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<td>Wang, Jue</td>
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<td>2017</td>
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Innovation and government intervention: A comparison of Singapore and Hong Kong

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Hong Kong

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 whereas Hong Kong focuses on letting the market alone provide incentives for knowledge production. 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 statist 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 inefficiencies in 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...
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 predetermined 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 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, 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 (Chudnowsky 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 ($2.7 billion) for R&D in 2012, accounting for 0.8% of GDP (Table 1.6 in ASTAR, 2013). 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...
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 headquarters for MNCs. Despite the fact that patents may be filed by the local office in either Singapore or Hong Kong, we still use the headquarters 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 Service 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 headquarters 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 coordinate innovation policies and activities. Financial support 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&S, 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).
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. 1. Innovation initiatives in Singapore and Hong Kong.

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)
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. 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...
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 was in 1997–2006; 0 if not

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

Poterrie, 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.
6.4. Models and analysis

The empirical models take the following format:

\[
\text{Citation} = f(\beta_0 + \beta_1 \text{ Local} + \beta_2 \text{ Phase}_2 + \beta_3 \text{ Phase}_3 + \beta_4 \text{ Local} \times \text{Phase}_3 + \alpha + b, \epsilon)
\]

\[
\text{IPC4} = f(\beta_0 + \beta_1 \text{ Local} + \beta_2 \text{ Phase}_2 + \beta_3 \text{ Phase}_3 + \beta_4 \text{ Local} \times \text{Phase}_3 + \alpha + b, \epsilon)
\]

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. \( \beta_s \) are the coefficients for the independent variables, \( a \) the year effect, \( b \) the technological field effect, and \( \epsilon \) 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 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 6). 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 6
Summary statistics of variables.

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<th>Variable</th>
<th>SG</th>
<th>HK</th>
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<tr>
<td>Citations</td>
<td>Obs: 8847</td>
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</tr>
<tr>
<td></td>
<td>Mean: 12.39</td>
<td>Mean: 11.68</td>
</tr>
<tr>
<td>IPC4_Count</td>
<td>Obs: 8848</td>
<td>Mean: 1.42</td>
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<tr>
<td></td>
<td>Mean: 1.47</td>
<td>Mean: 1.36</td>
</tr>
<tr>
<td>Local</td>
<td>Obs: 8848</td>
<td>Mean: 0.376</td>
</tr>
<tr>
<td>Phase2</td>
<td>Obs: 8848</td>
<td>Mean: 0.669</td>
</tr>
<tr>
<td>Phase3</td>
<td>Obs: 8848</td>
<td>Mean: 0.310</td>
</tr>
<tr>
<td>Local × Phase2</td>
<td>Obs: 8848</td>
<td>Mean: 0.245</td>
</tr>
<tr>
<td>Local × Phase3</td>
<td>Obs: 8848</td>
<td>Mean: 0.126</td>
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### Table 7
Negative binomial regression for industries in Singapore and Hong Kong.

<table>
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</tr>
<tr>
<td></td>
<td>SG</td>
<td>HK</td>
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<tr>
<td>Local</td>
<td>−0.388***</td>
<td>−0.433***</td>
</tr>
<tr>
<td></td>
<td>(0.184)</td>
<td>(0.088)</td>
</tr>
<tr>
<td></td>
<td>−0.433***</td>
<td>−0.158***</td>
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<tr>
<td></td>
<td>(0.038)</td>
<td>(0.027)</td>
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<tr>
<td>Phase2</td>
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<td>−1.332**</td>
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<tr>
<td></td>
<td>(0.246)</td>
<td>(0.610)</td>
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<td></td>
<td>−0.016</td>
<td>0.170***</td>
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<tr>
<td></td>
<td>(0.051)</td>
<td>(0.025)</td>
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<td>Phase3</td>
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<td>−6.019***</td>
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<td></td>
<td>(0.521)</td>
<td>(1.157)</td>
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<td></td>
<td>−0.021</td>
<td>0.103***</td>
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<td></td>
<td>(0.065)</td>
<td>(0.040)</td>
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<td>Local × Phase2</td>
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<td></td>
<td>(0.187)</td>
<td>(0.099)</td>
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<td>0.039</td>
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<tr>
<td>Year fixed effect</td>
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<td></td>
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<tr>
<td>_cons</td>
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<td>3.480***</td>
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<td></td>
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<td>(0.598)</td>
</tr>
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<td></td>
<td>0.431***</td>
<td>0.603***</td>
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<tr>
<td></td>
<td>(0.052)</td>
<td>(0.021)</td>
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<tr>
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</tr>
<tr>
<td>Wald χ2(43)</td>
<td>3323.64</td>
<td>1767.73</td>
</tr>
<tr>
<td></td>
<td>6955.69</td>
<td>7021.48</td>
</tr>
<tr>
<td>Pseudo R2</td>
<td>0.057</td>
<td>0.058</td>
</tr>
<tr>
<td></td>
<td>0.080</td>
<td>0.083</td>
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</table>

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).

Table 8 Negative binomial regression for local industries in Singapore and Hong Kong. (2 year lag).

<table>
<thead>
<tr>
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<tr>
<td><strong>Local</strong></td>
<td><strong>0.462</strong></td>
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<tr>
<td>(0.211)</td>
<td>(0.089)</td>
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<tr>
<td><strong>Phase_2</strong></td>
<td><strong>−1.635</strong></td>
</tr>
<tr>
<td>(0.259)</td>
<td>(0.610)</td>
</tr>
<tr>
<td><strong>Phase_3</strong></td>
<td><strong>−6.183</strong></td>
</tr>
<tr>
<td>(0.629)</td>
<td>(1.124)</td>
</tr>
<tr>
<td><strong>Local × Phase_2</strong></td>
<td><strong>0.443</strong></td>
</tr>
<tr>
<td>(0.214)</td>
<td>(0.105)</td>
</tr>
<tr>
<td><strong>Local × Phase_3</strong></td>
<td><strong>0.842</strong></td>
</tr>
<tr>
<td>(0.218)</td>
<td>(0.148)</td>
</tr>
<tr>
<td><strong>Field fixed effect</strong></td>
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</tr>
<tr>
<td><strong>_cons</strong></td>
<td><strong>3.220</strong></td>
</tr>
<tr>
<td>(0.254)</td>
<td>(0.587)</td>
</tr>
<tr>
<td><strong>Num of obs</strong></td>
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<tr>
<td><strong>Wald ch2(43)</strong></td>
<td>1349.56</td>
</tr>
<tr>
<td><strong>Pseudo R2</strong></td>
<td>0.057</td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses.

*p < 0.1.

**p < 0.05.

***p < 0.01.

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 (Pisces 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.

Acknowledgement

The study was supported by Singapore Ministry of Education [MOE AcRF Tier 1 Grant] and the Singapore National Research Foundation [NRF2014-NRF-SRIE001-0231]. Assistance in data cleaning and proof reading was provided by Rosalie Hooi, Gayathri Haridas and Liwei Zhang. Any opinions, findings, and conclusions or recommendations expressed in this article are those of the author and do not necessarily reflect the views of MOE and NRF.

Appendix A. Schemes for local industry development in Singapore

<table>
<thead>
<tr>
<th>Agency</th>
<th>Scheme</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPRING</td>
<td>Startup SG Founder</td>
<td>• Provides mentorship and startup capital grant to first-time entrepreneurs with innovative business ideas.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• SPRING will match $3 for every $1 raised by the entrepreneur.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Eligibility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Applicant(s) must hold or propose to hold at least 30% equity in the underlying company;</td>
</tr>
</tbody>
</table>
- 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.

SPRING Startup SG Tech grant
- **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
- 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 S$50,000.
- Company cannot be a subsidiary or joint-venture.

SPRING Innovation & Capability Voucher (ICV)
- 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)
- 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)
- 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.
  - Registered and operating in Singapore
  - At least 30% local shareholding
  - Group annual sales turnover ≤ S$100 m or group employment of ≤ 200 employees

NRF Early Stage Venture Funding Scheme (ESVF)
- 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
  - Each start-up can seek up to S$3 million from the selected VC

SPRING Government-backed SME loans
• Provides government-backed loans through Participating Financial Institutions
• Eligibility
  • Company registered and operating in Singapore
  • At least 30% local shareholding
  • Group annual sales of $\leq 100$ m or group employment size $\leq 200$

**IPOS**

**IP Financing Scheme**
• 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 $\leq 5$ 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**
• 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.
• Venture capitalist and consultancy firms will not be considered

**NRF**

**IDM Jump-start and Mentor (iJam)**
• Started in 2006, managed by Interactive Digital Media Programme Office
• Provides grant up to $\leq 50,000$ 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.
• Successful start-ups can apply for additional $\leq 100,000$

**NRF**

**Technology Incubator Scheme (TIS)**
• Initiative under NFIE, set up in 2008 with $\leq 50$ million
• NRF could co-invest up to 85% of investment (up to $\leq 500,000$ 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)**
• 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)**
• 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

- 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)

- 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

NRF Corporate Laboratories @ University Scheme

- 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)

- 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)

- 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)*

- Help students gain exposure to the startup community
References


Cameron, A., Colin and Trivedi, Pravin, K., 2009. Microeconometrics Using Stata. Stata Press, College Station, TX.


ITC, 2015. Innovation and Technology Fund: Memorandum Note. Innovation and Technology Commission, Hong Kong.


Springer, Young Entrepreneurs Scheme for Schools (YES! Schools)*

Sources: Official websites of the agencies; compiled by the author.

SPRING: Standards, Productivity and Innovation Board.


NRF: National Research Foundation.


EDB: Economic Development Board.

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

- 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 $10,000, to put in place a comprehensive structured entrepreneurship learning program for their students.
- It is available to secondary schools and junior colleges.


