Abstract
Singapore has consistently been ranked as one of the most innovative and competitive countries of the world. The Singaporean government is widely known for its unique policy style and extraordinary role in the economic development of the city state. Since its independence, state intervention in almost all policy domains including Science, Technology and Innovation (STI) policy has remained very high. Research and Development (R&D) expenditure, in Singapore, since the early 2000s has consistently remained above 2% of its GDP. However, statistics from the Agency for Science, Technology and Research (A*STAR) show that R&D expenditures by the local Small and Medium Enterprises (SMEs) have only gone up from S$ 322.39 million in 2002 to S$ 725.26 million in 2016. In contrast, R&D expenditures by the foreign companies have increased from S$ 1.12 billion in 2002 to S$ 4.08 billion in 2016. Empirical evidence on impact of R&D on the Singaporean economy in terms of growth in its Total Factor Productivity (Solow residual) shows that the absorptive capacities of the local firms, to commercialize developments in the emerging fields, is quite low. There is also leakage of value capture in Singapore due to its open economy, a small domestic market and limited local capability in its firms. High share of R&D expenditure by the foreign companies, especially the Multinational Corporations (MNCs), seems to exacerbate the situation of leakage of value capture. My research will investigate the negative aspects of Singapore’s heavy tilt towards encouraging MNCs and carrying out large portion of its public R&D activities around these giant corporations, for a relatively long period of time (1965 till end of 1990s). I will inquire how this approach has led to a weaker SME (manufacturing) landscape in Singapore in comparison to peers like Taiwan in terms of variables such as value added and direct exports by SMEs. This comparison will further take into account the role of innovation intermediaries for open innovation as these have delivered great results in the case of Taiwan. Singapore, surprisingly, is a late mover in understanding that SMEs need to be strengthened for sustaining its national competitiveness. Recent literature and STI policy framework, however, show a movement towards hybrid Triple Helix Model and strengthening of intermediaries like Intellectual Property Intermediary and Enterprise Singapore for driving growth and innovation opportunities for Singaporean enterprises. I hypothesize that in 2006, there was a paradigmatic shift driven by various state and non-state actors, in Singapore’s STI policy in the shape of Science and
Technology Plan 2010 which has been subsequently be followed by inventive Research, Innovation and Enterprise Plan (RIE) and RIE 2020 plans. I will make use of quantitative data from primary and other published sources for reaching conclusions about what was happening before 2006 and what have been the effects post 2006 especially after the paradigm shift. Statistical analyses for drawing causal inferences will be done.
Sustaining Singapore’s Competitiveness: Role of Intermediaries for Promoting Innovation in SMEs

Abstract

Singapore has consistently been ranked as one of the most innovative and competitive countries of the world. The Singaporean government is widely known for its unique policy style and extraordinary role in the economic development of the city state. Since its independence, state intervention in almost all policy domains including Science, Technology and Innovation (STI) policy has remained very high.

Research and Development (R&D) expenditure, in Singapore, since the early 2000s has consistently remained above 2% of its GDP. However, statistics from the Agency for Science, Technology and Research (A*STAR) show that R&D expenditures by the local Small and Medium Enterprises (SMEs) have only gone up from S$ 322.39 million in 2002 to S$ 725.26 million in 2016. In contrast, R&D expenditures by the foreign companies have increased from S$ 1.12 billion in 2002 to S$ 4.08 billion in 2016. Empirical evidence on impact of R&D on the Singaporean economy in terms of growth in its Total Factor Productivity (Solow residual) shows that the absorptive capacities of the local firms, to commercialize developments in the emerging fields, is quite low. There is also leakage of value capture in Singapore due to its open economy, a small domestic market and limited local capability in its firms. High share of R&D expenditure by the foreign companies, especially the Multinational Corporations (MNCs), seems to exacerbate the situation of leakage of value capture.

My research will investigate the effect on Singaporean SMEs due to heavy tilt towards encouraging MNCs and carrying out large portion of public R&D activities around these giant corporations. I will inquire how this approach has led to a weaker SME landscape in Singapore by analyzing variables such as patents, R&D personnel, R&D expenditure, and sales/licensing revenue from patents and new technology by SMEs. The study will further take into account the role of innovation intermediaries for open innovation especially in commercialization. Singapore, surprisingly, is a late mover in understanding that SMEs need to be strengthened for sustaining its national competitiveness. Recent literature and STI policy framework, however, show a movement towards hybrid Triple Helix Model and strengthening of intermediaries like Intellectual Property Intermediary and Enterprise Singapore for driving growth and innovation opportunities for Singaporean enterprises. I will make use of quantitative data from primary and other published sources for reaching conclusions about performance of SMEs in terms of variables mentioned above.

Key Words: Research and Development, Innovation Intermediaries, Open Innovation, Small and Medium Enterprises
Introduction

Singapore’s remarkable economic growth has been studied extensively. Wong (1999a) attributes this rapid growth of the country to continuous industrial restructuring and upgrading. Consequently, Singapore has consistently been ranked as one of the most innovative and competitive countries of the world. The journey from an impoverished resource constrained tiny piece of marshy land to a first world country was completed in less than three decades. This unimaginable transformation has baffled many across the globe. Successive governments, led by the People’s Action Party are considered as one of the main factors behind this mind boggling transition of Singapore into one of the most affluent societies of the world. The Singaporean government is widely known for its unique policy style and extraordinary role in the economic development of the city state. Since its independence, state intervention in almost all policy domains including Science, Technology and Innovation (STI) policy has remained very high.

Wong (2001) explains how the initial industrial policy of the government for the first twenty five years, after separation from Malaysia, focused on attracting multi-national corporations (MNCs) for technology transfer. Labor intensive off-shore manufacturing for MNCs was pervasive in the first decade. Subsequently, in the second and third decades a shift occurred towards technology intensive manufacturing. Significant economic growth was achieved during this period despite the conspicuous absence of innovation activities in Singapore. However, there were limits of this model of growth and in 1989 a committee of Ministers of State was formed to devise a long-term strategy for Singapore’s development. Research and Development (R&D) were recognized as important elements of the future strategy known as “The Next Lap.” The need to catch-up with the advanced countries over the next twenty years was also highlighted in this document (Government of Singapore, 1991). Year 1989 thus marks the beginning of public policy emphasis on R&D as the engine of growth for Singapore’s economy.

From 1990 till the Asian Financial Crisis (AFC), R&D expenditure in Singapore did not increase much. Since the early 2000s R&D expenditure has consistently remained above 2% of its GDP. Table 1 shows total R&D expenditure in Singapore from 1990 onwards.

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Table 1: R&D Expenditure in Singapore

<table>
<thead>
<tr>
<th>Year</th>
<th>Total R&amp;D Expenditure (S$ million)</th>
<th>Private R&amp;D Expenditure (S$ million)</th>
<th>Total R&amp;D Expenditure % GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>571.7</td>
<td>309.5</td>
<td>0.81</td>
</tr>
<tr>
<td>1991</td>
<td>756.8</td>
<td>442</td>
<td>0.96</td>
</tr>
<tr>
<td>1992</td>
<td>949.54</td>
<td>577.62</td>
<td>1.12</td>
</tr>
<tr>
<td>1993</td>
<td>997.93</td>
<td>618.58</td>
<td>1.02</td>
</tr>
<tr>
<td>1994</td>
<td>1174.98</td>
<td>736.23</td>
<td>1.04</td>
</tr>
<tr>
<td>1995</td>
<td>1366.56</td>
<td>881.37</td>
<td>1.10</td>
</tr>
<tr>
<td>1996</td>
<td>1792.14</td>
<td>1133.42</td>
<td>1.32</td>
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<tr>
<td>1997</td>
<td>2104.56</td>
<td>1314.52</td>
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</tr>
<tr>
<td>1998</td>
<td>2492.26</td>
<td>1536.1</td>
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<tr>
<td>1999</td>
<td>2,656.3</td>
<td>1,670.9</td>
<td>1.82</td>
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<tr>
<td>2000</td>
<td>3,009.5</td>
<td>1,866</td>
<td>1.82</td>
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<tr>
<td>2001</td>
<td>3,232.7</td>
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<td>2002</td>
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<td>2003</td>
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<tr>
<td>2004</td>
<td>4,061.9</td>
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<td>2005</td>
<td>4,582.2</td>
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<tr>
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<tr>
<td>2016</td>
<td>9,519.3</td>
<td>5,733.4</td>
<td>2.22</td>
</tr>
</tbody>
</table>

Source: A*STAR Annual Reports

Ho and Wong (2017) empirically show the impact of R&D on the Singaporean economy in terms of growth in its Total Factor Productivity (TFP). They concluded that the absorptive capacities of
the local firms, to commercialize developments in the emerging fields, is quite low. There is also leakage of value capture in Singapore due to its open economy, a small domestic market and limited local capability in the local firms. High share of R&D expenditure by the foreign companies, especially the MNCs seems to exacerbate the situation of leakage of value capture.

The debate about strengthening Singaporean small and medium enterprises (SMEs) started back in 1986. However, concrete measures to boost the innovative capacities of SMEs started after the AFC in 1997. In the aftermath of the crisis the need to diversify the economy was discussed along with a renewed commitment towards enhancing R&D capabilities of the indigenous industry. Singapore, surprisingly, seems to be a late mover in understanding that SMEs need to be strengthened for sustaining its national competitiveness. Recent literature and STI policy framework in Singapore, however, show a movement towards hybrid Triple Helix Model and strengthening of innovation intermediaries like Intellectual Property Intermediary (IPI) and Enterprise Singapore for driving growth and innovation opportunities for Singaporean enterprises.

This paper will investigate, through the use of time series analysis, the performance of SMEs in Singapore in terms of patents’ output and licensing and sales revenue from patents and new technologies. I will also trace the evolution of SME policy in Singapore and the measures introduced to help enhance the competitiveness of SMEs. The major steps have been taken after 2002 so this evolution is important to be discussed in detail. Quantitative analysis in this paper shows that the Singaporean SMEs have not been able to benefit substantially in terms commercializing their patents and new technologies. Lastly, I will emphasize the importance of innovation intermediaries for open innovation and improving innovative capabilities in Singaporean SMEs for sustaining Singapore’s competiveness. I will also propose future course of research which can take the shape of comparison with countries like Taiwan where intermediaries have delivered great results for the local SMEs.

**Literature Review**

R&D has been defined as “creative work undertaken on a systematic basis in order to increase the stock of knowledge and the use of this stock of knowledge to devise new applications (A*STAR, 2002). R&D covers three activities: basic research, applied research and experimental development. Sören-Peter Olesen at the University of Copenhagen describes the goal of basic research as, “to collect information about how nature and people are put together. It’s not important
that this knowledge can be used for anything concrete, the most important thing is that we improve our understanding.”

Basic research is also called “blue skies research” as it enhances our knowledge and leads to innovation. Applied research is a movement beyond theory to apply knowledge, innovations and technology for a specific practical purpose. Finally, experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience that is directed to producing new materials, products or devices; to installing new processes, systems and services; or to improving substantially those already produced or installed. R&D is considered important for economic growth and enhancing the competitiveness of any nation.

**Role of Innovation Intermediaries**

Schumpeter (1934) defines an innovation as a new or improved good, a new method of production or distribution, the opening of a new market, the use of new supplies or engagement of new suppliers, or a new mode of industrial organization. There are various actors working within the national, regional and sectoral innovation systems for improving innovative capabilities within a particular system. One of these actors which will be discussed in this paper in the context of Singaporean national innovation system are the innovation intermediaries.

Any organization or organizational unit striving to enable innovation can be considered an innovation intermediary. Innovation intermediaries may spur innovation, either directly by enabling the innovativeness of one or more firms, or indirectly by bolstering the innovative capacity of nations, regions, or sectors. They intermediate at the inter-organizational level through nurturing of inter-organizational networks and at inter-community level by supporting technology development activities between the enterprises and the researchers.

Howells (2006: 720) defines an innovation intermediary as, “an organization or body that acts as an agent or broker in any aspect of the innovation process between two or more parties. Such intermediary activities include: helping to provide information about potential collaborators;

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brokering a transaction between two or more parties; acting as a mediator, or go-between, bodies or organizations that are already collaborating; and helping find advice, funding and support for the innovation outcomes of such collaborations.” In the current literature, innovation intermediaries are known by various names such as third parties (Mantel and Rosegger, 1987), intermediary firms (Stankiewicz, 1995), bridgers (Bessant and Rush, 1995; McEvily and Zaheer, 1999), brokers (Hargadon and Sutton, 1997; Provan and Human, 1999), information intermediaries (specifically associated with information exchange; Popp, 2000) and superstructure organizations (Lynn et al., 1996). Irrespective of the nomenclature, these organizations are considered as important actors in the innovation process due to the variety of tasks being performed by them. Bessant and Rush (1995) have shed light on a broad range of their functions. These are articulation and selection of technology options; scanning and locating new sources of knowledge; building linkages with external knowledge providers; development and implementation of business and innovation strategies.

A study conducted by Howells (2006) in the UK shows how the diversity of roles performed by innovation intermediaries are increasing depending on where they are operating in the value chain. This study explains how intermediaries active in the upstream part of the value chain may be performing the functions of scoping and intelligence. On the contrary, downstream intermediaries may be involved in IP protection and commercialization. Similarly, some of them may be assisting the firms in diversifying into new technologies and industries while others may be working with their clients in domestic or foreign market development. Roles of intermediaries are also evolving as national, regional and sectoral innovation systems increase in complexity and sophistication. For example, the assumption of a simple one-to-one-to one; vertical relationship through the intermediary between the supplier and the customer may not be applicable in distributed and complex innovation networks. In these situations, intermediaries may be involved in vertical and horizontal relationships such as many-to-many-to-many, many-to-one-to-many, many-to-one-to-one and one-to-one-to-many. The multiple and complex relationships also affect other attributes such as the power dependency between the client and the intermediary. Thus, an intermediary having a large number of clients is likely to exercise more power over any particular client (Braun, 1993).
Another interesting development in the role of intermediaries is regarding the widely held assumption that a supplier initiates the relationship with an intermediary for technology push i.e., supplying customers with a new innovation. On the contrary, the relationship may start and progress in the opposite direction. IKEA, the famous multi-national Swedish company, approached CERAM (British Ceramic Research Ltd.) for finding solution to the high fracture rate of its pottery. Based on its technical expertise such as computational modeling, process and tunnel kiln simulation, CERAM (now known as Lucideon Ltd.) proposed to IKEA to improve its supplier relationship for overcoming the breakage and wastage problems. This example indicates the interesting developments in the role of intermediaries in recent years.

In the inter-organizational networks, intermediaries may support the inward flow of knowledge or perspectives from a range of sources to the firms, possibly including the intermediaries themselves. Such activities involve scanning and information processing (Howells, 2006), diffusing information and best practice techniques (Grindley et al., 1994) and transferring specialized knowledge (Bessant & Rush, 1995). On the contrary, the intermediary may also support the outward flow of knowledge or perspectives from the firms to various recipients. Such activities involve cluster promotion (Sapsed et al., 2007) and industry promotion (Human & Provan, 2000).

The technology development and related activities performed by intermediaries include the provision of access to expertise and equipment (Howells, 2006; Mian, 1996), standards development and support for systems development (Fuchs, 2009; Grindley et al, 1994), testing and validation of new technologies and equipment (Grindley et al, 1994; McEvily & Zaheer, 1999), adapting technologies for alternate applications (Mazzoleni & Nelson, 2007; Bessant & Rush, 1995), and intellectual property management and other activities associated with the commercial exploitation of the inventions of university and other public sector researchers/ institutes.

Another important role of the innovation intermediaries is related to the conduct or support of technology development activities in the innovation gap. Business and research communities are separated by an innovation gap, alternatively known as a commercialization gap or the ‘valley of death’ (Branscomb & Auerswald, 2002; Dasgupta & David, 1994; Furman, Porter and Stern, 2002; Kaufmann & Tödtling, 2001; Murphy & Edwards, 2003; Wessner, 2005). Innovation intermediaries may purposefully position themselves for plugging the innovation gap between the industry and researchers.
Keeping in view the multi-faceted and a wide variety of roles performed by the innovation intermediaries (Dalziel, 2010) argues that their performance is difficult to measure and attempts to measure their performance in terms of business or research indicators risk diverting them from their scope of work. These measurement challenges and difficulties may lead to lesser support of the innovation intermediaries by the government. Direct support of research on the other hand may be able to get greater share of resources and assistance than the intermediaries despite the fact that latter may bring large social and economic benefits by enabling and facilitating the innovation capabilities of a country, region or sector. The willingness of governments to invest in scientific research is also more because the impact of the investments are simpler to measure and the results can also be demonstrated to the citizens. As a consequence of the reluctance of governments to fund activities whose outcomes are difficult to measure, innovation intermediaries are perpetually vulnerable organizations (Dalziel, 2010). Moreover, there are no annual rankings of innovation intermediaries that these organizations can show to their stakeholders along with other evidence of their effectiveness. Vulnerability of intermediaries have been shown in the case of Canada where from being active on all the ten provinces their presence was reduced to five provinces only (Statistics Canada, 2006).

Innovation intermediaries can take the shape of science parks, business incubators, accelerators, industry associations, chambers of commerce and industry and economic development organizations. Mazzoleni and Nelson (2007) identify their critical role in economic development of developing countries through promotion of entrepreneurship and technology catch-up. In developed countries, however, they facilitate inter-organizational collaboration at the domain level (Trist, 1983), bringing together firms, governments, and universities to address long-term, multi-dimensional problems such as urban mobility and environmental degradation. Innovation intermediaries are, therefore, not only providing immediate, ‘one-off’ intermediary services to the clients, but are also offering longer term, ‘relational’ innovation capabilities to them as well. These collaborations can last for long periods. With regards to their future roles, created technology and intellectual property’s external commercialization has also been discussed in the literature (Gassman et al., 2010). I will be discussing the role of Intellectual Property Intermediary (IPI) in Singapore for the latter. IPI has been established recently and its activities are very important to improve the commercialization capabilities of Singapore’s domestic industry.
Small and Medium Enterprises, Open Innovation and Intermediaries

The topic of innovation in SMEs has received a great deal of attention from scholars (Edwards et al., 2005). Most of the research efforts have focused on studying how SMEs manage collaboration and innovation relative to their larger counterparts (Hoffmann and Schlosser, 2001, Narula, 2004, Rogers, 2004). Limited absorptive capacity (Mitchell et al., 2014), lack of innovation finance (Caputo et al., 2002), deficiency of functional expertise (Kaufmann and Tödtling, 2002), diseconomies of scale (Bessant and Rush, 1995), and short-term orientation (Nooteboom, 1994) have been shown as the weaknesses of SMEs that impede innovation. These weaknesses create the necessity for SMEs to form collaborative networks with external parties. Pittaway et al., (2004) argue that collaborative networks increase the flow of information and have a significant role in the diffusion and adoption of innovations. Facilitating collaboration or networking for innovation is important since it offers opportunities for new or alternative relationships, links, or markets and allows access to new or complementary competencies and technologies (Lazzarini et al., 2001, Pittaway et al., 2004). For SMEs, network building is an important innovation strategy (Ketchen et al., 2007, Zeng et al., 2010). SMEs are more innovative when they are able to join and manage networking activities (Avermaete et al., 2003, Gellynck et al., 2007, Sarkar and Costa, 2008). The positive effects of collaborative networks include increased turnover, higher profit margins, and diversification of the product/service range (De Jong and Vermeulen, 2006, Van Gils and Zwart, 2004).

The aforementioned benefits associated with collaborative networks do not automatically imply that SMEs will be able to form, join and play roles in these networks. There are several challenges and difficulties for SMEs to benefit from such inter-organizational innovation initiatives. First, SMEs are very often managed by their owners or entrepreneurs themselves, who are accustomed to independence in operations within a certain region. Wissema and Euser (1991) mention that entrepreneurs are not really keen on open collaboration with other organizations outside their immediate circles. Second, Hoffmann and Scholosser (2001) acknowledge that cultural differences and lack of joint research experience hinder collaborative networks amongst SMEs. Third, SMEs lack proper planning and management for orchestration of collaborative networks, which might lead to unintentional spillover of research knowledge Kristijian et al., 2015). Last, as the number
and diversity of actors in the collaborative networks increase, the scarcity of related experience and knowledge among SMEs decreases the chances of success of these networks.

Collaboration in networks requires readiness to indulge into open innovation. Open innovation can be distinguished between inbound open innovation, referring to the organization’s internal use of external knowledge sources for innovation efforts, and outbound open innovation, referring to the transfer of innovations created internally to other external organizations (Chesbrough et al., 2006). More specifically, the creation of innovations with knowledge from external sources such as universities, research centers, customers, suppliers, competitors, venture capitalists, and industry/cluster associations can be considered as inbound open innovation, whereas the transfer of internal innovations to other organizations, for example, through out-licensing of patents or revealing of source code, can be considered as outbound open innovation (Chesbrough et al., 2006).

The era of open innovation has just dawned. A major shift has started towards a new paradigm in the sense of Kuhn’s (1962) scientific paradigms. A real paradigm shift differs from fashion and science hypes in terms of its long-term impact (Gassman et al., 2010). Leading industries of today are opening up their innovation processes. For example, following the open source trend in software, organizations like Microsoft and SAP have established decentralized research laboratories on university campuses to increase their absorptive capacities for outside-in innovation processes. Modern technology is becoming so complex that even large firms cannot afford to develop new products alone. Consequently, there is a strong trend towards R&D partnerships and alliances (Hagedoorn and Duyster, 2002).

It is not only these large firms opening up their innovation processes. Small and medium enterprises have also started indulging into open innovation. Empirical evidence regarding ‘born globals’ – rapidly growing SMEs already active on a global scale early in their existence – indicates that the source of their competitive advantage is the protection and leveraging of their intellectual property (Gassman et al., 2010). Rapidly growing SMEs can also take advantage of external technology commercialization through open innovation initiatives. The analysis in the latter part of this paper shows how this aspect is quite weak in the case of SMEs in Singapore.
SMEs are the largest number of enterprises in any economy but the research literature on open innovation activities in these ubiquitous entities is scant. The complexity of challenges encountered by SMEs in their open innovation efforts call for the rise of the intermediaries for tackling these challenges. I attempt to identify the roles of innovation intermediaries that can assist Singaporean SMEs reap maximum benefit from open innovation.

The subsequent part of this paper will shed light on how Singapore’s public policy needs to bring into stronger consideration the important role of innovation intermediaries for promoting open innovation in Singaporean SMEs. Singapore has come a long way in showing casing to the world its cutting edge national innovation system. Sustaining this and taking it to the next level of sophistication need to bring in the SMEs into the equation.

**Evolution of Singapore’s SME Policy**

As mentioned in the earlier part of the paper, Singapore is a highly developed economy. It is ranked among the best on various indicators such as Human Development Index, national competitiveness and quality of living standards. Singaporean STI policy has evolved since 1989- the year “The Next Lap” came into force. At present a plan for enhancing the national competiveness is being implemented in the shape of Research Innovation and Enterprise 2020 (RIE 2020).

Singapore experienced a recession in 1985. After the economic storm subsided, the policy makers came together to chart out the future course of action for the Singaporean economy. There was a common realization to strengthen the indigenous production capacity of Singapore and move away from too much focus on MNCs and big government linked companies (GLCs) as the main drivers of economic growth of the country. A report, Singapore Economy: New Directions, produced by the Economic Development Board (EDB) noted that SMEs accounted for 90% of the country’s total business establishments, yet they lagged behind their foreign counterparts in terms of productivity, management skills, marketing and technology (OECD, 2018). In the light of this report those at the helm of affairs decided to give targeted support to SMEs in order to increase their competitiveness and to augment resilience and growth in the Singaporean economy. With limited domestic market, the importance of accessing foreign markets and promoting local businesses to go global was recognized.
An SME Master Plan to boost SME productivity and help them internationalize was also announced in 1989. Later in 1996, Productivity and Standards Board (PSB) was established with the responsibility for SME policies. Besides the establishment of PSB, SME Enterprise Development and Growth Expansion Program was also launched in 1996. In 2001, a second SME Master Plan in the shape of SME 21 was launched. The three innovation oriented strategic goals of this plan were: creating a knowledge-based, pro-enterprise environment; grooming innovative, high growth SMEs and developing a productive SME sector.

In 2002 Standards, Productivity, Innovation and Growth (SPRING) replaced PSB as a new body for the promotion of SME sector. Currently, the responsibility for elaborating the SME policy of Singapore lies with the Ministry of Trade and Industry (MTI). It formulates and coordinates all enterprise development strategies. MTI works closely on this agenda with its statutory boards, EDB and Enterprise Singapore which was formed in April 2018 by merging International Enterprise Singapore and SPRING. Besides this other agencies such as Info-communications Media Development Authority and representatives from industry, academia and civil society are also taken on board. MTI has also established a Research and Enterprise Division (RED), with the mandate of creating an enabling business environment for Singaporean enterprises to form, compete and grow. RED works closely with other government agencies such as Enterprise Singapore, Agency for Science, Technology and Research (A*STAR) and public and private stakeholders. Integrating SMEs into global value chains (GVCs) is a key feature of many government initiatives to develop Singapore’s industries and promote innovation (OECD, 2018)

Another key initiative was the Partnership for Capability Transformation (PACT), which was jointly administered by the EDB and SPRING Singapore. PACT started in 2010 with a funding of S$ 250 million to promote partnerships between original equipment manufacturers and their suppliers, including SMEs. Under the PACT initiative, SPRING worked with large companies to transfer knowledge to SMEs, to support capability upgrading for a large enterprise’s suppliers and to develop and test innovation between a large company and at least one SME. In this way, participating SMEs got opportunities to develop linkages with bigger companies and upgrade their ability to develop innovative products.

The most recent initiative to promote SME integration into GVCs is the Local Enterprises and Association Development (LEAD) programme, jointly administered by SPRING and IE
Singapore. LEAD’s budget has been increased from S$ 90 million to S$ 100 million for the 2016-2020 period (MTI, 2017), with more trade associations and chambers (TACs) engaged under the programme. Under LEAD, TACs have been given the responsibility to lead in industry development and improve the overall capabilities of local SMEs and assist them in internationalisation. By 2017, more than 8 300 local SMEs were expected to have benefitted from projects led by TACs since May 2016 (OECD, 2018). Similarly under the Collaborative Industry Projects (CIP), TACs have been working together to develop solutions that could help SMEs upgrade their capabilities for moving up the value-chain and exploring global market opportunities.

The latest National, Science and Technology Plan in Singapore is being implemented in the shape of the RIE 2020. Through RIE 2020, Singapore is seeking to leverage STI for addressing the challenges being faced by the small open economy. 23 Industry Transformation Maps have been developed for tackling innovation at the industrial level. In April 2017, the SMEs Go Digital initiative was launched to help SMEs use digital technologies and to prop up their capabilities in technology application. A*STAR also partners with SMEs under the Gearing for Growth strategy for enhancing their absorptive capacity for innovation. Under the Grow Enterprise through Technology Upgrade (GET-Up) program, SMEs are being assisted by A*STAR for upgradation of their technical capability.

After the RIE 2020 unveiling, IPI, IE Singapore and the Singapore Manufacturing Federation (SMF), established a consortium to inaugurate the Enterprise Europe Network Singapore (EEN). This innovation and business network covers 28 European Union (EU) countries and over 30 countries outside the EU. EEN has created a great opportunity for Singaporean SMEs as they could enter into partnership with European SMEs in technology transfer and research collaboration.

**Evaluating the Competitiveness of Singaporean SMEs**

The raft of policy measures introduced by the government since late 1980s were aimed to diversify Singapore’s economy by shifting away from an overreliance on MNCs to a robust local SME sector. Higher indigenous productivity was the overarching aim of the various policy initiatives.
In 2016 there were 215,500 SMEs in Singapore. These made up 99 percent of all the enterprises in the country. The total nominal value added by these firms was S$ 196.8 billion.

Statistics from the A*STAR show that R&D expenditures by the local Small and Medium Enterprises (SMEs) have gone up from S$ 322.39 million in 2002 to S$ 725.27 million in 2016. In contrast, R&D expenditures by the foreign companies have increased from S$ 1.12 billion in 2002 to S$ 4.08 billion in 2016. Table 2 shows the comparison of R&D expenditure between local SMEs and foreign companies from 2002 to 2016. These expenditures are necessary to be considered for the subsequent analysis, in the paper, as the amount which is spent on R&D is considered to be an important input for the innovation process.

Table 2: R&D Expenditure by Local SMEs and Foreign Companies

<table>
<thead>
<tr>
<th>Year</th>
<th>Private R&amp;D Expenditure by Local SMEs (S$ million)</th>
<th>Private R&amp;D Expenditure by Foreign Companies (S$ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>322.39</td>
<td>1106.08</td>
</tr>
<tr>
<td>2003</td>
<td>366.06</td>
<td>1245.27</td>
</tr>
<tr>
<td>2004</td>
<td>416.81</td>
<td>1656.96</td>
</tr>
<tr>
<td>2005</td>
<td>423.47</td>
<td>2026.43</td>
</tr>
<tr>
<td>2006</td>
<td>487.79</td>
<td>2243.93</td>
</tr>
<tr>
<td>2007</td>
<td>517.76</td>
<td>3135.23</td>
</tr>
<tr>
<td>2008</td>
<td>496.36</td>
<td>4082.93</td>
</tr>
<tr>
<td>2009</td>
<td>564.69</td>
<td>2708.75</td>
</tr>
<tr>
<td>2010</td>
<td>501.25</td>
<td>2815.22</td>
</tr>
<tr>
<td>2011</td>
<td>550.98</td>
<td>3504.28</td>
</tr>
<tr>
<td>2012</td>
<td>546.44</td>
<td>3116.1</td>
</tr>
<tr>
<td>2013</td>
<td>576.28</td>
<td>3138.75</td>
</tr>
<tr>
<td>2014</td>
<td>795.39</td>
<td>3549.4</td>
</tr>
<tr>
<td>2015</td>
<td>693.27</td>
<td>4352.36</td>
</tr>
<tr>
<td>2016</td>
<td>725.27</td>
<td>4078.55</td>
</tr>
</tbody>
</table>
Methodology

Time series data were used for fifteen years from 2002 to 2016 for evaluating the innovation related activities of the Singaporean SMEs, by constructing two regression models. In the first model patents awarded, to the SMEs since 2002, were regressed on the number of researchers and R&D expenditures of these firms. Patents awarded are considered a relevant output in estimating innovative activities of firms. They create incentives for inventors and entrepreneurs to invest in innovations and protect them from imitators for gaining temporary monopolistic profits. Whereas the number of people engaged and the amount of money spent on R&D indicate the inputs going into the innovative processes. Both of these are considered as explanatory variables for award of patents which has been treated as the dependent variable.

For the second model, licensing revenue and sales revenue, of the SMEs, from the patents and new technologies were combined and regressed on the number of researchers and R&D expenditures of these firms. Here the dependent variable was changed from patents awarded to revenues earned through commercialization of the innovation outputs to gauge the extent of difference between patents and revenues as a result of R&D activities. This variable is also important to take into account given the limited resources SMEs have. The assumption for bringing in this dependent variable is that SMEs may only be able to improve their R&D spending for future projects if they are able to fetch good revenues from licensing and sales of their previous R&D activities.

Data Sources

Data sets on local SMEs, their R&D expenditure, number of personnel involved in R&D, patents applied, granted and owned, revenues from licensing and sales of patents and new technologies were obtained from official statistics website of Singapore and A*STAR reports.

Results

The results of the regression models are shown in Tables 3 and 4. For the first model, it is clear that the impact of R&D expenditure on patents awarded is almost three times as much as the number of researchers. The respective coefficients of 0.16275 and 0.05795 show this. The results
are also statistically significant as depicted by the p-values. In the second model, the results were not found to be statistically significant. This means that Singaporean SMEs are able to take some benefit in the shape of award of patents from the increase in their R&D expenditure and personnel over the last fifteen years. The impact of increasing the R&D expenditure is greater as compared to increasing the number of researchers. However, results in Table 4 show that SMEs in Singapore have not been able to fetch handsome revenues from their R&D activities as the impact is not statistically significant in terms of revenues obtained by the Singaporean SMEs. This finding validates Wong and Ho’s (2017) findings in their study of impact of R&D capital stock on TFP in Singapore. This means that Singaporean local SMEs have weak capacity to commercialize their innovative products.

Table 3: Impact of No. of Researchers and R&D Expenditure on Patents Awarded to SMEs

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>Estimate</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>-179.13051*</td>
<td>69.24545</td>
</tr>
<tr>
<td>Researchers</td>
<td>0.05795**</td>
<td>0.01790</td>
</tr>
<tr>
<td>R&amp;D Expenditure</td>
<td>0.16275*</td>
<td>0.07310</td>
</tr>
</tbody>
</table>

R²: 0.6363
Adjusted R²: 0.5756
Num obs.: 15

***p < 0.001, **p < 0.01, *p < 0.05

Table 4: Impact of No. of Researchers and R&D Expenditure on Licensing and Sales Revenue earned from patents and new technologies in SMEs

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>Estimate</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>3813.938</td>
<td>3881.295</td>
</tr>
<tr>
<td>Researchers</td>
<td>-1.531</td>
<td>1.003</td>
</tr>
<tr>
<td>R&amp;D Expenditure</td>
<td>6.851</td>
<td>4.097</td>
</tr>
</tbody>
</table>

R²: 0.2511
Adjusted R²: 0.1263
Num obs.: 15

***p < 0.001, **p < 0.01, *p < 0.05
Conclusion

In the light of the results obtained from the quantitate analysis it is clear that SMEs in Singapore need more assistance on commercializing their products. The domestic market is very small but there are immense opportunities arising from growing markets in ASEAN region as well as Singapore’s contiguity to huge markets of China and India. The role of downstream innovation intermediaries will be very important for achieving substantial improvements in the area of commercialization.

The establishment of IPI as a non-profit organization in April 2011 by the Ministry of Trade and Industry of Singapore is a good step in the right direction. IPI has worked for some years for developing a worldwide network of technology partners and marketplace featuring innovative technology from a variety of different industries.

In the first five years after its inception, IPI reached out to 1,000 companies in Singapore for matching them with technology. Various forums, talks and industry roundtables are organized by IPI for sharing emerging trends and technologies. Participants of these events include local and overseas technology partners/companies along with trade and industry associations. In addition to it, an online Technology Marketplace has been established by IPI where technology innovation seekers and providers interact for matching technology needs and offers. An annual industry-to-technology matching event known as TechInnovation is also organized by IPI. TechInnovation provides a great opportunity for accelerating the commercialization of emerging technologies by bringing together international technology providers and enterprises. The event is also important from the point of view of seed licensing opportunities and promoting open innovation collaborations. TechInnovation is an ideal platform to “Discover, Connect & Collaborate with local SMEs, technology providers, multi-national corporations, enterprises and public agencies.”

IPI welcomes inventors, research organizations, technology transfer offices, IP service providers or enterprises with licensable technologies to work with it as partners. TechInnovation offers a great opportunity for businesses to discover and explore potential technologies for achieving operational effectiveness. For example, at the TechInnovation of 2014, Courex Pte. Ltd., a third party logistics company came across a technology offering real time traffic prediction and route

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guidance developed by Nanyang Technological University. IPI facilitated the interaction between the company and the university. Eventually Courex commissioned NTU to build a smart algorithm to optimize its route planning for deliveries in dense urban centers. Courex was able to cut on time and fuel costs in addition to a reduction in its carbon footprint, a great success story indeed.

EEN Singapore for connecting SMEs of Singapore to Europe is also a commendable step. However, more efforts are needed for assisting SMEs through larger role of innovation intermediaries operating in the downstream part of the value chain. Singaporean success story has been remarkable but sustaining the trajectory of innovation is a challenging proposition given the small home market, openness of the economy and presence of large MNCs. Taiwan’s case is worth studying for drawing lessons.

**Limitations and Future Research**

Patents and licensing/sales revenue from patents and new technology have been used in the model. However, using other variables such as nominal value added and exports of SMEs may also bring out clearer picture of how the SMEs are doing in Singapore. Moreover, IPI came into being only seven years ago and before that the aspect of commercialization of SME products was not being handled in an organized manner as it is being done now. This is evident in the activities and achievements of IPI which need to be explored further. The time series data considered in the paper takes into account data from nine years before IPI’s establishment. The results of IPI activities may show effect with a lag. Future studies may take that into account when drawing more conclusions about role of intermediaries especially in downstream activities for SMEs.

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