing Hong Kong rapidly since 2004, the difference is not that big. Singapore has only 33% more patent grants than Hong Kong in 2012. A further investigation of patent kind shows that the composition of patents is different in these two regions. While patents filed by Singaporean inventors were predominantly utility patents, Hong Kong inventors were equally interested in utility patents and design patents. Starting from 2001, half of USPTO patents in Hong Kong were design patents. A comparison of utility patents only shows a trend similar to the patent application data but with an even more striking contrast. Singapore surpassed Hong Kong in 1995 with a growing gap that reached its maximum in 2008, when Singapore had 2.75 times the patents in Hong Kong. Given that utility patents have a higher standard for innovation, the analysis in the rest of the paper refers to utility patents only.

5.2. Research areas

Innovation output in Singapore is highly concentrated in selected fields. Electronics and ICT, sectors that Singapore has been promoting since the 1980s, yield 57% and 32% of total patents respectively (Fig. 3), which is similar to the overall patenting trends in USPTO in recent years (USPTO, 2017). In Hong Kong, the fields of patents are more dispersed. The leading category of patenting is human necessities (31%). Electronics (30%) and ICT (27%) are the other two active categories, which is similar to Singapore. Both Singapore and Hong Kong have planned for the preferred areas of innovation. In Singapore, in 2006, Strategic Direction for S&T Policy 2006–2010 identified two new strategic areas for R&D: environmental and water technologies (clean water and clean energy), and interactive and digital media. Similarly in 2006, the ITC in Hong Kong set up five R&D centers to drive and coordinate applied R&D in five focus areas: automotive parts and accessory systems; information and communications technologies; logistics and supply chain management enabling technologies; nanotechnology and advanced materials; and textiles and clothing. The areas are highlighted in red (for Singapore) and blue boxes (for Hong Kong) in Fig. 3. It is interesting to note that innovation in Singapore is responding strongly to the government initiatives with patenting activities being rather coordinated and concentrated in the strategic areas, while in Hong Kong it is less obvious.

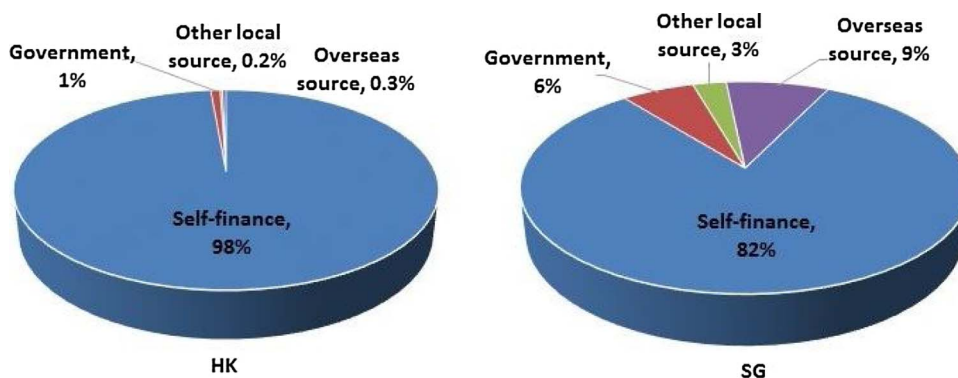


Fig. 2. Sources for R&D expenditure in the business sector in 2012. Source: Data are compiled by the author (ASTAR 2013; C&SD 2013)

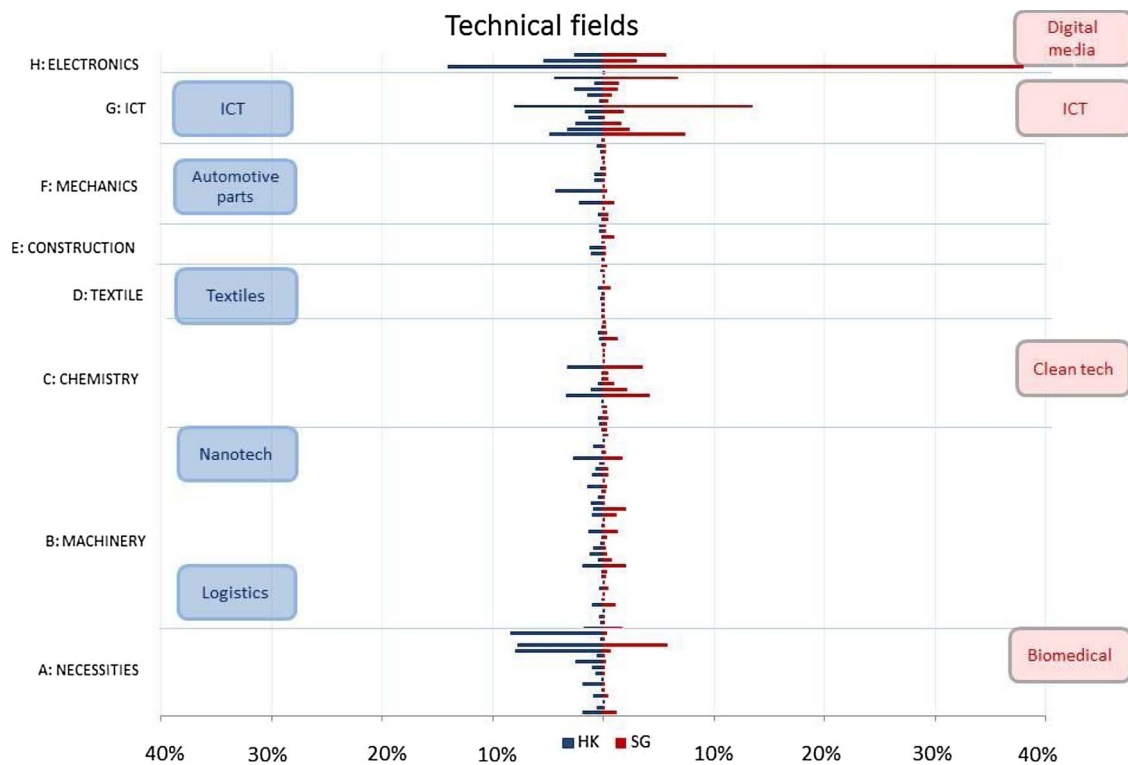


Fig. 3. Fields of patents and research priorities.

5.3. Research performers

The patent applicant profile shows that 84% of USPTO patents with Singaporean inventors were from industry, 7% from universities, and 7% from research institutes. Individuals (not co-filed with institutional partners) contributed 5%. All the top patent applicants were companies in the semiconductor and electronics industry except for two public research institutions (Table 2). MNCs contributed 69% of industry patents in Singapore and constituted six out of ten top patent holders. The only two local innovators on the top patent assignees list, Chartered Semiconductor and STATS ChipPAC, have obvious connections with the Singapore government through their status as state-owned enterprises or government-linked companies (GLCs). The link to the government can also be found in some other leading local innovators, such as those marked with an asterisk in Table 3. A total of 540 local companies have been granted USPTO patents, with top ten companies contributing 75% of patents filed by local industry (Table 3). In Hong Kong, universities produced 9% of patents and research institutes 4%. They accounted for six of the top ten patent assignees. Three local firms and one US firm made up the rest (Table 2). The industry sector filed 4098 patents (i.e.,

67% of total patents), half of which came from local firms with the other half from MNCs, mainly US, followed by China (mainland) and UK. Innovation activities are more spread out, with 1348 local companies being granted patents and the top ten companies accounting for only 26% of the local industry patents (Table 3). Surprisingly individuals in Hong Kong are quite enthusiastic in filing patents. The share of patents filed by individuals with no institutional assignees was as high as 18.9% and the proportion was still increasing in most recent years. It is likely that some individuals are small entrepreneurs but choose not to file under the names of the companies. Cross sectional collaboration is not common in both regions. In Singapore, only about 12% of patents in universities and 10% of patents in government institutes are co-filed with industry partners. In Hong Kong, the share is much lower with only 3% and 1% respectively.

6. Industrial innovation performance

The differences between innovation activities in Singapore and Hong Kong might be confounded by various factors unique to these two economies. Therefore, we adopt a difference-in-differences approach to

Table 2
Top ten Patent Assignees in Hong Kong and Singapore.

HK Assignee			SG Assignee			
	#	%		#	%	
1	Hong Kong Applied Science and Technology Research Institute (HK)	189	3%	Chartered Semiconductor Manufacturing (SG)	968	9%
2	Hong Kong Polytechnic University (HK)	159	3%	STATS ChipPAC (SG)	796	7%
3	Hong Kong University of Science and technology (HK)	151	2%	Agency for Science Technology and Research (SG)	729	7%
4	SAE Magnetics (HK)	148	2%	Micron Technology (US)	377	4%
5	City University of Hong Kong (HK)	93	2%	Seagate Technology (US)	358	3%
6	Asm Assembly Automation (HK)	82	1%	National University of Singapore (SG)	355	3%
7	Astec International (US)	77	1%	Hewlett-Packard (US)	301	3%
8	Chinese University of Hong Kong (HK)	69	1%	STMicroelectronics (Switzerland)	294	3%
9	Johnson Electric (HK)	69	1%	Panasonic Corporation (Japan)	287	3%
10	University of Hong Kong (HK)	64	1%	Globalfoundries (US)	240	2%
	Sum of top ten	1099	18%	Sum of top ten	4619	43%
	Total patent counts	6147	100%	Total patent counts	10,685	100%

Table 3
Top ten local firms, patent counts and share in local industry patents.

	HK Local Assignee	#	%	SG Local Assignee	#	%
1	SAE Magnetics	148	7%	Chartered Semiconductor Manufacturing*	968	35%
2	ASM Assembly Automation	82	4%	STATS ChipPAC*	796	29%
3	Johnson Electric	69	3%	Creative Technology	110	4%
4	ASAT	53	3%	TriTech Microelectronics*	56	2%
5	Wonderland Nurserygoods	48	2%	United Test & Assembly Center	43	2%
6	Defond Manufacturing	36	2%	Trek 2000 International	30	1%
7	Silverlit Toys Manufactory	34	2%	ST Engineering (ST)*	21	1%
8	The Sun Lock Company	25	1%	Systems on Silicon Manufacturing Company*	21	1%
9	VTECH Electronics	25	1%	Advanpack Solutions	20	1%
10	World Wide Stationery Manufacturing	24	1%	E-Book Systems	19	1%
	Sum of top ten	544	26%	Sum of top ten	2084	75%
	Total local industry patents	2056	100%	Total local industry patents	2784	100%

isolate the marginal effect of the government intervention to the industry. In Singapore, the government has gradually moved the priority from MNCs to local industry since the 1990s and introduced various policy instruments targeting only local firms (see the eligibility requirement in the Appendix A). It is reasonable to assume that the local industry is benefiting more from the government support and the benefit increases over time with the augmented government budget on R&D. If these policy instruments are effective, the innovation performance of the local industry in Singapore should improve more than its foreign counterparts in the country and we could expect to see a reduced gap between the local and foreign industry in the recent decades. By contrast, as no substantial government intervention targeting the local industry is observed in Hong Kong, both local and foreign firms are facing the same global and local economic challenges and should experience a similar pace of development. It is expected that the difference between local and foreign industry in Hong Kong remains the same over time. Data used in this part of analysis is restricted to patents granted to industry only.

6.1. Dependent variables

We use two patent related innovation measures proposed by OECD (Squicciarini et al., 2013): technological significance and technological scope (Table 4). The two indicators used are forward citations and patent subclass classifications. Patent forward citation is often used to indicate the technological significance (Singh and Fleming, 2010), as well as the subsequent economic value (Trajtenberg, 1990) or the organizational market value (Hall et al., 2005). Technological scope is measured by the number of distinct 4-digit subclasses of International Patent Classifications (Squicciarini et al., 2013). A patent with more subclasses implies a broader technological scope (Jung and Lee, 2014) and more diverse underlying ideas (Guelllec and van Pottelsberghe de la

Table 4
Variable descriptions.

Variables	Description
Citations	Number of forward patent citations
IPC4_Count	Number of distinct 4-digit IPC subclasses
Local	1 if the patent assignee is a local firm; 0 if not
Phase_2	1 if the patent's priority filing was in 1997–2006; 0 if not
Phase_3	1 if the patent's priority filing was in 2007 and onwards
Local × Phase_2	Interaction term: Local × Phase 2
Local × Phase_3	Interaction term: Local × Phase 3
Technology field	A set of dummy variables for the 1-digit IPC code
IPC_H	1 if the patent has an IPC code of H; 0 if not
IPC_G	1 if the patent has an IPC code of G; 0 if not
IPC_B	1 if the patent has an IPC code of B; 0 if not
IPC_C	1 if the patent has an IPC code of C; 0 if not
IPC_A	1 if the patent has an IPC code of A; 0 if not
IPC_F	1 if the patent has an IPC code of F; 0 if not
IPC_E	1 if the patent has an IPC code of E; 0 if not

Potterie, 2000), which affects the technological and market value of the patent (Squicciarini et al., 2013) and subsequently the valuation of the firm that owns the patent (Lerner, 1994). It is also more likely to lead to new firm formation by providing technological opportunities with broader intellectual property protection (Shane, 2001).

In general, there is no substantial difference between Hong Kong and Singapore on these two indicators. The average citation count of industry patents is 12.39 for Hong Kong and 11.85 for Singapore, while the average count of 4-digit IPC subclasses is 1.47 for Hong Kong and 1.42 for Singapore (Table 5). The difference in mean citations between Hong Kong and Singapore is not significant as local firms in Singapore outperform their counterparts in Hong Kong but foreign firms score lower. The difference in IPC counts is significant but rather small. In both regions, foreign firms are performing much better than local firms.

6.2. Independent variables

The main independent variables are the indicator for local firms and the ones for the three phases of policy intervention. The local firm indicator *Local* measures whether the patent assignee is a local firm in Singapore or Hong Kong. The three phases represent whether the patent was first filed in Phase 1 (1980–1991), Phase 2 (1992–2006), or Phase 3 (2007–2013). The phases are proposed based on the development strategy in Singapore in different periods of time. As described above, the top priority for Singapore in the 1980s was to attract foreign investment. From the 1990s, Singapore started to promote local industry and develop indigenous R&D capacities, and the effort was greatly strengthened since 2006 as evidenced by the new initiatives and the commitment of sizeable R&D budget. Therefore, we propose to divide the government strategy into three time periods: 1980–1990 (focusing on foreign investment), 1991–2005 (promoting local industry), and 2006 and thereafter (escalated support for local R&D). While there are no similar government activities in Hong Kong, using the same period composition for Hong Kong would reveal a better contrast of innovation activities in these two regions. We allow for one year lag between government intervention and patent filing for the policy to take effect, which is a convention in research policy studies, for example in Jung and Lee (2014). We further generate two interaction terms between *Phase2/Phase3* and *Local* to test for the impact of policy intervention on innovation performance.

6.3. Control variables

Two sets of control variables are included in the models, one for technology fields and the other for year-fixed effects. Dummy variables indicating the 1-digit IPC subclass are included to control the variance across technology fields. Dummy variables for patent priority filing year are used to capture the temporal effect of technology development.

Table 5
The comparison of innovation performance in Singapore and Hong Kong.

	All firms			Local firms			Foreign firms		
	SG	HK	Difference	SG	HK	Difference	SG	HK	Difference
Citations	11.85	12.39	-0.54	11.68	9.35	2.32***	11.95	15.31	-3.36***
IPC4 Count	1.42	1.47	-0.05**	1.36	1.42	-0.05*	1.45	1.51	-0.06**

6.4. Models and analysis

The empirical models take the following format:

$$\text{Citation} = f(\beta_0 + \beta_1 \text{Local} + \beta_2 \text{Phase}_2 + \beta_3 \text{Phase}_3 + \beta_4 \text{Local} * \text{Phase}_2 + \beta_5 \text{Local} * \text{Phase}_3 + \alpha + b, \epsilon)$$

$$\text{IPC4_Count} = f(\beta_0 + \beta_1 \text{Local} + \beta_2 \text{Phase}_2 + \beta_3 \text{Phase}_3 + \beta_4 \text{Local} * \text{Phase}_2 + \beta_5 \text{Local} * \text{Phase}_3 + \alpha + b, \epsilon)$$

Both models use local companies as the treatment group and the foreign companies as the control group in Singapore and Hong Kong respectively, and examine the innovation performance in three phases. β_s are the coefficients for the independent variables, a the year effect, b the technological field effect, and ϵ the error terms.

We use negative binomial estimation to specify the models as both dependent variables are count variables and overdispersion is detected in the variable *Citation* (Table 6). The heteroskedasticity-robust standard errors for the parameter estimates are obtained to control for mild violation of underlying assumptions (Cameron et al., 2009).

As expected, the local industry lagged foreign companies in both innovation indicators for Singapore in the 1980s (Table 7). However, the difference between local and foreign companies in technological significance as measured by forward citations is significantly reduced in the most recent decade, as shown in the positive and significant coefficient of the interaction term *Local*Phase_3*. In addition, both Phase 2 and Phase 3 witnessed the narrowing gap between local and foreign companies on technological scope (refer to the coefficients of both *Local*Phase_2* and *Local*Phase_3* on *IPC4_Count*). It shows that the local industry in Singapore is rapidly catching up and growing faster than the foreign counterparts. In particular, the progress in Phase 3 was even greater than Phase 2. In the case of Hong Kong, local firms fell behind on citation measurement, but outperformed foreign companies in terms of the breadth of technological scope in Phase 1. The coefficients of the two interaction terms for Hong Kong are not significant with regard to patent citation, but negative on *IPC4_Count*. It shows the performance of the local industry in Hong Kong is not improving in the recent two decades, and is even regressing on the technical scope measurement compared with foreign companies.

6.5. Robustness check

Given that it is possible for MNCs to have different strategies in different locations, foreign companies in Singapore and Hong Kong may behave differently in their innovation activities. We then compare the

Table 6
Summary statistics of variables.

Variable	SG					HK				
	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Std. Dev.	Min	Max
Citations	8847	11.847	17.671	0	218	4098	12.389	19.495	0	407
IPC4_Count	8848	1.420	0.754	0	8	4098	1.466	0.757	1	7
Local	8848	0.376	0.484	0	1	4094	0.489	0.500	0	1
Phase2	8848	0.669	0.471	0	1	4098	0.679	0.467	0	1
Phase3	8848	0.310	0.463	0	1	4098	0.220	0.414	0	1
Local × Phase2	8848	0.245	0.430	0	1	4094	0.327	0.469	0	1
Local × Phase3	8848	0.126	0.332	0	1	4094	0.114	0.318	0	1

Table 7
Negative binomial regression for industries in Singapore and Hong Kong.

	Citation		IPC4_Count	
	SG	HK	SG	HK
Local	-0.388** (0.184)	-0.433*** (0.088)	-0.158*** (0.038)	0.064** (0.027)
Phase_2	-1.290*** (0.246)	-1.332** (0.610)	-0.016 (0.051)	0.170** (0.025)
Phase_3	-5.524*** (0.521)	-6.019*** (1.157)	-0.021 (0.065)	0.103** (0.040)
Local × Phase_2	0.286 (0.187)	-0.021 (0.099)	0.129*** (0.039)	-0.108** (0.030)
Local × Phase_3	0.703*** (0.191)	0.123 (0.126)	0.130*** (0.040)	-0.071** (0.035)
Field fixed effect	yes	yes	yes	yes
Year fixed effect	yes	yes	yes	yes
_cons	3.136*** (0.240)	3.480*** (0.598)	-0.431*** (0.052)	-0.603*** (0.021)
Num of obs	8845	4094	8846	4094
Wald chi2(43)	3532.64	1767.73	6955.69	7021.48
Pseudo R2	0.057	0.058	0.080	0.083

Robust standard errors in parentheses.

*p < 0.1

** p < 0.05.

*** p < 0.01.

local industry in Singapore directly with the local industry in Hong Kong and examine whether the difference changes over time. The result shows little difference in patent citations in the 1980s, but Singapore moved faster and enlarged the difference especially in the recent ten years (Table 8). The technological scope in Singapore initially appeared to be smaller than that in Hong Kong, but became much broader in the latter two phases.

In order to show the result is not sensitive to the way we set up the phases, we use an alternative coding for Phase 2. We set the phases ten years apart, with Phase 2 starting in 1997 and Phase 3 starting in 2007. This corresponds to the variation of Singapore government attention before/after 1996 and before/after 2006, again with one-year lag for its influence on patent filings. The results are generally consistent with previous findings, showing positive and significant progress on both indicators for Singapore in the recent two phases, but being mostly stagnant for Hong Kong (Table 9). In addition, given that the delay between receiving public support, performing R&D and producing patents is variable across firms, we also test the models using a two-year lag. The results are similar with those in the original model except that

Table 8
Negative binomial regression for local industries in Singapore and Hong Kong.

	Citation		IPC4_Count	
	SG	HK	SG	HK
SG	0.040 (0.154)		-0.129*** (0.037)	
Phase_2	-0.852*** (0.201)		0.064* (0.033)	
Phase_3	-5.469*** (0.730)		0.134** (0.060)	
SG × Phase_2	0.118 (0.160)		0.148*** (0.040)	
SG × Phase_3	0.283* (0.171)		0.094** (0.043)	
Field fixed effect	yes		yes	
Year fixed effect	yes		yes	
_cons	2.504 (0.189)		-0.527 (0.031)	
Num of obs	5327		5327	
Wald chi2(43)	1968.17		5880.52	
Pseudo R2	0.055		0.083	

Robust standard errors in parentheses.

- * p < 0.1.
- ** p < 0.05.
- *** p < 0.01.

Table 9
Negative binomial regression for industries in Singapore and Hong Kong (Phase 2: 1997–2006).

	Citation		IPC4_Count	
	SG	HK	SG	HK
Local	-0.276*** (0.079)	-0.304*** (0.070)	-0.149*** (0.025)	-0.029 (0.021)
Phase_2	-1.198*** (0.209)	-1.287** (0.620)	-0.012 (0.043)	0.125*** (0.022)
Phase_3	-5.428*** (0.505)	-5.995*** (1.162)	-0.013 (0.058)	0.064* (0.038)
Local × Phase_2	0.190** (0.087)	-0.206** (0.085)	0.131*** (0.027)	-0.002 (0.024)
Local × Phase_3	0.591*** (0.094)	-0.007 (0.113)	0.120*** (0.028)	0.023 (0.031)
Field fixed effect	yes	yes	yes	Yes
Year fixed effect	yes	yes	yes	yes
_cons	3.044*** (0.202)	3.455*** (0.609)	-0.437*** (0.044)	-0.563*** (0.017)
Num of obs	8845	4094	8846	4094
Wald chi2(43)	3550.74	1776.09	7279.92	7991.78
Pseudo R2	0.057	0.058	0.08	0.083

Robust standard errors in parentheses.

- * p < 0.1.
- ** p < 0.05.
- *** p < 0.01.

the impact is less significant on the measure of technological scope (Table 10).

Innovation activities often involve collaborations. In Singapore, 83% of patents have multiple inventors and 38% of patents involve inventors from other countries. The collaboration figures are relatively lower in Hong Kong, being 56% and 33% respectively. Given multiple inventors and inventor countries are found in most patents, it is important to distinguish the roles of the inventors in the patents and ensure those located in Singapore or Hong Kong are making major contributions. Therefore, we analyzed the inventor sequence for each patent and created a sub-dataset of patents for those with the first inventor located in Singapore or Hong Kong, with the assumption that the first inventor is making the leading contribution. As a result, we found 6995 patents with local inventors playing major roles for Singapore and 3293 for Hong Kong. We re-run the same negative binomial regression analysis as we did in Table 7. The results are consistent (see Table 11),

Table 10
Negative binomial regression for industries in Singapore and Hong Kong (2 year lag).

	Citation		IPC4_Count	
	SG	HK	SG	HK
Local	-0.264** (0.131)	-0.372*** (0.086)	-0.097*** (0.035)	0.042 (0.027)
Phase_2	-1.422*** (0.222)	-1.805*** (0.618)	0.024 (0.042)	0.128*** (0.026)
Phase_3	-5.456*** (0.513)	-6.060*** (1.155)	0.028 (0.058)	0.095** (0.041)
Local × Phase_2	0.190 (0.135)	-0.100 (0.097)	0.069* (0.037)	-0.081*** (0.029)
Local × Phase_3	0.632*** (0.144)	0.149 (0.130)	0.065* (0.039)	-0.050 (0.038)
Field fixed effect	yes	yes	yes	yes
Year fixed effect	yes	yes	yes	yes
_cons	3.039*** (0.217)	3.471*** (0.604)	-0.479*** (0.044)	-0.593*** (0.020)
Num of obs	8845	8846	4094	4094
Wald chi2(43)	3494.72	1784.45	6769.93	7256.78
Pseudo R2	0.057	0.058	0.080	0.083

Robust standard errors in parentheses.

- * p < 0.1.
- ** p < 0.05.
- *** p < 0.01.

Table 11
Negative binomial regression for industries in Singapore and Hong Kong (1st inventor only).

	Citation		IPC4_Count	
	SG	HK	SG	HK
Local	-0.462** (0.211)	-0.452*** (0.089)	-0.227*** (0.0397)	0.0691** (0.0272)
Phase_2	-1.635*** (0.259)	-1.394** (0.610)	-0.0812 (0.0664)	0.163*** (0.0284)
Phase_3	-6.183*** (0.629)	-5.373*** (1.124)	-0.0678 (0.0804)	0.158*** (0.0463)
Local × Phase_2	0.443** (0.214)	0.048 (0.105)	0.205*** (0.0414)	-0.115*** (0.0303)
Local × Phase_3	0.842*** (0.218)	0.088 (0.148)	0.207*** (0.0420)	-0.0951*** (0.0396)
Field fixed effect	yes	yes	yes	Yes
Year fixed effect	yes	yes	yes	yes
_cons	3.220*** (0.254)	3.480*** (0.587)	-0.371*** (0.0678)	-0.614*** (0.0228)
Num of obs	6994	3293	6995	3293
Wald Chi2(43)		1349.56		5563.76
Pseudo R2		0.057		0.081

Robust standard errors in parentheses.

- *p < 0.1.
- ** p < 0.05.
- *** p < 0.01.

which again confirms our findings.

7. Discussion

This study profiles innovation activities in Singapore and Hong Kong, and examines the influence of government intervention on innovation performance using patent data. Singapore and Hong Kong are two largely similar economies that differ mainly in the roles of the government. The Singapore government is perceived as pursuing a directive function, and has been actively implementing a series of strategies. The large amount of R&D budget, a series of S&T and innovation plans, and set-up of R&D coordination and funding agencies can be seen as evidence. The Hong Kong government is adopting the facilitative role and minimizes its influence on the market (Yu, 1997). The Hong Kong government allocated only 1% of its R&D budget to the industry sector

in 2012, which was less than one-tenth of the proportion for Singapore. Such negligible government support for industrial innovation partly explains why the manufacturing industry in Hong Kong is not very active in innovation. On the other hand, while the industry sector in Singapore performs better in R&D, much credit goes to MNCs. Over 70% of private sector R&D expenditure (ASTAR, 2013) and the bulk of industry patents came from MNCs. Since the 2000s, however, with greater policy emphasis on local innovation coupled with generous R&D funding support, the local industry has become more involved in R&D activities with a corresponding increase in its share of patent counts. The strong government intervention in Singapore also led to more coordinated R&D activities, which resulted in a high concentration of innovation activities in selected fields. Conversely, sectors not favored by the government produced minimal patents, evidence that innovation in Singapore is more top-down, pushed by the government. Private sector-led cluster development is still limited. By contrast, while Hong Kong government also cherry-picked several priority areas for development, patents turned out to be more distributed, suggesting that the targets of funding agencies are not responding to industrial needs (Shih and Chen, 2010). Indeed, the majority of innovation performers in Hong Kong are those less influenced by government policies, namely local private firms and individuals.

A further analysis of the impact of government intervention on selected innovation performance indicators points to more evidence of its effectiveness. Starting from a poorer position, the local industry in Singapore is quickly catching up with foreign companies and even surpassed them in recent decades. The gap between local companies and foreign companies in both technological significance and technological scope measures has been largely reduced since the 1990s. By contrast, the local industry in Hong Kong does not seem to perform better than foreign counterparts in the same time period. There is no significant change to the gap between local and foreign companies in Hong Kong, except for the citation measure in the second phase where local companies lagged even further. A direct comparison between local industries in Singapore and Hong Kong also shows that Singapore outperformed Hong Kong and the advantage was even bigger in the recent phases. The results confirm that local companies in Singapore indeed benefit from government support, and progress faster than foreign companies and their counterparts in Hong Kong.

8. Conclusion

The study provides some evidence of the success of government intervention but also points to the limitations. High government involvement appears to be effective in upgrading the innovation capabilities of the local industry. Innovation output has been increasing drastically in the recent decade. Local firms in Singapore are catching up quickly with foreign firms in innovation quality measurements and constantly reducing the gap between them. However, it is also noticeable that the number of local innovation players is quite limited in Singapore, with GLCs largely dominating the local innovation system. Policy attention and resources need to be directed away from the star companies. Motivating more local companies to perform R&D and

facilitating the knowledge spillover from MNCs and GLCs will be the key challenge for Singapore. Lessons can be learned from other countries that also have strong state intervention but at the same time have their local private industry appear as the main innovators (Breznitz, 2007). For example in Israel, while similar effort is made to attract MNCs and support state-owned firms especially those in the defense industry, private entrepreneurs appear to be rather active in innovation development and setting up new firms. Similarly, in Taiwan, the government tries to promote research in public institutions, but the effort subsequently also supports the development of private industry sector, for instance, the IT industry.

Hong Kong has lagged in the innovation competition, which has been in great part attributed to the neglect of the government and insufficient policy support. The technology industry appears to be shrinking and the top patent holders are mostly public sector universities and research institutes. However, despite low figures in R&D expenditure and patent statistics, local private companies are still dynamic and have good innovation potential. The number of firms with R&D in Hong Kong in 2012 was more than six times that in Singapore (ASTAR, 2013; C&SD, 2013). In particular, majority of them have performed self-financed spontaneous innovation that is not backed by the government, which forms a good base for Hong Kong to draw on for the development of innovation economy.

The study is among the first to explore the overarching impact of government intervention on innovation activities. It complements existing literature assessing the effectiveness of individual innovation policies or programs and provides additional empirical evidence for the effect of government commitment. It also has policy implications by highlighting the consequence of both strong and weak government intervention. Too much government interference could lead to the concentration of resources in a small number of players, while too little government support would result in the missing of development opportunities. Of course the study is not without limitations. For one, the value of patent scope is a subject of controversy with no positive effect being found in some empirical studies (Fischer and Leidinger, 2014; Harhoff et al., 2003; Lanjouw and Schankerman, 1997). Gilbert and Shapiro (1990) and Klemperer (1990) also pointed out the tradeoff between patent scope and social cost. In addition, the analysis of innovation output and performance is only based on patent data. Incorporating other innovation measures such as new products, sales of new products, and high-tech start-ups could greatly enrich the analysis and make the findings more compelling.

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Appendix A. Schemes for local industry development in Singapore

Agency	Scheme	Content
Financial assistance SPRING	Startup SG Founder	<ul style="list-style-type: none"> • Provides mentorship and startup capital grant to first-time entrepreneurs with innovative business ideas. • SPRING will match \$3 for every \$1 raised by the entrepreneur. • Eligibility • Applicant(s) must hold or propose to hold at least 30% equity in the underlying company;

SPRING	Startup SG Tech grant	<ul style="list-style-type: none"> • The company must have at least 51% of local shareholding; • The applicants must not have registered or incorporated any business entity; and received any funding for the proposed business idea from another government organization. • Proof-Of-Concept Project (POC) • Project at the conceptualization stage and the technical/scientific viability still needs to be proven. • Support up to 100% of qualifying costs for each project, subject to a maximum of S\$250,000. • Proof-Of-Value Project (POV) • To further development of a working prototype or to validate the commercial merit of an established concept. • Support up to 85% of qualifying costs for each project, subject to a maximum of S\$500,000. • Eligibility • Registered for less than 5 years at time of award; • At least 30% local shareholding; • Company's group annual sales turnover is not more than \$100 million or group employment size is not more than 200 workers and; • Core activities to be carried out in Singapore. • Project needs to be in one of the selected areas.
SPRING	Startup SG Equity	<ul style="list-style-type: none"> • It provides funding support to entrepreneurial Singaporeans to start business based on competitive applications. • Co-invest with independent, qualified 3rd party investors into a startup. • SPRING will match S\$7 to every S\$3 raised by the entrepreneur for up to S\$250 K for general technology and S\$500 K for deep technology, and 1:1 thereafter up to S\$2 M for general technology and S\$4 M for deep technology. • Both SPRING and the business angel investors will take equity stakes in the company in proportion to their investments. • Eligibility • Be a Singapore-based company with core activities carried out here. • Be incorporated as a Private Limited company for less than five years. • Have paid-up capital of at least \$50,000. • Company cannot be a subsidiary or joint-venture.
SPRING	Innovation & Capability Voucher (ICV)	<ul style="list-style-type: none"> • SMEs can use vouchers to procure R&D and other services to improve capacity in innovation, productivity, human resource and financial management. • Each voucher valued at S\$5000 • Each SME is entitled to a maximum of eight vouchers. • Eligibility • Registered and operating in Singapore • Have a minimum of 30% local shareholding • Have group annual turnover of not more than \$100 million OR group employment size of not more than 200 employees
SPRING	Productivity and Innovation Credit (PIC)	<ul style="list-style-type: none"> • Business can enjoy 400% tax deductions up to \$400,000 or 60% cash payout up to \$100,000, for investments in innovation and productivity improvements. • Eligibility • Carry on active business operations in Singapore. • Incurred qualifying expenditure • Three local employee condition (for the cash pay option)
SPRING	Capability Development Grant (CDG)	<ul style="list-style-type: none"> • CDG is a financial assistance program to help SMEs to build capabilities and enhance productivity. • The grant defrays up to 70% of qualifying project costs. • Eligibility • Registered and operating in Singapore • At least 30% local shareholding • Group annual sales turnover \leq S\$100 m or group employment of \leq 200 employees
NRF	Early Stage Venture Funding Scheme (ESVF)	<ul style="list-style-type: none"> • Launched in 2008 • It provides co-funding to selected venture capital firms to invest in early-stage start-ups in selected industries • Dollar-to-dollar match up to S\$10 million • Selected VC firms must raise at least S\$10 million
SPRING	Government-backed SME loans	<ul style="list-style-type: none"> • Each start-up can seek up to S\$3 million from the selected VC

IPOS	IP Financing Scheme	<ul style="list-style-type: none"> • Provides government-backed loans through Participating Financial Institutions • Eligibility • Company registered and operating in Singapore • At least 30% local shareholding • Group annual sales of ≤ S\$100 m or group employment size ≤ 200 • Introduced in 2014 • It supports business to apply loans through Participating Financial Institutions with IP assets as collateral • The government shares the risk of the IP loan with the Participating Financial Institution (PFI) • Companies can apply for loans up to S\$5 million up to six years. • Eligibility • Company incorporated in Singapore • Use a registered patent/trademark or valid copyright as collateral
Supporting incubators SPRING	Startup SG Accelerator	<ul style="list-style-type: none"> • Supports incubators and accelerators in strategic growth sectors • Provide funding and non-financial support for these partners to further enhance their programs and expertise in nurturing successful startups • Provides funding support to cover costs of developing programs, mentoring startups and eligible operating expenses. • Eligibility • Be incubators or venture accelerators with a unique value proposition or specific programs • Have a sustainable revenue model • Have a proven management team with the necessary experience and expertise.
NRF	IDM Jump-start and Mentor (iJam)*	<ul style="list-style-type: none"> • Venture capitalist and consultancy firms will not be considered • Started in 2006, managed by Interactive Digital Media Programme Office • Provides grant up to S\$50,000 to a start-up through appointed incubators • Grants will be used to offset up to 100% of start-up costs over a maximum period of two years.
NRF	Technology Incubator Scheme (TIS)*	<ul style="list-style-type: none"> • Successful start-ups can apply for additional S\$100,000 • Initiative under NFIE, set up in 2008 with S\$50million • NRF could co-invest up to 85% of investment (up to S500,000 per company) into a start-up per TI's recommendation • The TI is required to co-invest 15% of investment and provide mentorship • The TI can buy over the NRF's stake within three years by repaying the capital plus interest. • Currently supporting 15 incubators
Promoting collaboration SPRING	Collaborative Industry Projects (CIP)	<ul style="list-style-type: none"> • CIP supports collaborations between enterprises and industry partners, such as Trade Associations and Chambers, Centers of Innovation, productivity centers, and solution providers, to address common industry-specific business challenges. • A consortium comprising at least three SMEs has to be formed. • Participating SMEs can receive up to 70% funding support for qualifying development and/or adoption costs. • Eligibility • Registered and operating in Singapore • Have a minimum of 30% local shareholding • Have group annual sales turnover of not more than \$100 million OR group employment size of not more than 200 employees • The project has to be carried out in Singapore and should lead to revenue gain or productivity gain
SPRING	Partnerships for Capability Transformation (PACT)	<ul style="list-style-type: none"> • SPRING works with large organizations (LO) to identify and implement collaborative projects between the LO and local SMEs in certain areas. • Selected SMEs will be eligible for up to 70% funding support for qualifying development costs. • Under the enhanced Gov-PACT1, the Government will serve as the large organization • Eligibility • Registered and operating in Singapore • Have a minimum of 30% local shareholding • Have group annual sales turnover of not more than \$100 million OR group employment size of not more than 200 employees

A*STAR, SPRING, EDB, MOE and IE Singapore	Growing Enterprises with Technology Upgrade (GET-Up) Initiative	<ul style="list-style-type: none"> • Large organization: \$100 m in sales revenue and above • GET-Up is a multi-agency effort involving A*STAR, SPRING Singapore, EDB, MOE and IE Singapore with three technical assistance schemes. • Technology for Enterprise Capability Upgrading (T-Up) • Secondment of A*STAR Research Scientists and Engineers (RSEs) to local enterprises to work on their capabilities, product and process development projects, in selected fields. • T-UP subsidises up to 70% of the secondment costs. • All foreground IPs belong to company. • Operation and Technology Roadmapping (OTR) • Provides training sessions with senior management to assist companies in developing technology roadmap aligned to their business strategy/goals. • Delivers a customized technology roadmap with input from key company representatives and A*STAR technology specialists. • Technical Advisory (TA) • Appoint senior A*STAR scientists as Technical Advisor to companies to provide in-depth technical advice as well as facilitate collaborations between the company & A*STAR Research Institute(s). • Eligibility • Registered and operating in Singapore • Minimum of 30% local shareholding • Group annual turnover of not more than S\$100 million or group employment size of not more than 200 workers
SPRING and A*STAR	Technology Adoption Program (TAP)	<ul style="list-style-type: none"> • Supports collaboration between public sector research institutes and private sector to identify and translate new technologies into Ready-to-Go (RTG) solutions in six sectors: Marine, Aerospace, Precision Engineering, Construction, Food Manufacturing • Approved projects will be eligible for up to 70% funding support for qualifying deployment and/or adoption costs under the Capability Development Grant (CDG). • Eligibility • Registered and operating in Singapore • Have a minimum of 30% local shareholding • Have group annual sales turnover of not more than \$100 million OR group employment size of not more than 200 employees • It supports the establishment of key laboratories by industries in universities in order to encourage public-private R&D collaboration. • Provides funding to the establishment mostly in the range of S\$50–75 million.
NRF	Corporate Laboratories @ University Scheme	<ul style="list-style-type: none"> • It supports the establishment of key laboratories by industries in universities in order to encourage public-private R&D collaboration. • Provides funding to the establishment mostly in the range of S\$50–75 million.
Talent Development EDB	Industrial Postgraduate Program (IPP)	<ul style="list-style-type: none"> • Started in 2011 with S\$70 million • Grant for Masters training up to two years and PhD training up to four years. • Covers tuition fees and monthly salary capped at S\$3500. • The student is to spend at least 50% of the time on the project in the company. • The supervisory team comprised of one academic faculty and one staff from the company (with PhD qualification). • Eligibility • The company is based in Singapore. • The company shall have some PhD-level staff and R&D leaders who can assume the role of industry supervisors, and with sufficient R&D facilities. • The student must be Singapore Citizens or Permanent Residents (PR) • The student can be a fresh graduate from any of our local universities or be an existing employee in the company.
EDB	Initiatives in New Technology (INTECH)	<ul style="list-style-type: none"> • Co-funding to support manpower development in the application of new technologies, industrial R&D and professional know-how. • For trainees, the grant is based on fixed quantum per trainee day (t-day) up to a maximum period of 24 months. • For trainers, grant support is subject to a maximum of 50% of allowable costs for start-up training and 70% of allowable costs for research and development training. The maximum total grant is S\$10,000 per trainer per month up to a maximum period of six months. • Eligibility • Registered in Singapore • Trainees must be Singapore Citizens or Permanent Residents (PR) • Trainees should be employees of the company
SPRING	SME Talent Program (STP)*	<ul style="list-style-type: none"> • Help students gain exposure to the startup community

SPRING	Young Entrepreneurs Scheme for Schools (YES! Schools)*	<ul style="list-style-type: none"> • Facilitate internship matching between students and technology-based local startups • Provides 70% of stipends paid to intern. • Eligibility • Have a minimum of 30% local share-holding • Incorporated in Singapore • Less than 5 years from date of incorporation at time of application • Have less than 50% ordinary shares owned by other corporate entity • Able to pay interns the minimum monthly stipend* of \$800 to ITE and Polytechnic students, and \$1000 to University students. • It is to nurture and encourage youths to be enterprising and innovative through 'hands-on' entrepreneurship learning opportunities • It provides schools with grants of up to S\$10,000 to put in place a comprehensive structured entrepreneurship learning program for their students. • It is available to secondary schools and junior colleges.
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Sources: Official websites of the agencies; compiled by the author.

SPRING: Standards, Productivity and Innovation Board.

IPOS: Intellectual Property Office of Singapore.

NRF: National Research Foundation.

A*STAR: Agency for Science, Technology and Research.

IE Singapore: International Enterprise Singapore.

EDB: Economic Development Board.

*Programs discontinued in 2017 and likely to be replaced by new initiatives.

References

- ASTAR, 2013. 'National Survey of R&D in Singapore 2012'. Agency for Science, Technology and Research, Singapore.
- Aerts, Kris and Czarnitzki, Dirk, 2004. 'Using Innovation Survey Data to Evaluate R&D Policy: The Case of Belgium', ZEW – Centre for European Economic Research Discussion. (Paper No. 04-055).
- Almus, Matthias, Czarnitzki, Dirk, 2003. The effects of public R&D subsidies on firms' innovation activities: the case of eastern Germany. *J. Bus. Econ. Stat.* 21 (2), 226–236.
- Appelbaum, Richard, P., Henderson, Jeffrey (Eds.), 1992. *States and Development in the Asian Pacific Rim*. Sage, Newbury Park, CA.
- Arrow, J. Kenneth, 1962. Economic welfare and the allocation of resources for invention. In: Harold, M. Groves (Ed.), *The Rate and Direction of Inventive Activity: Economic and Social Factors*. National Bureau of Economic Research, Boston, MA, pp. 609–626.
- Breznitz, Dan, 2007. *Innovation and the State: Political Choice and Strategies for Growth in Israel, Taiwan and Ireland*. Yale University Press, New Haven; London.
- Cameron, A., Colin and Trivedi, Pravin, K., 2009. *Microeconometrics Using Stata*. Stata Press, College Station, TX.
- C&SD, 2013. *Hong Kong Innovation Activities Statistics 2012*. Census and Statistics Department, Hong Kong.
- C&SD, 2014. *Hong Kong Innovation Activities Statistics 2013*. Census and Statistics Department, Hong Kong.
- C&SD, 2015a. *2014 Gross Domestic Product*. Census and Statistics Department, Hong Kong.
- C&SD, 2015b. *Hong Kong Statistics*. (Accessed 6 November 2015). <http://www.censtatd.gov.hk/hkstat/sub/sp250.jsp?tableID=036&ID=0&productType=8>.
- Cheung Anthony, B.L., 2000. New interventionism in the making: interpreting state interventions in Hong Kong after the change of sovereignty. *J. Contemp. China* 9 (24), 291–308.
- Chudnovsky, Daniel, et al., 2006. Evaluating a Program of Public Funding of Private Innovation Activities. An Econometric Study of FONTAR in Argentina. Working Paper: OVE/WP-16/06.
- DOS, 2015. Department of Statistics Singapore: Statistics. (accessed Nov 6th, 2015). <http://www.singstat.gov.sg/statistics/browse-by-theme/national-accounts>.
- David, Paul A., Hall, Bronwyn H., Toole, Andrew A., 2000. Is public R&D a complement or substitute for private R&D? A review of the econometric evidence. *Res. Policy* 29 (4–5), 497–529.
- Demsetz, Harold, 1969. Information and efficiency: another viewpoint. *J. Law Econ.* 12 (1), 1–22.
- Etzkowitz, Henry, Leydesdorff, Loet, 2000. The dynamics of innovation: from national systems and mode 2 to a triple helix of university–industry–government relations. *Res. Policy* 29 (2), 109–123.
- Fischer Timo and Leidinger Jan (2014), 'Testing patent value indicators on directly observed patent value – An empirical analysis of Ocean Tomo patent auctions', *Research Policy*, 43 (3), 519–29.
- Gilbert, Richard, Shapiro, Carl, 1990. Optimal patent length and Breadth. *RAND J. Econ.* 21 (1), 106–112.
- Guellec, Dominique, van Pottelsberghe de la Potterie, Bruno, 2000. Applications, grants and the value of patent. *Econ. Lett.* 69 (1), 109–114.
- Hall, Bronwyn, van Reenen, John, 2000. How effective are fiscal incentives for R&D? A review of the evidence. *Res. Policy* 29 (4–5), 449–469.
- Hall, H. Bronwyn, Jaffe, A., Trajtenberg, M., 2005. Market value and patent citations. *RAND J. Econ.* 36 (1), 16–38.
- Harhoff, Dietmar, Scherer, M. Frederic, Vopel, Katrin, 2003. Citations, family size, opposition and the value of patent rights. *Res. Policy* 32 (8), 1343–1363.
- Huang, Can, Sharif, Naubahar, 2009. Manufacturing dynamics and spillovers: the case of guangdong province and Hong Kong, Macau and Taiwan (HKMT). *Res. Policy* 38 (5), 813–828.
- ITC, 2015. *Innovation and Technology Fund: Memorandum Note*. Innovation and Technology Commission, Hong Kong.
- Joseph, R.A., Johnston, R., 1985. Market failure and government support for science and technology: economic theory versus political practice. *Prometheus* 3 (1), 138–155.
- Jung, Hyun Ju, Lee, Jeongsik Jay, 2014. The impacts of science and technology policy interventions on university research: evidence from the U.S. National Nanotechnology Initiative. *Res. Policy* 43 (1), 74–91.
- Klemperer, Paul, 1990. How broad should the scope of patent protection be? *RAND J. Econ.* 21 (1), 113–130.
- Lanjouw, J.O., Schankerman, M., 1997. *Stylized Facts of Patent Litigation: Value, Scope, Ownership*. National Bureau of Economic Research, Cambridge, MA (NBER Working Paper No. 6297).
- Lerner, Joshua, 1990. The importance of patent scope: an empirical analysis. *RAND J. Econ.* 25 (2), 319–333.
- Link, Albert, Siegel, Donald, 2007. *Innovation Entrepreneurship and Technological Change*. Oxford University Press, Oxford.
- Luedde-Neurath, Richard, 1988. 'State intervention and export-oriented development in South Korea'. In: White, Gordon (Ed.), *Developmental States in East Asia*. MacMillan Press, London, pp. 68–112.
- Martin, Stephen, Scott, T. John, 2000. The nature of innovation market failure and the design of public support for private innovation. *Res. Policy* 29, 437–447.
- Mok, Ho Ka, 2005. Fostering entrepreneurship: changing role of government and higher education governance in Hong Kong. *Res. Policy* 34, 537–554.
- NRF, 2015. *Innovation and Enterprise Milestones*. (accessed June 5). <http://www.nrf.gov.sg/innovation-enterprise/innovation-enterprise-milestones>.
- Nelson, R. Richard, 1959. The simple economics of basic scientific research. *J. Pol. Econ.* 67 (3), 297–306.
- Nelson, R. Richard, 1993. *National Innovation Systems: a Comparative Analysis*. Oxford University Press.
- Shane, Scott, 2001. Technological opportunities and new firm creation. *Manag. Sci.* 47 (2), 205–220.
- Sharif, Naubahar, Baark, Erik, 2009. Understanding the dynamism in Hong Kong's innovation environment. *J. Knowl. Based Innov. China* 1 (1), 56–75.
- Shih, Chintay, Chen, Shin-Hong, 2010. 'On reform of Hong Kong's public research funding system'. In: Fuller, Douglas B. (Ed.), *Innovation Policy and the Limits of Laissez-faire: Hong Kong's Policy in Comparative Perspective*. Palgrave Macmillan, New York NY, pp. 114–144.
- Singh, Annette, Fleming, Lee, 2010. Lone inventors as sources of breakthroughs: myth or reality? *Manag. Sci.* 56 (1), 41–56.
- Squicciarini, M., Dernis, H., Criscuolo, C., 2013. Measuring patent quality: indicators of

- technological and economic value. OECD Science, Technology and Industry Working Papers. 2013/03: OECD Publishing.
- Teo, Chee Hean, 2015. Opening of the Singapore Scientific Conference 2015 (Accessed November 15). <https://www.mha.gov.sg/Newsroom/speeches/other-speeches/Pages/The-Opening-of-the-Singapore-Scientific-Conference-2015-Speech-by-Mr-Teo-Chee-Hean,-Deputy-Prime-Minister.aspx>.
- Trajtenberg, Manuel, 1990. A penny for your quotes: patent citations and the value of innovations. *RAND J. Econ.* 21 (1), 172–187.
- USPTO (2017), U.S. Patenting Trends by NAICS Industry Category: Utility Patent Grants, Calendar Years 1963–2012, https://www.uspto.gov/web/offices/ac/ido/oeip/taf/naics/doc/naics_info.htm Accessed 20 June.
- Wade, Robert, 1990. *Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization*. Princeton University Press, Princeton, NJ.
- White, Gordon, Wade, Robert, 1988. Development states and markets in east asia: an introduction. In: White, Gordon (Ed.), *Developmental States in East Asia*. St Martin's Press, New York, pp. 1–29.
- Wong, Kam Poh, 1988. The role of state in Singapore's industrial development. In: Wong, Poh-Kam, Ng, Chee-Yuen (Eds.), *Industrial Policy, Innovation and Economic Growth: The Experience of Japan and the East Asian NIEs*. Singapore University Press, Singapore, pp. 503–569.
- Yam, Richard C.M., et al., 2011. Analysis of sources of innovation, technological innovation capabilities, and performance: an empirical study of Hong Kong manufacturing industries. *Res. Policy* 40, 391–402.
- Yeung, Wai-Chung Henry, et al., 2000. State intervention and neoliberalism in the globalizing world economy: lessons from Singapore's regionalization programme. *Pac. Rev.* 13 (1), 133–162.
- Young, Alwyn, 1992. A tale of two cities: factor accumulation and technical change in Hong Kong and Singapore. *NBER Macroecon. Annu.* 7, 13–51.
- Yu, Tony F., 1997. Entrepreneurial state: the role of government in the economic development of the asian newly industrialising economies. *Dev. Policy Rev.* 15 (1), 47–64.