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Technology and Innovation Policies for Small and Medium-Sized Enterprises in East Asia

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Abstract

Policies for stimulating technological development and innovation in small and medium-sized enterprises can be divided into three groups. Supply-side policies aim at increasing firms' incentives to invest in innovation by reducing costs. Demand-side policies are public actions to induce innovation and/or speed up the diffusion of innovation. Systemic policies focus on strengthening interactive learning between actors in innovation systems. Policies can be implemented through various instruments comprising tax incentives, grants or direct subsidies, low-interest loans, and the government's direct equity participation. These instruments have pros and cons. The experiences of four late-industrializing East Asian economies—Taipei,China; Singapore; Malaysia; and Thailand—provide key lessons. Firms at different levels of technological and innovative capability need different policy instruments. The more successful economies have a higher level of flexibility and policy coordination and learning. The amount, duration, and continuity of government supporting schemes are crucial. Policy makers must have a deep understanding of what constitutes innovations and innovation systems, and how they evolve over time. Innovation financing policies require other corresponding policy initiatives to make them successful. Lastly, institutional factors do shape the choices and effective implementation of these policies.

JEL Classification: D22, L25, O31

Contents

1. INTRODUCTION

East Asian countries are latecomers to industrialization. According to Gerschenkron (1962), while, in general, latecomer countries enjoy the advantage of utilizing the technological and institutional advances created by the forerunner countries, they also face two disadvantages in competing in the global market:

(i) They lack research, development, and engineering capability, and their poorly developed industrial and technological infrastructure operates in isolation from the world centers of science and innovation.

(ii) They are dislocated from international markets, whose demands help stimulate technological advances and innovation (Hobday 1995).

Most developing countries before the 1990s experienced these two conditions.

Nonetheless, several firms in latecomer economies in East Asia—especially Japan; the Republic of Korea; Singapore; and Taipei,China—were able to exploit their advantages and overcome their disadvantages by increasing their technological capabilities and designing organization setups. This enabled them to enter and upgrade in the global value chain from original equipment manufacturers to own-design manufacturers, and, in some cases, to own-brand manufacturers. Some small and medium-sized enterprises (SMEs) became large, even global, firms, but most remained weak in technology and innovation.

This paper aims at examining the effectiveness of technology and innovation policies for SMEs in Asia. We will examine the pros and cons of different types of technology and innovation policies for SMEs based on the experiences of selected economies.

2. TYPES OF TECHNOLOGY AND INNOVATION POLICIES FOR SMES

Technology policies for SMEs can be divided into three groups; supply-side technology policies, demand-side technology policies, and systemic technology policies.

2.1 Supply-Side Technology Policy

The aim of supply-side policies for innovation in firms is to increase incentives to invest in innovation by reducing costs. Supply-side policies encourage investments that otherwise might not be undertaken as liquidity constraints caused by capital market imperfections can be substantial when it comes to innovation.

The most commonly employed supply-side technology policy is subsidy in a broader sense for R&D. It includes tax incentives, grants and subsidies, loans, and direct equity participation (direct government investment as well as support through government-owned or -linked venture capital). These instruments have both pros and cons, which will be discussed in section 3. Relatedly, complementary supply-side policy is to help train skilled workers and scientists and engineers.

2.2 Demand-Side Technology Policy

Demand-side technology policy is not limited to policies to create markets for products made by SMEs. The most crucial demand-side technology policy is public procurement. Central and/or local governments might procure goods and services from SMEs that meet certain conditions, such as clearing certain technological thresholds or being able to deliver products or services with better functions than existing ones; for example, those that significantly reduce energy usage and carbon dioxide generation, or increase speed and productivity. Importantly, government can provide the first market for innovations that might not be ready for acceptance by private markets due to high risk and the highly uncertain nature of innovations. In essence, public procurement can provide the first business opportunities for firms with innovative products and services. This kind of opportunity is sometimes even more meaningful for firms than any financial support from government.

In addition to public procurement, government can stimulate the private market to accept innovative products and services through various mechanisms. These include labeling, market promotion, and subsidizing and/or providing tax incentives for buyers of innovative products or adopters of innovative processes. For example, the governments in several countries provide labels or support labeling campaigns on environmentally friendly and healthy products. Feed-in tariffs for electricity from renewable energy sources have been adopted in several developed countries. Financial incentives were provided to private house owners who installed photovoltaic systems on their roofs in Germany.

Governments can also help to create markets for the products of SMEs, who do not have resources for marketing, by facilitating the marketing of their products in other areas and countries. Caution should be exercised as this system has the risk of restricting competition and leading to corruption, and there are World Trade Organization regulations on government procurement.

Here, it should be noted that it is very important to create an environment where firms demand better technology to be successful in the market. In this sense, policies that will incentivize SMEs to demand better technologies are important, although they may be outside of the conventional technology policy. We consider this particularly important because it is often the case that many standard technology policies, such as the provision of subsidies or tax breaks for R&D, or opportunities for closer ties with universities, are not used by firms. This is particularly so in the case of SMEs. Therefore, various policies should be employed to incentivize SMEs to demand better technology. It is important to note that those who successfully obtain better technologies and use them to produce or significantly improve their products or processes are rewarded by markets. It is of vital importance for policy makers to create such an environment through patent policy, antitrust policy, antigraft policy, and so on. These policies create an environment in which those who invested in learning and adopting better technologies are rewarded. These policies may be beyond the scope of technology policy in a narrow sense. Nevertheless, they are extremely important policies. If the only companies who can prosper are those who steal technology, obtain government contracts through bribery or cozy relationships with politicians, or oppress smaller firms through market power—instead of companies who work hard to upgrade their technology—these is little incentive to demand better technology.

2.3 Systemic Technology Policy

In addition to supply-side technology policy and demand-side technology policy, there is a set of technology policies that aims to improve the performance of innovation systems mainly by promoting better coordination of their actors. SMEs' performance can be improved by working more closely with universities and public research institutes. Various policy measures can be employed to promote closer relationships. For example, a targeted subsidy could be provided for collaboration between SMEs and universities to develop a particular technology or product. Closer ties between university researchers and engineers of SMEs are encouraged through these collaborative projects, networking events, consulting, contract research, and so on. These can be promoted through subsidies and other policy measures.

One interesting policy is to establish local technology centers in various areas in a country. It is not uncommon for countries to establish agricultural extension services to help farmers to choose the right crop or fertilizers for the region, to teach when to apply which fertilizers, and so on. This model can be applied to the manufacturing sector to help local industry. In Japan, such local technology centers were established around the turn of the century, and they helped local companies in industries such as textiles, food, and pottery to upgrade their technology, improve their management, control product quality, and train employees.

These technology centers were usually established by local governments. Therefore, the expertise of the people in local government is important. They should be able to plan and execute effective local industrial policy. They should be able to coordinate local technology centers with local industry associations, vocational schools, and/or universities. They should make all the arrangements so that local technology centers become the hub of the local innovation system.

Another important way for SMEs to learn is to learn from large firms (multinational and domestic) who purchase their products as inputs. Large firms buying intermediate goods, parts, materials, and various services benefit from helping their suppliers, as better parts, materials, and services help their operations. Here, what policy can do is rather limited. Forcing the use of local contents is not a productive idea, as large firms will choose other places with no such requirements. Helping SMEs move closer to large buying firms' plants may be valuable, as geographic proximity is important for transfer of uncodified knowledge. Alternatively, government agencies can act as intermediaries to facilitate technology transfer and other linkages between large firms and SMEs. This will be elaborated upon in the discussion of the Singapore case in section 4.2.

3. ADVANTAGES AND DISADVANTAGES OF DIFFERENT POLICY INSTRUMENTS

Both supply- and demand-side policies can be deployed by several instruments, such as tax incentives, grants or direct subsidies, low-interest loans and loan guarantees, and government direct equity participation. Though application is needed and the outcome is not guaranteed, an R&D tax incentive has been adopted in many countries since it is much more generic and applies equally to all firms engaged in R&D. This relieves the government of the difficult task of choosing the right firm and monitoring their activities, as all R&D-performing firms are eligible to apply. However, this type of incentive is generally less focused than direct government subsidies, which can target particular activities, clusters, or sectors. The effectiveness of tax incentives also

depends largely on the definition of R&D, administration of incentives, eligibility of firms, and type of R&D tax incentives (OECD 2002).

Grants can be more effective than tax incentives in encouraging specific activities, sectors, clusters, or firms, but they require higher government capabilities to select and meet targets. The selection and management processes are also complicated and can be subject to political intervention as well as corruption, cronyism, and nepotism. Loan programs are more popular in countries with problems giving direct grants to the private sector for innovative projects. For these risk-averse countries, providing loans is safer for the government, simply because loans have to be paid and need collateral guarantees. Equity financing can be used selectively, like grants. Recipients can also get the money up front, which means investment risk can be substantially reduced, as funding agencies share the risk with firms from the very beginning of projects. Having government co-invest in a project can increase creditability of recipient firms. Still, writing off bad projects financed by public funds is problematic. Table 1 summarizes the advantages and disadvantages of these instruments.

Table 1: Technology and Innovation Policy Instruments: Advantages and Disadvantages

Type	Advantages	Disadvantages
Tax concession	– Nondiscriminatory, open to all – "Arm's length" instrument; activities chosen by industry – Maintenance of firm's confidentiality – - Speedy processing (where approval is automatic)	– Of no benefit to unprofitable or start-up firms – Subsidizes existing activity that would have occurred anyway (unless based on incremental performance, which is hard to police)
Repayable loan	- Can be targeted widely or focused - Priorities or scope (type, timing, size) set by government – Specific proposals can be made by firms	- Requirements (e.g., collateral) work against small and medium-sized enterprises and start-ups – Procedures are long and cumbersome
Grant	- Benefits targeted activities, sectors, clusters, some types of firms - Allows prioritization and therefore is appropriate for innovative projects – No need to write it off	- May be subject to criticism for being unfair – Government must have the ability to select recipient
Equity participation	- Benefits targeted activities – Firms get investment money up front, reducing risks and uncertainty and increasing creditability	- May be subject to criticism for being unfair - Government must have the ability to select recipient – Must write off bad projects

4. POLICY EXPERIENCES OF SELECTED EAST ASIAN ECONOMIES

This section aims to shed light on the effectiveness of policies to enhance technological and innovative capabilities of SMEs by examining the experiences of Malaysia; Singapore; Taipei,China; and Thailand. Two criteria were used to select them:

(i) SMEs should be economically significant in these economies. Although Japan and the Republic of Korea are technologically successful, their economies are dominated by large firms.

(ii) Serious industrialization and technological development should have taken place around the same time. The four selected economies started in the 1960s.

Within these four economies, Singapore and Taipei,China are now high-income economies, while Malaysia and Thailand are still middle-income economies that may be facing a middle-income trap. The differences in innovation policies and the concomitant performance between the two groups will be illustrated later in Section 4.

We will examine the extent to which these economies are influenced by different technology and innovation policy content and implementation. By adopting a history-friendly and longitudinal approach, the paper will trace any co-evolutions between government policies and the increase in technological capabilities and innovation in firms in the four economies and determine how they happened. The empirical results draw extensively on *Towards Effective Policies for Innovation Financing in Asia*, a study under the authors' leadership for the International Development Centre of Canada in 2010–2011 (Intarakumnerd and Wonglimpiyarat 2012).

The East Asian economies discussed here started serious industrialization in the 1960s and achieved remarkable growth rates. Singapore saw one of the most impressive economic growth records in the last 4 decades, with 7.6% gross domestic product (GDP) growth per annum over 1960–2009. Singapore's per capita GDP of $72,724 in 2012 (on a purchasing power parity basis) stands as one of the highest in Asia. Singapore's national innovation system was transformed from one with primary emphasis on technology adoption—particularly the assimilation and diffusion of technology by leveraging inward investments by transnational corporations—to one with a more balanced approach that significantly encourages indigenous innovation capability, including basic and strategic R&D and the creation of local high-tech firms (Wong and Singh 2012). Singapore's innovation financing schemes co-evolved with the development of its national innovation system. Its earliest schemes targeted diffusion of innovation and development of the capability to transfer technology, particularly from transnational corporations. These schemes remain the most common type of innovation assistance program. From the late 1980s, the government also focused on developing applied, and then basic, R&D capabilities, particularly through the use of grants and tax incentives. Start-up support schemes were first implemented in response to the policy focus on high-tech entrepreneurship during the late 1990s. Technology commercialization schemes, which began in the mid-2000s, are the more recent development in innovation policies (Wong and Singh 2012).

Similarly, Taipei,China's average annual growth rate has been an impressive 8% in the past 3 decades. Taipei,China is now a high-income economy, with GDP per capita (on a purchasing power parity basis) of $39,059 in 2012. It adopted the "second mover" strategy of entering the global high-tech market only after the product matured and exploiting manufacturing and project execution capabilities (Amsden and Chu 2003). The government-sponsored research institutes, especially Industrial Technology Research Institute (ITRI), were important in implementing the strategy, which can be considered as a systemic policy. They assimilated advanced technology from overseas, including from transnational corporations, then rapidly diffused the technology to local firms through spin-offs, R&D consortiums, and the movement of researchers. Starting by licensing technologies from RCA, a leading American semiconductor firm, ITRI conducted further research to understand, assimilate, and upgrade the technologies. It later spun off several units that became global leaders in the semiconductor industry.

R&D consortiums were also used to diffuse and upgrade existing technologies and build trust among participating firms. A remarkable success story is the case of the

notebook PC. ITRI developed draft specifications for a "common machine architecture" and invited the Electrical and Electronic Appliance Manufacturers' Association to be the joint coordinator. Later no fewer than 46 companies joined the consortium. A prototype was then developed and translated into a series of standardized components that could be mass-produced by manufacturers in Taipei,China. ITRI followed up by providing extensive training to member firms. Many of the ITRI engineers moved across to member firms, which was another form of diffusion of technological capability (Mathews 2002).

The institutes have also increasingly served as the coordinating agency for promoting the creation of indigenous technology via innovation networks and strategic R&D programs (Wong 1999). As a result, although not yet technologically on par with their Western counterparts, many firms in Taipei,China that started as SMEs have enhanced their technological and innovative capabilities and climbed up the global value chain. Like Singapore's, Taipei,China's innovation financing policies, together with other government interventions (especially the intermediary role of government research institutes), have been significant in the learning processes of its firms. These programs also co-evolved with the development of Taipei,China's firms' technological capabilities and innovation system. The schemes of the 1960s–1980s focused on developing absorptive capacity to take advantage of foreign technologies. During the 1990s, the schemes began to focus more on helping firms develop new products, enhancing R&D capabilities, and encouraging the emergence of start-up companies in emerging sectors such as biotechnology (Liu and Wen 2012).

The experiences of Malaysia and Thailand have been significantly different from those of Singapore and Taipei,China. Although Malaysia and Thailand have made remarkable socioeconomic progress over the past 4 decades (with average annual GDP growth rates of more than 7%) and attained middle-income status, both are stuck in the "middle-income trap"—the inability to produce differentiated and sophisticated products and climb up the global value chain. The national innovation systems of Malaysia and Thailand are weaker and more fragmented than those of Singapore and Taipei,China (Thiruchelvam et al. 2012; Intarakumnerd et al. 2002). Likewise, firms in Malaysia and Thailand have lower technological capabilities and exhibit more "passive" learning patterns. The innovation financing schemes of these two economies have not co-evolved as much with the development of technological capabilities of firms and national innovation systems. Thailand, in particular, has been unable to quickly modify its schemes. Most policy instruments in Thailand are limited to tax incentives and only for R&D. In Malaysia, however, several grant schemes target firms' different development stages. Such schemes in both economies have been hindered by fragmented policies and government agencies' inability to monitor, evaluate, and learn from policy implementation.

We will now examine in detail the four economies' policy instruments to find similarities and differences in content and execution.

4.1 Tax Incentives

Malaysia, Singapore, and Thailand have R&D tax incentives based on R&D expenditure (double deduction) while Taipei,China has adopted R&D tax credits. Tax incentives based on R&D expenditure allow firms to deduct more expenses for tax purposes than what they actually spend, while R&D tax credits allow firms to deduct a percentage of their R&D spending directly from companies' final tax liability. Singapore's tax incentive system, like other financial incentives, has evolved according to the country's strategy and level of technological capability, unlike in Malaysia and

Thailand. When Singapore wanted to attract the labor-intensive electronics industry from the US and Japan, its government offered "pioneer status," with attendant tax holidays of up to 15 years and other benefits, to transnational corporations to invest in strategic projects in Singapore (see Table 2). From the late 1980s to the late 1990s, when the strategy shifted to position Singapore as an R&D hub for transnational corporations, the government launched the Research and Development Tax Deductions Program. Unlike in other economies, this deduction included R&D activities that took place outside Singapore (but were related to and benefited those in Singapore), although the deduction rate was lower than for those of local activities.

Table 2: Comparison of Tax Incentives in Thailand, Malaysia, Singapore, and Taipei,China

Year of Operation	Thailand	Malaysia	Singapore	Taipei,China
	1996	1982	1960s	1991
Type	Tax incentives on expenditures	Tax incentives on expenditures	Tax incentives on expenditures	Tax credits
Coverage	R&D (strict definition), training, collaboration with universities	R&D, commercialization of R&D	Pioneer activities, R&D, R&D hub (covering R&D outside Singapore), design, acquisition of intellectual property rights and automation equipment	R&D, training, using certain technologies
Focus (sector, cluster, technology, type of firm)	General	General, specific (biotechnology, information and communications technology, East Coast Development Region), and firm-specific (prepackaged incentives)	Pioneer status (strategic activities and sectors), convertible to grants for start-ups	General and specific (automation, energy saving, pollution control, digital technologies)
Project-by-project approval	Yes	No	No	No
Effectiveness	Number of approved projects increased but still from a limited number of firms	Increase in number of projects but decline in number of applying firms	Increase in number of firms doing R&D in Singapore, especially transnational corporations	Increased number of approved tax deductions in money terms but no significant changes in number of applying firms; increase in employment, gross domestic product, and net tax revenues

R&D = research and development.

It seems that Singapore's government officials have an understanding of how global R&D networks of transnational corporations operate and what constitutes an R&D hub, and that successful innovation needs more than R&D: it needs the support of a combination of several activities. Beginning in the late 1990s, when Singapore emphasized indigenous innovation by high-tech entrepreneurs, the government also

initiated the R&D Incentive for Start-Up Enterprises. It was designed to meet the needs of R&D-intensive start-ups, which usually spend the first few years developing products and incurring losses. Tax exemption is therefore not useful to them. The program also made these start-ups eligible for cash grants during their initial years equivalent to the benefit they would receive from R&D tax credits once they are profitable. Since 2010, firms have been able to deduct 400% of their expenditure from their income, subject to a cap of 800,000 Singapore dollars (S$), from innovation activities, including not only R&D but also design, registration and acquisition of intellectual property rights, and acquisition of automation equipment.

Taipei,China's tax credit program covers not only direct R&D activities but also expenditures on critical activities to upgrade firms' activities: automating production, reclaiming resources, controlling pollution, using clean and energy-saving technologies, and using digital information technologies more efficiently. The experience of Taipei,China illustrates that, like Singapore, it understands how to implement government incentives to tackle companies' technological upgrading problems.

Malaysia implemented its double deduction program more than 10 years earlier than Thailand. Malaysia's R&D tax incentive schemes are also much wider in scope than Thailand's, dealing not only with R&D activities but also the commercialization of R&D findings. Apart from double deduction of R&D expenditure, Thailand's Board of Investment initiated a scheme in 2003 to promote "skill, technology, and innovation" by offering 1 to 3 more years' tax exemptions for companies already receiving standard tax privileges if they conducted in-house R&D, in-house training, and R&D collaboration with local universities. Malaysia's tax incentive system is more selective than Thailand's. It has tax incentives for targeted industries such as information and communication technology (ICT) and biotechnology, activities such as medical device testing, and geographic clusters such as the East Coast Economic Development Region. Incentives customized on the merit of each case—the "prepackaged incentives"—have also been introduced recently. Unlike Thailand, therefore, Malaysia has both generic and selective tax incentives.

Regarding the efficiency of tax incentives, only Thailand scrutinizes companies wanting to apply for R&D tax incentives and on a project-by-project basis. Other economies periodically conduct ex-post evaluation of the overall impacts of tax incentives on firms' innovation and impacts on the economy. The application process in Thailand is cumbersome and conflicts with a main advantage of tax incentives, which is supposed to be a fast and almost automatic application process. The level of trust in Thailand's society is low and its government has been worried about false claims. Thus, the Revenue Department (responsible for double deduction of R&D expenses) authorizes the National Science and Technology Development Agency (the largest public research institute) to verify whether submitted applications are R&D projects and whether their proposed expenses are appropriate. Since many proposals are submitted, the average approval period is as long as 5–6 months. Similarly, project-to-project approval is required for firms wanting to take advantage of the Board of Investment's Skill, Technology and Innovation policy. The number of approved projects, however, has increased over the years. Likewise, in Taipei,China, after 2000, the monetary value of approvals has increased year by year, but the number of companies applying for such incentives has not significantly changed. It is mainly the large firms in Malaysia and Thailand that benefit from R&D tax incentives, not SMEs, which generally do not have R&D capabilities.

Only Taipei,China has conducted a formal study on the impacts of its tax incentives. It found that tax credits for encouraging R&D, training, and automation have induced further R&D investment, leading to more jobs and higher GDP. As a result, there have

been significant positive net effects on tax revenue (Liu and Wen 2012). In Thailand, however, although one cannot observe direct causation, results from community innovation surveys illustrate that innovative firms used R&D tax incentives more than non-innovative firms.

4.2 Grants

In Singapore, grants are the key instruments for financing technological capability development and innovation. Singapore has also had a greater variety of grant schemes targeting all activities in the value chains, which have evolved according to the country's level of development and the technological capabilities and needs of firms. In the 1970s and 1980s, Singapore initiated schemes such as the Local Industry Upgrading Program to promote technological diffusion from transnational corporations to local enterprises (Table 3). Under this scheme, the Economic Development Board subsidized for 2 years a percentage of the salary of a manager sent by a transnational corporation to work in a local enterprise. As of 2010, more than 200 transnational corporations and 1,000 local suppliers had been involved in the program. This is an illustration of using systemic policies to leverage transnational corporations' strength to upgrade local SMEs. Without targeted policies like this, the spillover impacts from transnational corporations would be limited.

Table 3: Comparison of Grant Schemes in Thailand, Malaysia, Singapore, and Taipei,China

	Thailand	**Malaysia**	**Singapore**	**Taipei,China**
Year of Operation	**1990s**	**2000s** (becoming more unified)	**1970s**	**1980s**
Level of significance compared with other mechanisms	Not significant	Very significant	Very significant	Very significant
Coverage	R&D, prototyping, pilot scale	The whole spectrum (pre-R&D, R&D, commercialization, acquisition of other firms' intellectual property rights)	Wide-ranging and evolving according to the needs and capabilities of firms	Wide-ranging and evolving according to the needs and capabilities of firms
Focus (sector, cluster, technology, type of firm)	General	Both general and specific (technologies, sectors, clusters, products)	Both general and specific (sectors, technologies, types of firms)	Both general and specific (sectors, technologies, products)
Effectiveness	Too small to have critical success	Criticism of lengthy approval processes and duplication of schemes	Effective older policies (e.g., Local Industry Upgrading Program, enhancing linkages between transnational corporations and local firms), but only moderate success with recent policy on promoting high-tech start-ups	Inducing substantial R&D investment from recipient firms, supporting creation of new industries or products; small and medium-sized enterprises benefited significantly

Grant schemes were also given to individuals and companies to promote critical skills such as ICT. In the 1990s, when firms in the country needed to increase their R&D capability, the government initiated a grant scheme to leverage Israel's R&D

capability by funding feasible collaborative R&D projects of firms in the two countries. Since the late 1990s, whenever the government has wanted to promote high-tech entrepreneurship and basic R&D, it has initiated grant schemes. An example is the Technology Innovation Program, which covers 50%–70% of equipment, materials, labor, software, and intellectual property costs of projects operated by individual SMEs and consortiums. Another is the Innovation Voucher Scheme, which provides SMEs with grants to pay for consultancy and technical services provided by reputable local and overseas universities and research institutes. The government also uses this scheme to promote interfirm collaboration by allowing up to 10 SMEs to pool their vouchers. Singapore astutely uses government schemes to tackle systemic failures of its national innovation systems, which are linkages among local SMEs, and between local SMEs and public research institutes and universities.

The Technology Enterprise Commercialisation Scheme, based on open call and selection, is a competitive grant scheme that was launched in 2008 to support locally owned technology-oriented start-ups and SMEs at the proof-of-concept stage (to conceptualize ideas) and the proof-of-value stage (to carry out further R&D and develop a prototype). Specific grant schemes commercialize technologies developed by universities, encourage polytechnic institutes to conduct translational research on R&D outputs from universities and research institutes, and bridge the gap between universities' seeds and firms' needs by allowing collaborating firms to license technology once proven, but to be under no obligation if the project fails. Some grant schemes are aimed at strategic service sectors (e.g., aviation and animation) and strategic and future-oriented technologies and capabilities (e.g., logistics capability, environmental technology capability, medical technology capability, marine capability, and tourism technology). These schemes are under the management of responsible sector-specific development agencies.

Some grant schemes have been provided by universities to their students to start their own businesses. These recent government schemes targeting early-stage companies, however, have had only moderate success. For example, only one-fifth of surveyed firms were aware of the Innovation Voucher Scheme. Start-ups that have taken part in the recent schemes gave an average rating of 3 on the 5-point Likert scale on three criteria: meeting firms' immediate objectives, improving their long-term growth prospects, and helping them move to the next growth stage. The bureaucracy involved in the application processes must be lessened and awareness of the various schemes raised.

For many years and in various programs, Taipei,China has been using grants as financial instruments to encourage firms to enhance their technological and innovative capabilities. As in Singapore, programs in Taipei,China have co-evolved with the development of firms' capabilities. Several programs are sector specific or even product specific. For example, when firms in Taipei,China gained production capabilities as subcontractors of transnational corporations and wanted to move up the global value chain by attaining product development capabilities, Leading Product Development Program was implemented in 1991 to subsidize R&D costs for high-tech products and know-how such as those produced by the ICT, aerospace, pharmaceutical, and semiconductor industries. About 800 of 1,600 cases were approved, about evenly divided between SMEs and large firms. The results of the Leading Product Development Program were impressive, as NT$1 of grant induced about NT$10 investment in R&D, NT$21 investment in production, and NT$42 in sales. On average, one project generated 3.7 patents and 2.9 derivative products (Liu and Wen 2012). Similarly, when the government wanted to promote local start-ups, it adopted as a model in 1998 the US Small Business Innovation Research

Program, which provided grants to firms in three phases: feasibility studies, R&D, and commercialization. A more generic grant scheme, the Industrial Technology Development Program, was initiated in 1999 to fund the preliminary study and R&D phases of firms aiming to develop forward-looking industrial technologies. NT$1 of grant induced NT$2.46 of R&D and NT$4.89 of capital investment (Liu and Wen 2012). In the 2000s, grants were given specifically to strategic technologies and industries such as conventional technology development, commercialization of biotechnology, and the knowledge-based service industry.

Similarly, Malaysia's Ministry of Science, Technology and Innovation has been providing various types of grants that cover the whole spectrum, from basic and applied research and prototype development (Science Fund) to development of technology for commercialization (TechnoFund) and innovation (InnoFund). The TechnoFund supports the development of pilot plants and upscaling of laboratory prototypes, and field trials and testing. It also has provisions for the acquisition of intellectual property rights from local and overseas entities to be further developed locally during the precommercialization stage. The InnoFund has two categories of grants. The first is allocated to assist individuals and micro and small enterprises in developing new or improving existing products, processes, or services with elements of innovation for commercialization (Enterprise Innovation Fund). The second grant type is used to assist community groups in converting knowledge and ideas into products, processes, and services that improve the groups' quality of life (Community Innovation Fund). This kind of support is for innovation at the bottom of the pyramid. In addition, the Cradle Fund provides support at the pre-R&D phase.

On another front, the Ministry of International Trade and Industry also provides several matching grant schemes to SMEs for business start-ups, product and process improvement, productivity and quality improvement, and the enhancement of *targeted* capabilities in design, labeling, product packaging, and market development and brand promotion (including their activities abroad). Apart from these general grant schemes, some schemes promote strategic technologies, industry clusters, and products. The Multimedia Super Corridor R&D Grant Scheme was set up to assist local companies and joint ventures in developing multimedia technologies and applications that would contribute to the overall development of the Multimedia Super Corridor. The Biotechnology R&D Grant Scheme was established in 2001 under the National Biotechnology Directorate to support biotechnology R&D activities and the commercialization of research findings in specific areas of national importance to the biotechnology industry. Matching grants for developing halal products are also available. All these schemes can be seen as attempts to promote technological and innovative capabilities in the private sector and to forge relations between industry, universities, and public research organizations. Most funds are devoted to applied and problem-solving research projects under the TechnoFund. Although the administration of these schemes has not been formally assessed, it is problematic because project approval takes a long time (Thiruchelvam et al. 2012).

In administering grant programs, Thailand is an exception. Grant schemes are limited in variety and size. The country relies more on indirect support to private firms through such means as tax incentives. Giving public money to private firms gives rise to allegations of cronyism and corruption. Neoclassical economists, who dominate national economic policy agencies (and academia), do not like the idea of selective government interventions in particular industrial sectors, activities, clusters, and firms, as these appear to be working against the market mechanism. The prospect of loss of public money, if grant projects were to fail, is not acceptable to government authorities, especially those in charge of the budget. As a result, grants are given mostly to public

research institutes and universities. Since 2008, R&D grants such as those awarded by the National Science and Technology Development Agency to private firms have been significantly reduced, even practically stopped. The most successful grant giver has been the Industrial Technology Assistance Program, started in 1992, which provides up to 50% financial support for hiring consultants (freelancers or university professors) to help solve SMEs' technological problems. More than 1,000 firms have received financial support from this program. Results, however, have been mixed, as some firms did not carry on developmental activities by themselves after the projects ended. The factors correlated with success appear to be active involvement of executives of firms; clarity of project goals; finding appropriately skilled and devoted experts; and, importantly, the National Science and Technology Development Agency's industrial technology assistants, who act as intermediaries between firms and experts.

Thailand's National Innovation Agency (NIA) also offers a grant scheme to support up to 75% of expenses for prototyping and pilot-scale activities of firms. It gives smaller grants than agencies in other countries (about $160,000 for 3 years) and gave grants to only 56 projects during 2003–2007. However, the number of supported projects significantly increased to 552 during 2010–2014. Recently, the NIA has focused more on the strategic sectors of bio businesses, design and solutions, and energy and environment. In 2011, the NIA adopted the idea of an "innovation coupon" that gives grants to private firms equal to 90% of the project cost to hire listed innovation service providers, either for feasibility studies or for pilot project implementation. The Federation of Thai Industries, the largest association of manufacturers, is a partner in the scheme to help the NIA select the right projects. The results are yet to be seen.

4.3 Loans

Loans are a more prominent innovation financing mechanism in countries such as Thailand. The National Science and Technology Development Agency's Company Directed Technology Development Program has been providing soft loans of up to 75% of total project cost and less than $1 million per project for R&D, product and process upgrading, and building, or refurbishing laboratories. The number of approved projects each year has been small (fewer than 20), however, and recently even smaller as selection criteria have become more stringent: activities of firms must be R&D related and employ technologies new to the industry. For example, acquisition of machinery not related to R&D is unlikely to receive a loan. Most Thailand SMEs, therefore, are not qualified since they do not have R&D capabilities, and the problems they face are more production related. Although the NIA provides zero-interest loans of up to 5 million baht (B) for innovation projects for the first 3 years, setting up the scheme is problematic as loans have to be channeled through commercial banks whose usual selection requirements are not favorable to financing risky innovative projects. As a result, only 38 projects were approved during 2003–2007. Nonetheless, the number of projects increased to 61 during 2010–2014.

In Singapore, loan programs are a much less prominent government financing mechanism than grants and equity. As early as 1976, when Singapore was still trying to exploit technologies generated elsewhere, SPRING's Local Enterprise Finance Scheme was initiated to provide low-interest loans to automate and upgrade factories and equipment, and to purchase factories (Table 4). More recently, a program was set up to help SMEs acquire working capital and machinery. A loan insurance scheme to help SMEs secure loans by providing insurance against default has become available as well.

Table 4: Loan Schemes in Thailand, Malaysia, Singapore, and Taipei,China: A Comparison

Year of Operation	Thailand	Malaysia	Singapore	Taipei,China
	1990s	1970s	1970s	1980s
Level of significance compared with other mechanisms	Significant	Significant	Not significant	Significant
Coverage	Increasingly focused on research and development	The whole spectrum	Evolving according to needs and capabilities of firms	Wide-ranging and evolving according to needs and capabilities of firms
Focus (sector, cluster, technology, type of firm)	General	General and specific technologies, sectors, and activities	General and specific activities	General and specific sectors, technologies, and activities
Facilities supporting access to loans	SME credit guarantee	SME credit guarantee, SME credit rating agency	SME credit guarantee	SME credit guarantee
Effectiveness	Number of applications in some programs has dropped significantly	Applications increased significantly, especially from SMEs, but 90% of recipient firms are Bumiputra (Malay ethic)	Not significant	Number of approved projects increased

SME = small and medium-sized enterprise.

Taipei,China has several loan schemes, including for purchasing automating machinery for manufacturing and agriculture enterprises, revitalizing traditional industries, purchasing energy-saving equipment, promoting industrial R&D, and purchasing computer hardware and software. Firms in service industries, such as the internet and technical service providers, are also eligible. The loan per company is about $2 million to $3 million. From the beginning of the schemes in the 1980s to April 2010, more than 50,000 cases had been approved. Both loans and approved projects are on a much greater scale than in Thailand. The SME Credit Guarantee Fund is also available to help SMEs secure loans from these government programs.

Malaysia has used loans as financial instruments since the 1970s and implemented many schemes for different purposes. Specific low-interest loan schemes for high-tech enterprises and entrepreneurs have been used to stimulate technology development and innovation. Loans for particular groups such as university graduates are also available. Schemes for strategic sectors (e.g., automotive, food), technology (e.g., adoption of automation technology, ICT), and activities (e.g., international branding) are also in place, as well as more generic schemes. Credit Bureau Malaysia (formerly known as SME Credit Bureau) was incorporated in 2008 to give independent credit ratings to SMEs, which usually lack “reputational collateral” for access to finance. The ratings are based on information from the central bank and financial institutions. The bureau is popular and trusted, with a membership of 27,000 SMEs and 38 financial institutions. The credit bureau does not directly evaluate firms’ innovation performance, but they take into account indicators such as new business activities and new products that are related to innovation.

4.4 Equity Financing

Table 5: Equity Financing Schemes in Thailand, Malaysia, Singapore, and Taipei,China: A Comparison

Year of Equity Financing Operation	Thailand	Malaysia	Singapore	Taipei,China
	1987	1984	1983	1983
Stages of VC investment	Expansion and mezzanine	Growth and expansion	Early, growth, and expansion	Established, mass production, and expansion
Specialized funds to support innovative firms through VC	SME VC Fund, Market for Alternative Investment (MAI) Matching Fund	Malaysian Technology Development Corporation (MTDC), Malaysia Venture Capital Management Berhad (MAVCAP)	Platform for Test-bedding, Research and Innovation and New Maritime Technologies (TRIDENT)	Development Fund and SME Development Fund
Sector of VC investment	Food and drink, machinery and equipment, household furnishings, wood products, costumes	Manufacturing, ICT, biotechnology	ICT, biotechnology, medicine, genetic engineering, software, and technology-enabled business services	Optoelectronics, biotechnology, electronics
Formal VC association	Thai VCA established in 1994	Malaysia VCA established in 1995	Singapore VCA established in 1992	Taipei,China VCA established in 1999
Business angel financing	Infancy stage of business angel clubs and networks	Infancy stage of business angel clubs and networks	Has formal business angel network (SPRING)	Has formal business angel network (TWBAN)
Government's direct equity financing	None	None	Several schemes both by government alone and coinvestment with private VC	Large government funds (Development Fund and SME Development Fund)
Effectiveness	Low uptake in government VCs; private VCs are risk averse; fund of funds initiative failed because of insufficient demand; lack of mentoring services	Helped sustain private sector R&D but not yet effective in creating new start-ups.	Surveys show moderate success of new programs but the overall number of high-tech start-ups increased significantly, especially in the past few years	Helped increase high-tech start-ups but not significantly as only 28% of VC funds went to early stages

ICT = information and communication technology, R&D = research and development, SME = small and medium-sized enterprise, VC = venture capital, VCA = venture capital association.

In Thailand, the venture capital industry was first set out by foreign venture capital funds in 1987 (see Table 5). Venture capital investments generally target growth and expansion in the venture life cycle. The major organizations providing venture capital funds to support entrepreneurial development are the Office of Small and Medium Enterprises Promotion, the NIA, One Asset Management, Stang Holding, and the Market for Alternative Investment (MAI) Matching Fund. The Matching Fund, a fund of

funds
with assets of B2,000 million, was set up to increase the number of newly listed companies (including those backed by venture capital) on the MAI. However, the fund ceased operation in 2010 because of a less-than-successful track record. The Revenue Department also provides taxation schemes to support venture capital fund investments. These schemes assist venture capital funds and investors through corporate and personal tax exemption policies. Venture capital funding in Thailand per company is B720 million on average and lasts about 10 years before the exit. Most venture capital funds invest 30% in the early stage and 70% in the growth and mature stages. The leading business angel in Thailand is the Thai–Chinese Business Association. Currently, business angel investment is about B90 million. The deals range from B4 million to B50 million, with no exit strategies (Scheela and Jittrapanun 2010). This means that angel investors in Thailand do not really behave like those in more successful countries like the US, who take a high risk and exit their invested companies when they become successful. Therefore, in practice, innovative Thai businesses at the early and risky stages are not financed by angel investors.

In Malaysia, the venture capital industry began in the early 1980s with the establishment of Malaysian Ventures, whose primary aim was to invest in high-tech industries. The Malaysia Venture Capital Association was established in 1995 to develop a venture capital industry to further support technological innovations. The government is a major source of venture capital financing: most venture capital funds are channeled to Bumiputra-owned and government-linked firms. The major organizations providing venture capital investment funds to support entrepreneurial activities are Malaysia Technology Development Corporation, established in 1992 to provide financial support for multinational subsidiaries, and Malaysia Venture Capital Management Fund, established in 2001 to support entrepreneurial activities of local high-tech firms. Only 7% of total venture capital funds in 2004, however, were invested in the start-up phase.

In Singapore, the government launches innovation financing schemes and programs to support innovative firms, as most venture capital funds are set up with government co-funding (such as Temasek Holdings and Technopreneurship Investment Fund Ventures, which act as funds of funds), and are managed directly by government agencies or government-linked companies (e.g., Economic Development Board Investments, Vertex Management, Economic Development Board Life Science Investment). These government venture capital funds invest in various sectors but mainly in government strategic areas of ICT and, subsequently, biomedical sciences, clean technology, and digital media. To fill the gap in early-stage funding left by private venture capitalists, a government venture capital firm called TDF Management was formed in early 1995. It provides seed funding to entrepreneurs and high-tech start-ups. Apart from funding through venture capital, the government provides "direct" financing, especially to new entrepreneurs and start-ups. For example, the Economic Development Board launched the Startup Enterprise Development Scheme, a cofinancing scheme to take dollar-for-dollar equity stakes in promising start-ups backed by third-party private sector investors in order to fill a market gap in seed-stage funding (Mani 2004). In 2008, the Early-Stage Venture Funding Scheme was founded to match 1 Singaporean dollar of investments in early-stage technology start-ups with one dollar invested by selected venture capital firms. Singapore has also tried to groom its angel investment network, as business angel investors often provide seed funding to support the early stages of new venture development. Business Angel Funds, managed by SPRING, co-funds preapproved business angel groups. Business Angel Funds and the Startup Enterprise Development Scheme complement each other. A start-up that has already received funding from Startup Enterprise Development

Scheme can still apply under Business Angel Funds for a follow-up investment up to 1.5 million Singapore dollars (S$). This is an example of how well financing innovation schemes in Singapore are coordinated, which is not usually the case in other countries. Schemes for promoting start-ups by particular groups of people, such as entrepreneurs under 26 years old, have also been made available. The effectiveness of these recent schemes is moderate. Results of surveys from around 300 start-ups revealed that about one-fifth have participated in such government assistance schemes, with those in the very early stages of growth (i.e., prerevenue firms) having a higher propensity to participate than those in later-growth stages. Still, since 2006, close to 5,000 new high-tech enterprises have been registered each year, and the growth rate of firm formation of high-tech enterprises has increased in recent years, partly because of government financing policy measures.

In Taipei,China, venture capital financing began as early as 1983 with the implementation of the Regulation Governing Venture Capital Business Management to stimulate the development of the venture capital industry. Venture capital investing is mostly done in firms that are established, engaged in mass production, and/or expanding, where the government plays a major role. The Private Equity and Venture Capital Association was established in 1999 to encourage economic development. The Ministry of Economic Affairs supervises the management of venture capital funds. The success of venture capital development in Taipei,China can be tied to the social and economic bridge linking its high-tech industry with the US Silicon Valley. In addition to venture capital enterprises, Taipei,China, like Singapore, also has government direct financing schemes. As early as 1973, the Development Fund was set up to invest directly in innovative companies and invest indirectly through venture capital firms. Strategic sectors such as biotechnology, aerospace, and optoelectronics were the priorities. To stimulate the technological development of SMEs, the SME Development Fund was established in 1994 to invest directly and indirectly through government and private venture capital. These two large funds are the government's main investment arms to promote innovative firms as well as stimulate the growth of the venture capital industry.

The governments of Malaysia, Singapore, Taipei,China, and Thailand play a major role in promoting innovation through venture capital financing schemes that support companies with high growth potential (public sector interventions). Although the venture capital mechanism aims to provide risk capital to firms operating in high-risk environments, venture capital financing programs are not effective in the early stage of entrepreneurial development. Venture capital investment in these four economies tends to come in at the less risky, later stages (expansion), reflecting the funding institutions' aversion to high risk. The angel investment network is not fully developed except in Singapore, where it is a significant source of capital during the early stages of high-tech development. To overcome difficulties in early-stage financing, the governments in Singapore and Taipei,China have initiated "direct' equity" financing programs.

Only a small number of venture capital funds operate in Thailand despite the government policy to promote the venture capital industry. In 2010, only two venture capital funds applied for a venture capital license. The total funds raised by Thailand's venture capital industry represent 0.15% of GDP. In Malaysia, although the government is the main investor in developing technology-based start-ups, the venture capital market's growth is slow because of the lack of human capital and the risk-averse behavior of local venture capital firms. In Singapore, local high-tech companies have effectively used a variety of assistance schemes such as Growing Enterprises through Technology Upgrade, Economic Development Board, SPRING

Singapore, International Enterprise Singapore, and the Political Risk Insurance Scheme. The effectiveness of more recent programs targeting start-ups, however, seems to be moderate. The number of firms is not large but has increased over the years. More importantly, the programs helped to create interest among Singaporeans, especially the young, in starting their own businesses instead of working for the government and transnational corporations as before (Wong and Singh 2012). In Taipei,China, new venture capital investments grew from 1,155 cases in 1998 to 1,850 cases in 2000 as a result of the government tax credit policies to support venture capital companies. After 2000, however, the number of investments decreased after the tax credits stopped.

5. CONCLUSION AND LESSONS LEARNED

This section elucidates key findings from the case studies of the four economies and highlights lessons learned for other economies. The factors underlying successful technology and innovation policies for SMEs can be summarized under seven key points.

First, in the more successful economies—Singapore and Taipei,China—policy instruments co-evolved with firms' levels of technological and innovative capabilities. Different levels of technological and innovative capabilities of firms need different policy instruments. The ability to initiate and implement new policy instruments to fit the changing needs of firms at different levels of capability over time is critical. Policy makers must understand the current needs and technological barriers facing firms in the economies under study. Strategies based on copying other economies—which no doubt have different needs and challenges—will not be effective.

Second, Singapore, Taipei,China, and, to a lesser extent, Malaysia have a higher level of flexibility and policy coordination and learning. They offer a much greater variety of policy instruments that cater selectively to the particular needs of industrial sectors, clusters, technologies, types of firms, or even individual firm demands (the so-called "firm-specific" or "prepackaged" incentives). Incentives should be formulated and executed so that they complement each other and contribute to overall industrial technology development strategy, as illustrated in the cases of venture capital and business angel financing in Singapore, and the mandate of the Ministry of Economic Affairs to give opinions on the prospects of newly listed high-tech firms in Taipei,China's stock markets regarding their ability to develop technologies, rather than requiring them to meet a certain number of years of establishment and profitability targets, as in other standard stock markets (Liu and Wen 2012). When incentives do not work for some types of firms, they can be adjusted to fit those firms' demands. For example, Singapore's R&D tax incentives for start-ups can be converted to grants, since those firms do not make a profit in their initial years.

Third, developing firms' technological and innovative capabilities takes a long time. The amount, duration, and continuity of government-supported schemes are crucial as they reflect policy priorities and the commitment of governments. The case studies show that the governments of Singapore and Taipei,China are highly committed to fostering firms' capabilities.

Fourth, policy makers must have a deep understanding of innovations and innovation systems and how they evolve. While Thailand narrowly focused on R&D-led innovation, Singapore and Taipei,China broadened their incentives to other activities important in innovation, both inside and outside a single firm, such as services, business models, and solutions, among others. The difference between incentives to promote Thailand

and Singapore as R&D hubs is a good example of how their government officials understand the global R&D processes of transnational corporations.

Fifth, supply-side policies were predominant in all four economies, while demand-side policies were not extensively used. Nonetheless, Singapore and Taipei,China demonstrate the effective use of systemic policies. In the case of Singapore, policies were deployed at various points of time to establish and upgrade linkages between transnational corporations and local firms, especially SMEs. In Taipei,China, public research institutes, especially the Industrial Technology Research Institute, played very important roles in diffusing foreign knowledge to local SMEs.

Sixth, innovation financing policies require corresponding policy initiatives that produce qualified human resources, attract foreign talent, and help organizations work together. Examples of this synergy are public research institutes in Taipei,China and entrepreneurial universities in Singapore.

Seventh, institutional factors shape choices and policy implementation. They include laws and regulations, unity and capability of government bureaucracy, trust, entrepreneurship, attitudes toward corruption, and the government's role in supporting private firms. Institutional shortcomings can, to some extent, be corrected. Successful economies can use financing innovation incentives as well as other government mechanisms (such as using public research institutes as intermediaries in innovation systems as in Taipei,China) and initiatives (such as Malaysia's credit rating agencies for SMEs and Singapore's promotion of business angel networks) to overcome or mitigate these shortcomings.

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