CHAPTER 10

Innovation Policy, Inputs, and Outputs in ASEAN

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10.1 | Introduction

When the Association of Southeast Asian Nations (ASEAN) was formed in 1967, it was aimed primarily at containing the imminent threat posed by Communist China and Viet Nam. Indonesia, Malaysia, the Philippines, Singapore, and Thailand were the founding members. The economic focus at that time was to stimulate export-oriented industrialisation and support rural development to reduce unemployment and alleviate poverty and inequality (Rasiah, 2010). It was not until the late 1970s that government efforts to stimulate value-added upgrading on a national scale began in ASEAN, initiated by Singapore (ASEAN, 2014).

As the fastest-growing ASEAN economy, Singapore was the first to introduce upgrading policies as wages started to rise rapidly and labour markets tightened by the end of the 1970s. Since the 1980s, Singapore has pursued aggressive leveraging strategies to stimulate upgrading to activities with higher value-added. Malaysia enjoyed rapid gross domestic product (GDP) growth rates from the late 1980s until the Asian financial crisis struck in 1997. This created massive infrastructure bottlenecks and drove wages up. However, unlike Singapore, Malaysia and Thailand faced serious balance of payments deficits from the 1990s until 1997. Consequently, Malaysia launched meso-organisations (intermediary organisations) to stimulate innovative activities. Faced with massive populations and infrastructure problems, Indonesia and the Philippines have focused their innovation policies on the environment and poverty alleviation. Despite the paucity of important data, Viet Nam is included in this chapter. Cambodia, Lao PDR, and Myanmar could not be included owing to the lack of innovation data.

This chapter examines the evolution of innovation policies and their impact on innovation inputs and outputs. It is organised as follows. Section 10.2 presents the theoretical considerations. Section 10.3 discusses the methodology and data. Section 10.4 critically evaluates innovation-related policies launched in the five countries. Section 10.5 analyses innovation inputs introduced in the five economies. Section 10.6 discusses the innovation outputs generated in these countries. Section 10.7 concludes and draws policy implications.

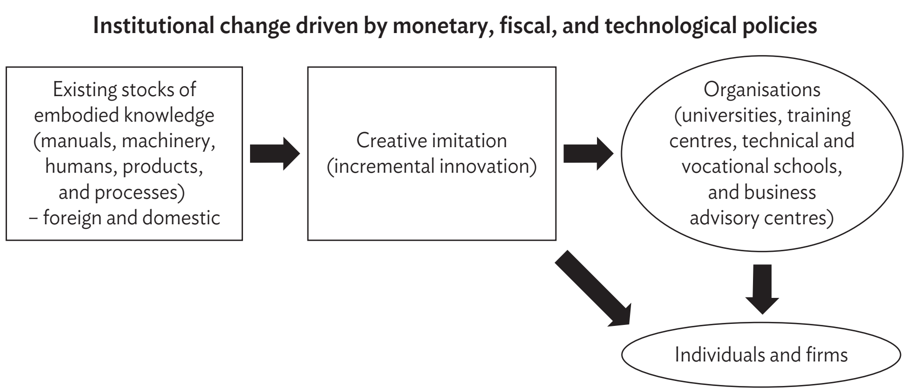
10.2 | Theoretical Considerations

Innovation as a concept is simply defined as the creation of or extension of knowledge that shows a new way of doing things or a new product, process, or structure. What constitutes innovation ranges from minor adaptations to major breakthroughs. Minor adaptations are largely based on adapting existing stocks of knowledge, while major breakthroughs arise from the production of new stocks of knowledge. Schumpeter (1934, 1943) referred to minor adaptations as 'incremental' innovation and major breakthroughs as 'radical' innovation. Rosenberg (1975, 1982) dealt with the most important aspects of innovation to provide a clear understanding of technology. While significant amounts of incremental innovation are achieved in developing economies from domestic sources – as Amsden (1989 1993), Rasiah (1995), and Kim (1997) have shown – sustained, long-term, rapid economic growth in latecomer countries has been achieved through the adaptation of foreign sources of knowledge, which draw on the rationale behind the concept of technological catch-up (Gerschenkron, 1952; Abramovitz, 1956).

The extension of Schumpeter's notion of incremental innovation on a broader national scale is shown in Figure 10.1. The user–producer link is a significant channel that stimulates innovation through interdependent learning processes (Lundvall, 1992). Such interactions occur both within and across borders, either through connecting with global value chains or imports of machinery, manuals, and equipment, or in the process of using inputs. Existing stocks of knowledge, which are not new to the universe but are new to the enterprises seeking them, are both imported from abroad and drawn from national sources through manuals, machinery, licensing, and the acquisition of brownfield firms, as well as accessed through non-pecuniary knowledge flows. These knowledge sources are creatively adapted to solve production and distribution problems and generate new products, processes, and organisational structures. Institutional change through a blend of institutions then moulds economic agents – both firms and individuals – to solve collective problems and stimulate incremental innovation in national economies.

The financing of such technical change can largely be done by firms, but the government's role has often been critical in institutionalising methods, processes, and connections between producers and users, especially those involving public goods and public utilities. Hence, there is a need for governments to build infrastructure, such as science and technology parks, to support adaptive learning and to serve as incubators for new firms and innovators to stimulate scaling activities. Schumpeter (1943) emphasised the initiators of new cycles of innovation and business cycles by focusing on large research and development (R&D) laboratories that generate new stocks of knowledge to produce radical innovations. Since he did not envisage the development of science and technology parks and strong university–industry links, his focus was on the internalised R&D operations of large firms, which would raise the concentration ratio in particular industries. Innovation structures have since transformed to allow smaller firms to produce new stocks of knowledge by integrating with science and technology parks and university R&D laboratories (Figure 10.1).

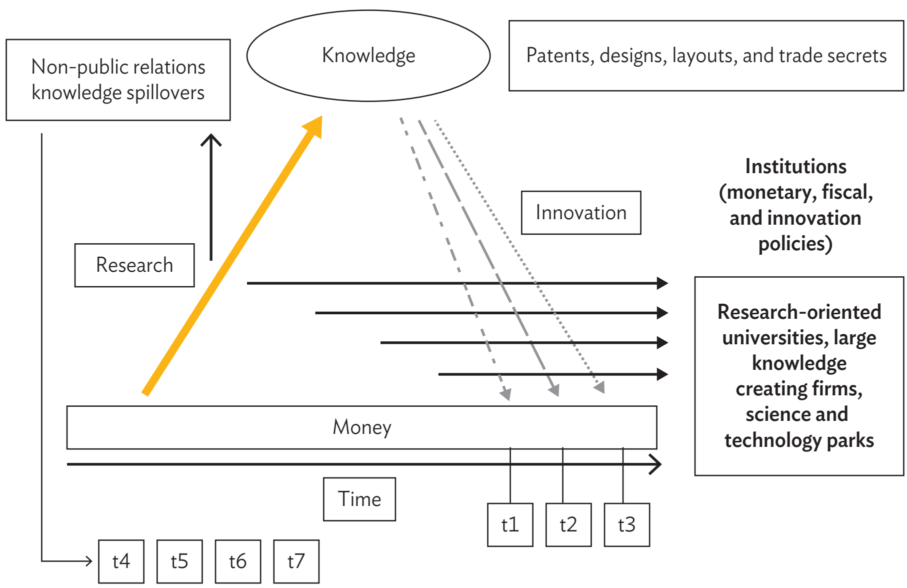
Figure 10.1: Systemic Flows of Knowledge and Entrepreneurial Synergies



Source: Rasiah (2017).

As shown in Figure 10.2, research is critical in generating new stocks of knowledge. However, the returns from research are always uncertain. Hence, even if new stocks of knowledge are generated, not all can be appropriated and registered under property rights by researchers. Also, not all registered property rights can be scaled up to generate returns. Yet, such new stocks of knowledge are critical for spurring cycles of innovation. Latecomers eventually appropriate significant aspects of the new knowledge without paying for it owing to the non-excludable nature of public goods. Hence, latecomers and up produce products t4 to t7 in Figure 10.2, while first movers only manage to sell products t1 to t3. Since public goods are also non-rivalrous, it is important for governments to finance major aspects of them.

Figure 10.2: New Stocks of Knowledge Synergies



Source: Rasiah (2017).

Except in a few large firms, the financing of radical innovation activities generally requires strong government assistance. Not only is there a need to institutionalise links between R&D labs and universities and firms, it is also important for governments to develop science and technology parks to scale up research in firms. Also, the uncertainty element should be underwritten using R&D grants. Since the incidence of failure can be high in such frontier R&D activities, governments offering financial support must have an evaluation and appraisal mechanism to reduce failures and the dissipation of new knowledge. A significant proportion of new discoveries made in Germany, Japan, and the United States were financed by the respective governments (UNESCO, 2015).

The innovation route through incremental innovations from foreign sources of knowledge was proposed by neoclassical economists who argued that the dispersal of production on the basis of factor endowments offered the opportunity for developing economies to connect with and develop through multinational companies (Helleiner, 1973). This logic was later discussed through the lenses of production fragmentation and production sharing (Kimura and Ando, 2003; Athukorola and Yamashita, 2005). Sturgeon (2002), Sturgeon and Kawakami (2011), Gereffi (2003), and Gereffi, Humphrey, and Sturgeon (2005) later argued that the drivers of global value chains matter in the way multinational corporation stages are dispersed, including the opportunities that enable host-site firms to upgrade in modular global value chains. Economic geographers then framed the global production networks concept using largely the rationale advanced by the exponents of global value chains (Coe, Dicken, and Hess, 2008). All four approaches have offered some circumstances and opportunities that arise from the globalisation of production. However, none of them provide an exhaustive assessment of the channels through which external sources of knowledge are appropriated to synergise economic agents at host sites. A lot of knowledge flows through non-pecuniary and informal channels, while not all intra-firm and arms-length knowledge flows are visible in accounting terms. Also missing is the critical role of the state in engendering the conditions at host sites for incremental innovation to take root. The state has been the central actor in driving institutional change and mobilising technological catch-up in firms.

It is clear that learning is an adaptive process that in its most dynamic sense creates incremental innovation, while the creation of new stocks of knowledge or the adaptation and configuration of a wide range of existing knowledge stocks is essential for generating radical innovation. The evolution of the theory of technological upgrading enjoyed significant development after Schumpeter (1934) to explain how creative imitation through incremental innovation takes place (Kim, 1997). Following carefully the incisive evolutionary paths created by Nelson and Winter (1985), Kim (1997) identified through research visits to firms how creative imitation drove the early catch-up experience of firms from the Republic of Korea (henceforth Korea). Further developments appeared promising as Malerba and Nelson (2012) focused on sectoral innovation systems to capture upgrading within the boundaries of sectors. However, despite the requirement for inductive research to understand such processes, the lack of research on the actual firm dynamics of technology has reduced such works to mere conjecture and led to a heavy reliance on narrow measures of upgrading, such as patents. Hence, Lee (2015) discussed Schumpeterian catch-up waves primarily using patent data, and in doing so charted three paths: followship, stage skipping, and path creating. While the first and third are stages in the same process of catching up and leapfrogging, the second was articulated much better by Edquist and Jacobssen (1987) through the acquisition of firms.

Unfortunately, none of these works demonstrate incremental innovations from the standpoint of how knowledge evolves to drive product and process proliferation, and its diffusion to transform different industries. Product proliferation through the adaptation, diffusion, and integration of existing stocks of knowledge has propelled latecomer Taiwanese firms to produce a wide range of products, such as command navigation software, smart lights, and modern deep-sea fishing baits, that fetch high prices in the international market. Thus, United Microelectronics is a firm that fabricates application-specific integrated circuits without leapfrogging incumbents to synergise productivity gains in the whole economy.[1] Also, smartphone firms, such as Samsung and Nokia, have integrated a wide range of product functions to integrate markets using the Blue Ocean Strategy expounded by Kim and Mauborgne (2004).

Having understood the two prime sources of innovation and the need to study them inductively, the next section presents the methodology and data required to review innovation and innovation-related science and technology policies, and the innovation inputs and outputs in Indonesia, Malaysia, the Philippines, Singapore, and Thailand. However, capturing incremental innovation entirely based on a national scale is impossible, and, hence, this chapter only discusses some aspects.

10.3 | Methodology and Data

The analysis in this chapter uses largely an interpretative methodology by drawing on secondary data sources. Given the paucity of data from the transition economies of Brunei Darussalam, Cambodia, Lao PDR, Myanmar, and Viet Nam, the analysis in this chapter is confined to Indonesia, Malaysia, the Philippines, Singapore, and Thailand. Since institutions are largely accepted to be the influences that mould and condition the conduct of economic agents – in the case of this chapter, innovations – we examine the regulatory framework of innovation that has been put in place to stimulate innovation in these countries. The review is extended to organisations set up to solve collective action problems in the promotion of innovation.

1 Interview by the author with Wu Tai Yuan, then chairman of the Semiconductor Manufacturing Association, in Taiwan on 13 September 2008 at Hsinchu Science Park.

While it is fairly easy to define innovation and configure the channels through which innovations are achieved and appropriated, it is difficult to capture them exhaustively and even more difficult to establish causal links between sources and outcomes. Hence, the subsequent assessments on innovation inputs and outputs are based on the available time series data. An econometric assessment was avoided because of the short time series available on key innovation output statistics from the countries. Also, it is not possible to measure all innovations in a given country and their direct contribution to economic performance, even if governments are keen on commercialising the output of their innovation inputs. Hence, this chapter attempts to measure innovation output where data are available with the understanding that some of the outputs may already have been measured elsewhere, and some of them may not result in improved economic performance.

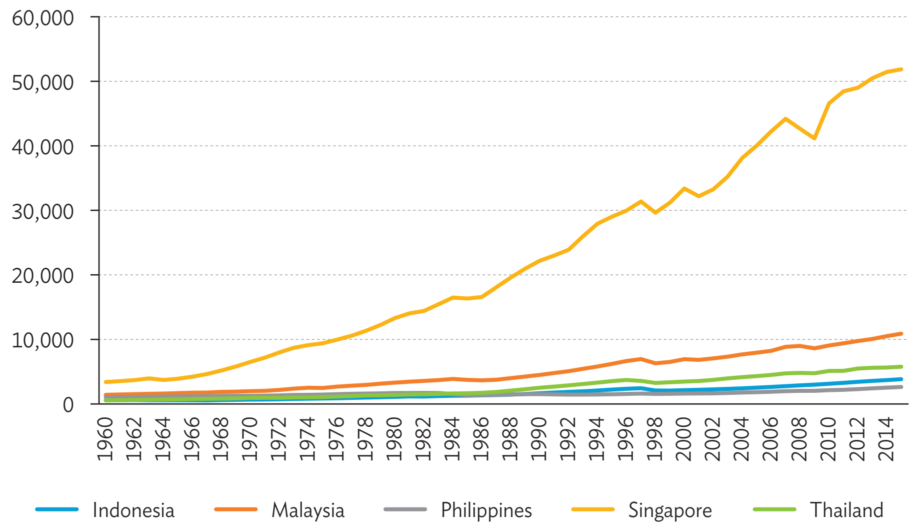
Thus, in this chapter, innovation input is measured from R&D expenditure in GDP, and R&D scientists and engineers per million people. Innovation output is measured from intellectual property exports, imports, and the trade balance; patents taken in the United States; and scientific publications and citations in the Institute for Scientific Information and Scopus-based journals. We do not include trademarks, trade secrets, geographical indicators, or industrial designs and layouts for intellectual property because these items are not recorded consistently and fully. Also, we do not include high-tech exports because some of the countries involved engage only in the lowest value-added activities in this bracket.

10.4 | Innovation Policies and Infrastructure

Since the work of Marx (1957) and Schumpeter (1934, 1943), it has been widely acknowledged that long-term economic growth is powered by innovation. Evidence also shows that incremental innovation fuels early economic growth. After a certain amount of economic growth is achieved, efforts to participate in the funding of R&D to support radical innovation should emerge. However, despite the significant economic growth rates enjoyed in the 1960s and 1970s (Figure 10.3), there were no formal attempts to promote science, technology, and innovation (STI) policies in Indonesia, Malaysia, the Philippines, Singapore, and Thailand over this period.

Whereas Singapore began focusing on STI policies to support technological upgrading from the 1980s, Malaysia began such a move from the 1990s, while efforts from Indonesia, the Philippines, and Thailand started after 2000. Singapore managed to stimulate sustained GDP growth by successfully leveraging incentives and grants and coordinating smoothly with multinational corporations and national firms since the 1980s. In Malaysia, while natural resources have been helpful, exports by multinational corporations, primarily of electronics products, sustained GDP growth rates. Thailand already had strong multinational corporation activities in electronics since the 1980s and in automotive products since the 1990s, which gave such firms in the country a stronger stimulus to participate in innovative activities. The Philippines' experience with electronics production since the 1970s did not result in a transition from assembly-type to higher-value-added activities. Thus, Malaysia and Thailand enjoyed the second- and third-highest levels of GDP per capita among the five countries, followed by the Philippines and Indonesia.

Figure 10.3: Gross Domestic Product per Capita of Selected ASEAN Countries, 1960–2015 (US$)



ASEAN = Association of Southeast Asian Nations.
Source: World Bank (2016).

Ad hoc and formal forays into supporting innovation in Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam – particularly adaptive learning – can be traced back to colonial times. Incremental innovation drawn from knowledge inflows from abroad has been widely used in these countries to support infrastructure development and maintenance, mining, and agriculture. Both foreign direct investment (FDI) and the colonial governments of Dutch Indonesia, British Malaya (including Singapore), the Spanish Philippines, and French Viet Nam, as well as independent Thailand, engaged in such activities for the extraction of minerals and cultivation of agriculture (Allen and Donnithorne, 1956; Thoburn, 1977). Also, formal R&D to support agriculture was undertaken in these countries. The focus on innovation remained largely in incremental engineering following independence in the five economies. Technology transfer agreements were started in countries such as Malaysia, and imports and exports of intellectual property were recorded from the 1970s. The Government of Thailand and the post-colonial governments started R&D laboratories primarily to support agriculture from the 1960s. They have focused on protecting plants and animals and raising yield while at the same time supporting R&D researchers at national universities. The five countries largely integrated with the capitalist world economy early on and, hence, enjoyed massive flows of investment, trade, and knowledge. Viet Nam started to integrate into the world economy after the launch of its Doi Moi (open door) policy in 1986. While governments of these countries have started to finance STI policies, particularly since the 1990s, the extent and emphasis have been mixed.

10.4.1 Indonesia

While ad hoc activities and strategic policies targeting particular industries had been in place earlier on (e.g. for the aircraft industry under Habibie's ministry prior to the 1997–1998 Asian financial crisis), the first formal thrust to support STI activities on a national scale followed the enactment of the Vision and Mission of Indonesian Science and Technology Statement. Launched in 2005 with four-year plans until 2025, the vision was driven by the National Research Council of Indonesia (Dewan Riset Nasional) headed by the president following its establishment in 1999 (LIPI, 2015; Aminullah, 2015; UNESCO, 2015; OECD, 2016). The first two four-year master plans for 2005–2009 and 2010–2014 addressed strongly the need to support business R&D and to focus on strategic sectors. However, the expenditure devoted to R&D did not increase significantly, and, hence, much of Indonesia's STI capacity has remained in public organisations. Allocated the equivalent of only 1% of the budget enjoyed by the Institute of Sciences, the National Research Council of Indonesia does not have sufficient resources to spearhead R&D activities in Indonesia. Most Indonesian R&D scientists are employed in universities (Oey-Gardiner and Sejahtera, 2011). Nevertheless, about 30% of R&D scientists and engineers were employed in industry in 2014, although their contribution to intellectual property has been small (see Section 10.5).

The coordination of research activities by different players may be influenced by the National Research Council, chaired by the Ministry of Research and Technology, which groups representatives of 10 other ministries and has reported to the president since 1999. Although it continues to advise the Ministry of Research and Technology, the National Research Council also advises the regional research councils (Dewan Riset Daerah), which have assumed greater significance through the processes of decentralisation undertaken by the Government of Indonesia. Indonesia's innovation effort is weak on two counts: the role played by the private sector is very modest, and the ratio of the gross expenditure in R&D (GERD) to GDP is negligible at 0.08% in 2009. In 2012, as part of the Master Plan to 2025's key strategy for strengthening human resource capacity and national science and technology, the Ministry of Research and Technology released a plan to foster innovation in six economic corridors.

Despite efforts to target strategic industries and develop six regional corridors to decentralise innovation activities following the launching of the STI master plans, no significant progress has been made. The focus has been on resource-based industries, with steel, shipping, palm oil, and coal identified for Sumatra; food and beverages, textiles, transport equipment, shipping, information and communication technology (ICT), and defence identified for Java; steel, bauxite, palm oil, coal, oil, gas, and timber strategised for Kalimantan; nickel, food and agriculture (including cocoa), oil, gas, and fisheries specified for Sulawesi; tourism, animal husbandry, and fisheries classified for Bali and Nusa Tenggara (Lesser Sunda Islands); and nickel, copper, agriculture, oil and gas, and fisheries targeted for the Papua and Maluku Islands. Indeed, the government had already committed 10% of the US$300 million allocated for infrastructure development by 2015. The remaining investment for infrastructure development is expected to come from state-owned enterprises and from the private sector through public–private partnerships.

The government has also attempted to raise value-added through an increasing focus on the private sector and improvement in information communication services. The multi-donor Program for Eastern Indonesia SME Assistance, launched in 2003, was part of this initiative. The programme has also been operated as a five-year programme to support technical assistance with a focus on training commercial bank employees in outreach services and improving the regulatory environment and corporate governance among firms in Eastern Indonesia. Unlike the experiences of Malaysia, Singapore, and Taiwan, where science and technology parks have been major recipients, the Ministry of Cooperatives and SMEs is regulating the Start-up Incubator

Program for small and medium-sized enterprises (SMEs) in Indonesia.[2] Some have been very influential. For example, a team of researchers from Padjadjaran University have not only assisted in improving the quality of wild coffee in Kalimantan but have also successfully registered the intellectual property through geographical indication to fetch higher prices internationally (Miranda, 2016).

10.4.2 Malaysia

Generous incentives have led to a massive inflow of FDI into Malaysia in major export-oriented activities since the early 1970s. While incremental innovation has long stimulated economic activity, technical progress was largely slow until the 1980s. The initial spur came through the automation of production and the introduction of continuous improvements in work practices (*kaizen*), which have led to the substitution of dexterous skills with cognitive, technical, and statistical ones since the 1980s in semiconductor firms (see also Rasiah [1995]). Two United States multinational corporations and one Japanese one are reported to have undertaken adaptation activities in 2008, especially in production organisation and processes (Rasiah, 2010). In addition, Rasiah (2010) reported the proliferation of total preventive maintenance and total quality management processes in nine semiconductor firms. Process engineers in one of these firms even adapted the electron-beam-induced current in 1990, which allowed massive magnification capabilities to assist back-end activities by strengthening their failure laboratory analysis. Workers at all levels in two of the semiconductor firms were reported by their officials to be equipped with strong numerical and technical skills. Although less spectacular, the single national firm engaged in semiconductor operations in this study also reported similar developments on the shop floor.

Links between foreign electronics firms and national firms have appeared promising since the 1980s, when demand for proximate sourcing increased (Rasiah, 1988, 1989). Indeed, significant supplies of precision tools, semi-automated machinery, and fabrication opportunities were established between multinational and national firms in Penang in the 1980s and 1990s. However, as the demand for knowledge-based activities rose further, national suppliers were unable to upgrade into design and R&D activities because of a lack of human capital supply in the country and weak university–industry R&D links (Rasiah, 2010).

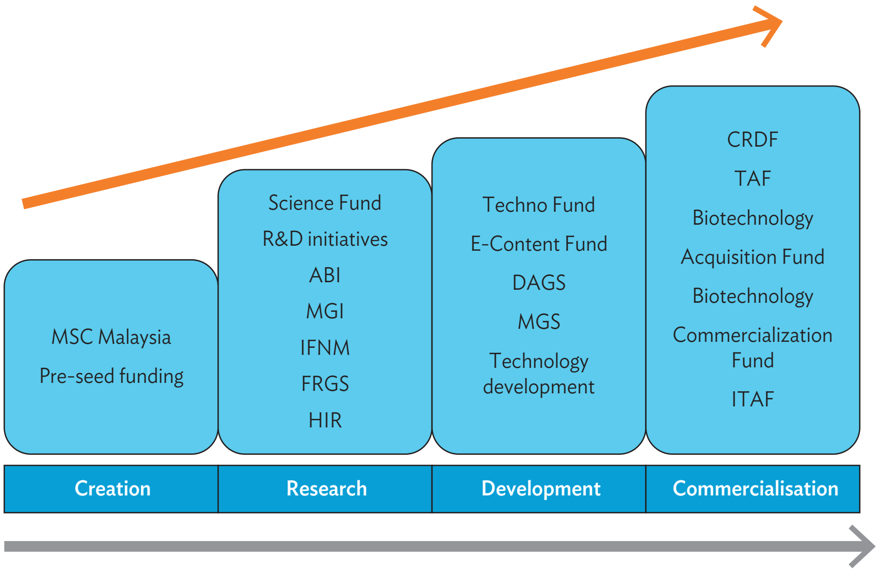
[2] Singtel, 'Business in Indonesia: Start-ups Can Leverage Incubator Program for Growth', https://mybusiness.singtel.com/techblog/business-indonesia-start-ups-can-leverage-incubator-program-growth (accessed 10 March 2018).

Malaysia's first formal thrust to stimulate science and technology occurred during 1986–1989 when the First National Science and Technology Policy (NSTP1) was launched. Subsequently the Action Plan for Industrial Technology Development was launched alongside the Way Forward to stimulate the development of strategic and knowledge-intensive industries. Several meso-organisations were introduced to solve collective action problems so as to promote the innovation essential to make Malaysia a developed country by 2020 (Government of Malaysia, 1991). The government subsequently launched the second STI policy (NSTP2) (2002–2010), which attempted to address the critical issues comprehensively with specific strategies. The NSTP2 addressed seven priority areas: (i) strengthening research and technological capability and capacity; (ii) promoting the commercialisation of research output; (iii) developing human resources capacity and capability; (iv) promoting a culture of science, innovation, and techno-entrepreneurship; (v) strengthening the institutional framework and management of STI and monitoring of policy implementation; (vi) ensuring the widespread diffusion and application of technology, leading to enhanced market-driven R&D to adapt and improve technologies; and (vii) building competence for specialisation in key emerging technologies. The Third National Science and Technology Policy (NSTP3) (2013–2020) targeted improving the contribution of STI to economic development. The NSTP3 emphasised four important foundations: the generation and utilisation of knowledge, talent development, energising innovation in industry, and improving the governance framework for STI to support innovation. While significant financing has been allocated by the government to support these plans, the country has lacked tangible translation of these resources into commercialisation. Most of the grants involving the private sector require matching with an equivalent contribution by the firms, but the appraisal mechanism used has not been effective.

The government launched three grant schemes to achieve the goals set in the NSTP1, NSTP2, and NSTP3: the Long-Run Research Grant Scheme, the Fundamental Research Grant Scheme, and the Science Fund emphasising both basic and applied research (Figure 10.4). However, many of these policies have yet to provide the stimulus for commercialisation, although a number of science and technology parks have evolved across the country (Rasiah and Chandran, 2009).

Nevertheless, at least one meso-organisation – the Malaysian Palm Oil Board (MPOB) – has produced significant innovation synergies, although national firms still lag foreign firms in the filing of patents. While the major innovations in the palm oil industry have evolved from internalised R&D laboratories in large firms, such as Sime Darby, IOI, and

Figure 10.4: Government Innovation Funding in Malaysia, 2012



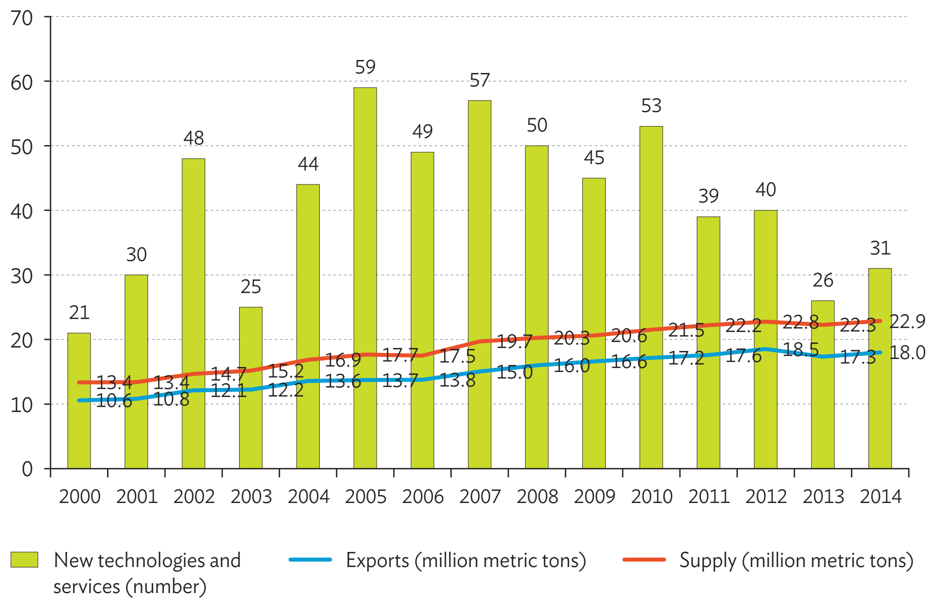
ABI = Agro-Biotechnology R&D Initiative, CRDF = Commercialisation of R&D Fund, DAGS = Demonstrator Application Grant Scheme, FRGS = Fundamental Research Grant Scheme, HIR = High Impact Research, IFNM = Pharmaceutical and Nutraceutical R&D Initiative, ITAF = Industrial Technical Assistance Fund, LRGS = Long-Run Research Grant Scheme, MGI = Genome and Molecular Biology R&D Initiative, MGS = MSC Malaysia R&D Grant Scheme, TAF = Technology Acquisition Fund.

Source: Adapted from Government of Malaysia (2012).

United Plantations, the MPOB has been instrumental in problem-solving innovations (Figure 10.5). Hence, although Indonesia has overtaken Malaysia as the top exporter of crude palm oil, Malaysia still leads in the production and export of downstream products.

In addition, sporadic university–industry links have emerged between foreign multinationals and national universities. While the strong links that existed during 1978–1996 between Universiti Sains Malaysia's innovation centre and electronics firms in Penang on the development of undergraduate courses in engineering and computer science have declined, engineers from these firms have continued to work with academics in the national universities on an ad hoc basis. Also, government grants, such as the Long-Run Grant Scheme administered by the Ministry of Higher Education, and the Techno Fund coordinated by the Ministry of Science, Technology and Innovation (MOSTI), explicitly encourage university–industry links (Government of Malaysia, 2016). Indeed, the provision of such grants has helped Malaysian

Figure 10.5: Oil Palm Supply, Exports, and New Technologies and Services Developed from the Cess Fund, 2000–2014



Sources: Malaysian Palm Oil Board and Comtrade website.

universities significantly increase the number of publications in scientific journals and file patents (Rasiah and Chandran, 2015). However, interviews with firms show that researchers at national universities have not been interested in undertaking firm-based projects, thereby making such links marginal to their operations.

The government attempted to participate directly in supporting technological upgrading in the electronics industry when it launched the Malaysian Institute of Microelectronics Systems (MIMOS) in 1985. MIMOS was moved from the Prime Minister's Department in 1993 and corporatised. Despite attempts to attract participation by multinational corporations, MIMOS has only managed to develop its own technologies for the launching of national firms. Among its achievements are the creation of the Silterra and 1st Silicon national wafer fabrication plants. The latter was later sold to a foreign firm called X-Fab (Yap and Rasiah, 2017). Silterra is a foundry engaged in the fabrication of complementary metal oxide semiconductor wafers. While the firm has R&D and designing operations, it is at the bottom of a world ranking of wafer fabrication plants by market share.

Following the launch of the Way Forward in 1991, the government set up the Human Resources Development Council, the Malaysian Technology Development Corporation, the Multimedia Development Corporation, and the Malaysia Industry–Government Group for High Technology in 1993, and the MSC (Multimedia Super Corridor) Malaysia in 1995 to support structural transformation of industry from low- to high-value-added activities. The Human Resources Development Council collects 2% of the payroll from firms with 50 or more employees, which firms can only reclaim only through approved training expenditure. While this practice is reported to have stimulated an intensification of training among industrial firms in Malaysia, other organisations created have yet to produce significant results (Rasiah, 2011).

Grants to support R&D began when the Way Forward was launched in 1991; but among the electronics firms, take-up was originally confined to Silterra. Interviews showed that the government favoured *Bumiputera* (indigenous Malaysian) firms at that time. Grants were extended to foreign firms after 2005, which led to Intel, Osram, Infineon, Dell, and Agilent, among others, obtaining grants to participate in wafer fabrication and chip design activities (Rasiah, Yap, and Yap, 2015). Collaborative Research in Engineering, Science and Technology (CREST) was subsequently formed in 2012 to strengthen R&D collaboration between universities, government, and industry.[3] Using government grants, CREST finances approved R&D that is then carried out in universities and firms to support new innovations jointly developed by universities and firms. Its members in April 2016 included Alterra, AMD, Avago, Bose, Clarion, Intel, Keysight Technologies, Motorola Solutions, National Instruments, Osram, and Silterra. However, the capacity of CREST to widen and deepen R&D activities to support technological transformation in the electronics industry greatly depends on its ability to sustain government funding and attract participation by firms and universities, and on the reinvigoration of existing, related supporting organisations and the expansion of the requisite human capital in the country.

MOSTI and the Ministry of Education are the principal drivers of Malaysia's national innovation system. There seems to be some agreement that applied research is the purview of MOSTI, whereas basic research falls under the Ministry of Education, but there is no coordination mechanism. Also, MOSTI monitors innovation through surveys, the provision of grants, and evaluations but lacks the industrial exposure to coordinate industrial grants effectively, a failing that is evident from the absence of an

3 Interview conducted by the author on 12 December 2015 in Georgetown.

effective performance criterion for some government grant programmes, including the Techno Fund. It is important that a body closer to industry, such as MOSTI or its sub-organ the Malaysian Industrial Development Authority, is entrusted with this role. Accountability and effective monitoring is essential for ensuring that investment yields a desirable rate of return.

Since the 1990s, the government has promoted innovation through the Commercialisation of R&D Fund (1996), the Technology Acquisition Fund (1996), the Biotechnology Acquisition Fund (2006), the Biotechnology Commercialization Fund (2006), the Industrial Technical Assistance Fund (1990), the Techno Fund (2006), the E-Content Fund (2006), the Demonstrator Application Grant Scheme (2006), the MSC Malaysia R&D Grant Scheme (1997), the Science Fund (2006), the Agro-Biotechnology R&D Initiative (2006), the Genome and Molecular Biology R&D Initiative (2006), the Pharmaceutical and Nutraceutical R&D Initiative (2006), the Fundamental Research Grant Scheme (2006), the Long-run Research Grant Scheme (2009), and High Impact Research (2009). However, despite the long-standing role of government in funding R&D programmes, there is no systematic mechanism to appraise and monitor them in Malaysia (Rasiah, 1999; Rasiah, Lin, and Anandakrishnan, 2015).

The palm oil industry, nevertheless, is a model of innovation in Malaysia. Palm oil has ranked third after petroleum and gas, and electronics among Malaysian exports since the 1990s. Although internalised R&D operations by the large plantations have been the prime driver of innovations in the industry, its continued success in generating innovative process improvements and sustainable production activity has benefitted enormously from oil palm and related companies organised under the MPOB, coordinated by the Government of Malaysia. The strategic collaboration between oil palm firms has successfully led to the allocation of *cess* (tax) revenues collected from members of the MPOB to oil-palm-related R&D activities. The MPOB has succeeded in stimulating value addition in the palm oil industry by creating new products and technologies (Figure 10.5).

10.4.3 Philippines

The Philippines' low GDP growth rates are largely a consequence of the country's specialisation in low-value-added activities with little innovation. Relative to GDP per capita, the Philippines has been a high investor in infrastructure, driven not only by its vast spread of islands but also by its vulnerability to natural disasters. The equipment installed to handle disasters includes a Doppler radar that generates 3D disastersimulation models from light detection and ranging (LiDAR) technology, and locally developed sensors for accurate and timely disaster information nationwide. Massive efforts have also been taken to adapt foreign technology to evolve the national capability to apply, replicate, and produce disaster management technologies in the country.

The Philippine Development Plan 2011–2016 launched strategies for using STI to boost productivity and competitiveness in agriculture and small businesses, especially in sectors and geographical areas dominated by poor, vulnerable, and marginalised residents. Following the launching of the Harmonized Agenda for Science and Technology 2002–2020, the Philippines' Department of Science and Technology has strongly supported the building of self-reliance in technology, which is coordinated by sectoral councils targeted at inclusive growth and disaster risk reduction. The Harmonized Agenda seeks to promote the establishment of five government-funded centres of excellence by 2020 in biotechnology, nanotechnology, genomics, semiconductors, and electronics design. The University of the Philippines Los Banos established agro-centred R&D, which received the Biotech Plot Plant in 2012 and the Centre for Nanotechnology Application in Agriculture, Forestry and Industry in 2014 at the Los Banos campus. The Philippines Genome Center was built at the University of the Philippines Diliman, which operates two core facilities for DNA sequencing and bioinformatics. The Advanced Device and Materials Testing Laboratory is located at the Department of Science and Technology's compound in Bicutan in Taguig City, which started operations in 2013 with three laboratories in surface, thermal, chemical, and metallurgical analysis. The Electronics Product Development Center is targeted to be built at the Department of Science and Technology in Bicutan, Taguig City, to provide cutting-edge design, prototyping, and testing facilities for printed circuit boards. Meanwhile, the Philippine National Health Research System Act (2013) formed a network of national and regional research consortia to boost the prevention and treatment of diseases. In addition to dealing with natural disasters, researchers from the International Rice Research Institute and the University of California developed flood-tolerant species, such as submarine rice, in 2009–2010 (Renz, 2014; Asia Rice Foundation, 2011; UNESCO, 2015; Fernandez, 2016).

Recognising that R&D capacity in the country is weak, the government supported an expansion in the number of graduates, including doctoral graduates, between 2009 and 2013. Hence, while the Philippines only invested 0.3% of GDP in higher education in 2013, tertiary enrolment experienced a rise from 2.6 million in 2009 to 3.2 million in 2013. The number of doctoral graduates more than doubled from 1,622 in 2009 to 3,305 in 2013 (UNESCO, 2015).

10.4.4 Singapore

Like the other ASEAN market economies, Singapore's economy was largely driven by low-value-added activities until the end of the 1970s. From mild efforts to stimulate upgrading – initially through the imposition of a training levy that firms drew on to train their workers, Singapore began to promote higher-value-added activities from the 1980s. Through the Economic Development Board, it has systematically stimulated technological upgrading in the country, leveraging its world-class infrastructure, efficient civil service, and provision of incentives and grants in return for continuous technological upgrading by foreign multinational firms. Efforts have been taken, especially since the 1990s, to support science parks and R&D through the development of science and technology infrastructure to finance strategic technologies in knowledge-based industries. Singapore had two science parks in 2016 that have acted as R&D hubs for companies – Science Park I and Science Park II. The first science park was developed by Jurong Town Corporation with government funding in the early 1980s. Both parks are now managed by Ascendas, a business property developer. By 2015, the parks housed more than 350 organisations and companies.

With few natural resources, the small island nation of Singapore has developed from an emerging economy into a knowledge economy. Although enjoying the highest R&D intensity among the five countries, Singapore's GERD–GDP ratio was far below the 4.5 % and 4.1% enjoyed by Israel and Korea, respectively, in 2014 (UNESCO, 2015). Singapore's GERD accounted for 2.1% of GDP in 2006. This grew to 2.6% in 2008 before falling to 2.0% in 2012. A contraction in business expenditure on R&D since 2008 due to the global financial crisis largely explains this relative fall. Nevertheless, it rose to 2.1% in 2015 (Singapore, 2016). The strong emphasis on innovation activities has resulted in Singapore becoming the international hub for R&D activities in the Asia-Pacific region. The government has dedicated large amounts of funding to the development of science and technology at Singapore's leading universities – the National University of Singapore and Nanyang Technical University. Scientific publications have also grown. Since 2010, Singapore's major universities have gained an international reputation. In 2011, the National University of Singapore and Nanyang Technical University were ranked 40th and 169th, respectively, in the Times Higher Education World University Rankings. By 2014, they had risen to 26th and 76th, respectively.

Since the 1990s, Singapore has promoted the clustering of knowledge-based, clean industries with a strong emphasis on R&D, bringing together foreign multinational and national firms with strong links. The government has invested heavily in cutting-edge research facilities, including R&D labs, machinery, and equipment, and has opened employment in the country to world-class scientists and engineers. This has driven up Singapore's researcher intensity to one of the highest levels in the world (see Section 10.5). The government's well-financed higher education policies, in which its expenditure on higher education in GDP exceeded 1% between 2009 and 2013 (UNESCO, 2015; Turpin et al., 2015), has ensured a reservoir of human capital to serve foreign and national firms.

Major institutional developments since 2000 include the grouping of national research organisations into knowledge hubs and their promotion as centres of excellence with links to global knowledge hubs in the areas of biomedical research and ICT. Biopolis was opened in 2003 to promote biomedical research, while Fusionopolis was established in 2008 to promote research in ICT. The Research, Innovation and Enterprise Council also approved the establishment of a National Framework for Innovation and Enterprise in 2008, which seeks to commercialise the cutting-edge technologies developed by R&D laboratories and to encourage universities and polytechnics to pursue academic entrepreneurship to support commercialisation. The National Framework for Innovation and Enterprise enjoyed a total allocation of S$4.4 billion during 2008–2012. The Agency for Science, Technology and Research began to sponsor a new initiative for a 'Smart Nation' in November 2014 aimed at developing new partnerships across the public and private sectors. These partnerships are intended to strengthen Singapore's capabilities in cybersecurity, energy, and transport so as to 'green' the country and improve its public services. In 2015, the agency's Institute for Infocomm Research signed an agreement with IBM for the creation of innovative solutions in the areas of big data and analytics, cybersecurity, and urban mobility as a contribution to the Smart Nation initiative.

The clustering initiative received a further push from the setting up of a Smart Nation Programme Office at the Prime Minister's Office to bring residents, the government, and industry players together to deliberate on critical issues, and co-develop prototypes and commercialise them. The purpose is to raise business participation in R&D so that Singapore becomes one of the most R&D intensive countries in the world.

Singapore's National Research Foundation offers enterprises financial incentives through several schemes targeted at innovation collaboration. The Incubator for Disruptive Enterprises and Start-ups (IDEAS) Fund was launched jointly by the National Research Foundation and Innosight Ventures, a venture capital firm. The Technology Incubation Scheme was established in 2009. The IDEAS Fund provides coordination and support in the formative years for innovation projects that show promise. Start-ups can draw a maximum of S$600,000, with the National Research Foundation footing 85% and the remaining 15% borne by the incubator. Given that the funding is provided upfront, an investment committee rigorously appraises the start-up's viability so as to limit any potential dissipation of rent from its failure. The government allocated S$50 million in 2013 to stimulate the early-stage investment ecosystem for start-ups in the country. This was to complement the Innovation and Capability Voucher, which was introduced in 2009 and targets at facilitating knowledge transfer from knowledge organisations to SMEs. Through the Early Stage Venture Fund, the National Research Foundation invests in a 1:1 ratio as seed funding for Singapore-based, early-stage high-tech start-ups. The National Research Foundation administers this scheme, which provides researchers from universities and polytechnics with grants of up to S$250,000 for technological projects at the proof-of-concept stage. A similar programme, Spring Singapore, is run for private firms. Through the Technology Incubation Scheme, the National Research Foundation co-invests up to S$500,000 in Singapore-based start-up companies. In addition, the Global Entrepreneur Executives – a co-investment scheme – was launched to attract high-growth and high-tech venture-backed companies in the strategic fields of information communication, medical, and clean technologies. The Innovation Cluster Programme provides funding to build partnerships between businesses, researchers, and government showing strong market potential.

10.4.5 Thailand

Generous incentives from the Board of Investment, such as tax holidays and tariff-free operations, began to attract the first major agglomeration of electronics assembly and testing operations to Thailand in the 1980s and automotive assembly operations in the 1990s. Since the 1990s, the government has promoted technology diffusion and innovation starting with the National Science and Technology Development Agency, which established the Industrial Consultancy Services in 1992 to promote the use of local and foreign technical consultants and facilitate the formation of alliances (UNCTAD, 2005). The agency launched Software Park Thailand to stimulate innovation in start-up firms. The Board of Investment also developed the Unit for Industrial Linkage Development (BUILD) programme to strengthen links and help small and medium-sized contract manufacturers improve their productivity and facilitate cooperation between foreign and domestic firms. About US$148 million worth of transactions took place in BUILD in 2001 (UNCTAD, 2005).

However, without R&D grants, Thailand lacked the sufficient interventions to solve collective action problems in critical areas, such as design and the R&D of integrated circuits. Hence, the Thai Embedded Systems Association was founded in 2001 by a group of academics and local private industrialists as a forum to coordinate the activities of developers and technology users in the field of embedded computing technology. This initiative emerged following efforts by the Ministry of Industry to launch the Thailand Electrical and Electronics Institute in 1998 to check a slowdown in the electronics industry. Among other things, the Thai Embedded Systems Association started a platform to train university students to handle embedded electronic systems. Interviews have shown that this effort has largely been successful, especially in the development of software systems for automotive components. These programmes have the support of a wide network of members, including electronics firms, universities, and customers, and by 2015 they had developed eight technology roadmaps related to the embedded systems industry for three ministries, provided testing services and certified electronic products, and matched new start-ups with investors (Intarakumnerd, Chairatana, and Chayanajit, 2015).

The lack of an adequate supply of technical and engineering human capital, the absence of R&D grants to stimulate design and R&D, and the lack of electronics-based research in universities and other laboratories drove United States chip manufacturing out of Thailand from the 1980s (Rasiah, 2009). The country remained entrenched in the assembly and testing of automotive-based integrated circuit design and industrial and consumer electronics products and disk drives. Nevertheless, substantial technological upgrading from acquisition by multinational corporations and learning-by-doing has enabled improvements in process technology (Hobday and Rush, 2007). In addition, some design, including in integrated circuits related to automotive systems, has emerged as some multinational corporations have established collaborative links with the University of Chulalongkorn, Mongkut University of Technology Ladkrabang, and Chiang Mai University (Intarakumnerd, Chairatana, and Chayanajit, 2015).

The founding of the Hard Disk Drive (HDD) Institute helped provide scientific infrastructure for the HDD industry by establishing a central laboratory and networks of government laboratories. Because the HDD Institute was created with strong support from HDD manufacturers, and it could understand the rapidly changing HDD technologies in manufacturing, it functioned well as a broker and resource provider. The institute was initially managed by a steering committee comprised of representatives from the National Electronics and Computer Development Center, the Board of Investment, the Ministry of Industry, the Asian Institute of Technology, Thammasat University, and four major HDD manufacturers (Intarakumnerd and Chaoroenporn, 2013).

Although multinational corporations undertake little in the way of core R&D activities in the electronics industry in Thailand, preferring instead to use the capabilities in their parent locations (Hobday and Rush, 2007), they are engaged in incremental engineering activities, including design. With 16,400 employees, Seagate Technology, an HDD manufacturer, was among the largest employers in the country's electronics industry in 2015 (Reuters, 2015). Seagate has the capabilities to design and re-engineer machinery and equipment in its Thai subsidiaries. Similarly, Toshiba Semiconductor Thailand participates in incremental engineering activities, especially in adapting machinery and equipment, through small group activities and quality control circles.

National firms, such as Hana Microelectronics, Stars Microelectronics Thailand, and Silicon Craft Technology, began designing customised integrated circuit packaging (Intarakumnerd, Chairatana, and Chayanajit, 2015). Hana Microelectronics acquired the Ohio (United States) factory of S-Vision in 1999, which provided the firm with the technology and facilities needed to assemble the 'video monitor on a chip' for reflective 'liquid crystal on silicon' micro displays (UNCTAD, 2005). This allowed Hana Microelectronics to produce micro displays, which have high potential as a key component in large-screen television and computer monitors, multimedia projectors, viewfinders for digital and video cameras, and video headsets and handheld devices. Hana Microelectronics and Stars Microelectronics Thailand have also evolved capabilities to train their suppliers and fresh graduates from Thai universities. National firms have also established innovation research links with Thai universities to support upgrading in the firms through the National Electronics and Computer Development Center. However, the scale of their support is not comparable to the synergies evolved in Taiwan. Interviews with a Thai expert from a national firm showed that Thai firms are technologically inferior to electronics firms in Korea and Taiwan because of the lack of cutting-edge R&D facilities in the country.[4] Indeed, research conducted in Thai universities is not at the technology frontier.

Clearly, there is a need to develop a business environment that encourages multinational corporations to invest in R&D, as Malaysia and Singapore have done.

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[4] Interview by the author in Bangkok.

Unlike the Governments of Malaysia and Singapore, the Government of Thailand has so far been reluctant to offer financial incentives and grants to foreign firms. Hence, while Thailand is a major world producer of disk drives and automobiles, a transition to higher-value-added activities would require the development of human capital and incentives to stimulate R&D. Nevertheless, the government maintains a fairly high rate of investment in tertiary education, with the main universities of Chulalongkorn, Thammasat, Mahidol, and Chiang Mai focusing strongly on R&D. Also, although expenditure on higher education as a share of GDP has fallen from 1.1% in GDP in 2002 to 0.7% in 2012, the government has attempted to raise the share of science, technology, engineering, and mathematics (STEM) students. A pilot programme was started in 2008 to establish science-based schools for gifted science-oriented students (Durongkaveroj, 2014). Project- and problem-based teaching and learning have evolved to help pupils specialise in STEM courses. The National Science and Technology Development Agency has become a major anchor for stimulating R&D, which employed over 7% of the country's full-time researchers in four institutions in 2015: the National Centre for Genetic Engineering and Biotechnology; the National Electronics and Computer Technology Centre; the National Metal and Materials Technology Centre; and the National Nanotechnology Centre.

However, although the 10-year National Science and Technology Action Plan, 2004–2013 attempted to launch a national innovation system framework, little was spelt out on how innovation should be evolved through science and technology. The subsequent National Science, Technology and Innovation Policy and Plan, 2012–2021 corrected this problem with its focus on infrastructure development, capacity-building, regional science parks, industrial technology assistance, and tax incentives for R&D. The new plan also takes into account regional development to correct the socio-economic disparities in the country. In addition, it has set a target of 1% GERD in GDP by 2021 with a private–public ratio of 70:30. Since then, financial incentives and grants have been introduced to promote the upgrading of skills and technology in the private sector. They include matching grants with innovation coupons, assistance with industrial technology, low-interest loans for innovation, and tax incentives. The 200% tax reduction for R&D, which was introduced in 2002 to enable companies that have invested in R&D to claim a double deduction for their expenses incurred during the same fiscal year, was increased to 300% in 2015. The statement issued by the Minister of Science and Technology in May 2015 drew attention to the Industrial Technology Assistance Program for SMEs, which includes innovation coupons, loan guarantees, and access to ministry-run testing labs.

Moreover, a new talent mobility programme allows researchers in universities or government laboratories to be seconded to private firms. Under this initiative, the firm reimburses the university or research laboratory for the researcher's salary for the duration of the secondment. Importantly, SMEs are exempt from this clause, which is supported by a subsidy targeted at reimbursing the laboratory on their behalf. Recent legislative changes now allow for the transfer of ownership of intellectual property from funding agencies to grantees, and a new law allows government agencies to set up funds for the commercialisation of technology. Collectively, these initiatives are intended to reform the incentive system for R&D.

On the administrative side, there are plans to establish an STI Advisory Committee that will report directly to the prime minister. This development should coincide with the transfer of the National STI Policy Office from the Ministry of Science and Technology to the Office of the Prime Minister. Another challenge will be to transfer the knowledge and skills currently concentrated in research institutions and science parks to productive units situated in rural areas, including farms and SMEs. Inspired by the One Village, One Product programme in Japan in the 1980s, which sought to combat depopulation, the Government of Thailand introduced the 'One Tambon, One Product' programme between 2001 and 2006 to stimulate local entrepreneurship and innovative, quality products in rural areas. A superior product was selected from each *tambon* (sub-district) for formal branding from one to five stars to indicate the standard of quality before undergoing nationwide promotion. The programme's items include clothing and fashion accessories, household goods, foodstuffs, and traditional handicrafts.

10.4.6 Viet Nam

Liberalisation since 1986, the lifting of the embargo by the United States in 1994, and accession to ASEAN in 1995 and the World Trade Organization in 2007 have increasingly integrated Viet Nam into the world economy (Frost, 1995; Vietnam Economic News, 2017). As a share of GDP, inward FDI hit its peak at 12% in 1994 before gradually falling with the rapid growth of GDP. Nevertheless, inward FDI rose again sharply to reach 10.5% of GDP in 2008 (OECD, 2013). However, not only has the government dominated STI issues it also has few links with the private sector (OECD, 2013).

Recognising the lagging of Vietnamese firms, since the mid-1990s the government has allowed research centres to participate in technology development. Turpin et al. (2015) reported that Ton Duc Thang University, which opened in 1997, had set up 13 centres for technology transfer and services by 2015 that together produced 15% of the university's revenue. Despite the nascent participation of Viet Nam in the world economy, several of its research centres act as intermediaries between public research institutes, universities, and firms.

Through the Strategy for Science and Technology Development for 2011–2020, which was passed in 2012, the government seeks to raise by 2020 the value added of high-tech and applied science products to about 45% of GDP and the ratio of scientific researchers and professional staff in ICT to 9–10 per 10,000 employees (including highly skilled engineers), and to build 60 basic and applied science research centres of international standing (OECD, 2013). The strategy lays out broad policy directions and priority areas for investment, particularly in mathematics and physics; climate change and natural disaster mitigation; operating systems for computers, tablets, and mobile devices; and applied biotechnology for agriculture, forestry, fisheries, and medicine. The strategy also seeks to promote greater international scientific cooperation, with a plan to establish a network of Vietnamese scientists overseas and to initiate a network of outstanding research centres to link key national science institutions with foreign partners.

Viet Nam has also launched a set of national development strategies for selected sectors of the economy, many of which involve elements of STI. Examples are the Sustainable Development Strategy (2012), the Mechanical Engineering Industry Development Strategy (2006), and Vision 2020 (Ministry of Science and Technology [MOST, 2006]). These dual strategies also provided incentives to produce 20,000 doctorates by 2020 backed by strong investment in R&D, and fiscal policies to encourage technological upgrading in the private sector and private-sector investment. Enrolment in higher education grew tenfold during 1995–2012 to well over 2 million. By 2014, there were 419 higher education institutions (Brown, 2014). Several foreign universities also operate private campuses in Viet Nam, including the Royal Melbourne Institute of Technology (Australia) and Harvard University (United States).

The Government of Viet Nam has launched a number of programmes to stimulate innovation in domestic firms. One example is the Vietnamese–Korean Technological and Material Support Programme, a government-to-government programme initiated in 2013 and designed to stimulate technological upgrading in the garments, leather, machinery, and electronics sectors. This collaboration has played a productive role in coordinating the transfer of 100 key technologies to domestic firms. Collaboration between the Vietnam Electronic Industries Association (VEIA) and the Korea Institute for Advancement of Technology, for example, led to the training of participants from 10 domestic member companies of the VEIA by Korean experts through field visits to research institutes and Korean high-tech electronics firms. This has contributed considerably to the development of human capital for the electronics industry in Viet Nam (Ngoc, 2016). Vetted by experts from Korea's corresponding industries, qualifying applicants are supported through the upgrading process. Also, the Government of Viet Nam offers financial support for piloting the production of new products to compliment these arrangements. Viettronics Binh Hoa, Viettronics Thu Duc, and the Vietnam Electronics and Informatics Corporation have submitted proposals to participate in the transfer of pulse transformers technology, LED chip technology, and touchscreen technology, respectively (Ngoc, 2016).

Another programme supported by the Government of Viet Nam is the Vietnam-Japan Monozukuri Partnership programme to support ancillary industries. Since 2013, the Government of Japan has promoted the development of local supporting industries in Viet Nam in the electronics, automotive products, shipbuilding, agricultural machinery, agriculture and aquaculture, and environment-friendly and energy-saving industries. The Japan International Cooperation Agency and the VEIA have since jointly organised off-firm training to support human capital development in the electronics sector.

A third example is the allocation of financial support through the National Technology Innovation Fund by the Government of Viet Nam, which has helped the VEIA organise a series of dialogues between members and the National Technology Innovation Fund to facilitate technology-based financing (Ngoc, 2016). In addition to stimulating connectivity and coordination, the VEIA has been encouraging its members to focus on collaboration among domestic firms to support one another's activities. Such initiatives are critical to compete with foreign firms and have resulted in the more technologically advanced firms using four-dimensional printing to share their upgrading and R&D experiences with other domestic firms. The VEIA's close association with the government has opened strong linkage potential with both multinational and domestic firms. The latest such effort is the VEIA's attempt to convince the government to offer domestic firms the same duty exemptions and rental subsidies enjoyed by foreign firms, such as Samsung (Ngoc, 2016).

The VEIA has also participated in efforts by the United Nations Industrial Development Organization and the Vietnam Chamber of Commerce and Industry to improve safety standards, product quality, and labour governance. The VEIA has supported government efforts to raise the valued-added of locally manufactured products to levels that accord with international standards. The successful upgrading of a number of national firms in Viet Nam can be attributed to strong connectivity and coordination between these firms, government agencies, universities, and multinational corporation buyers. However, while these developments are impressive given the short time frame, Viet Nam's infrastructure, both basic and high-tech (including university–industry links), is largely weak and must be upgraded to stimulate further firm-level innovation. Also, there is a greater need to stimulate firm-level R&D activity. It is for these reasons that Viet Nam is still in the Indonesia and Philippines group when it comes to innovation inputs and outputs despite the steady economic growth the country has achieved since 1990.

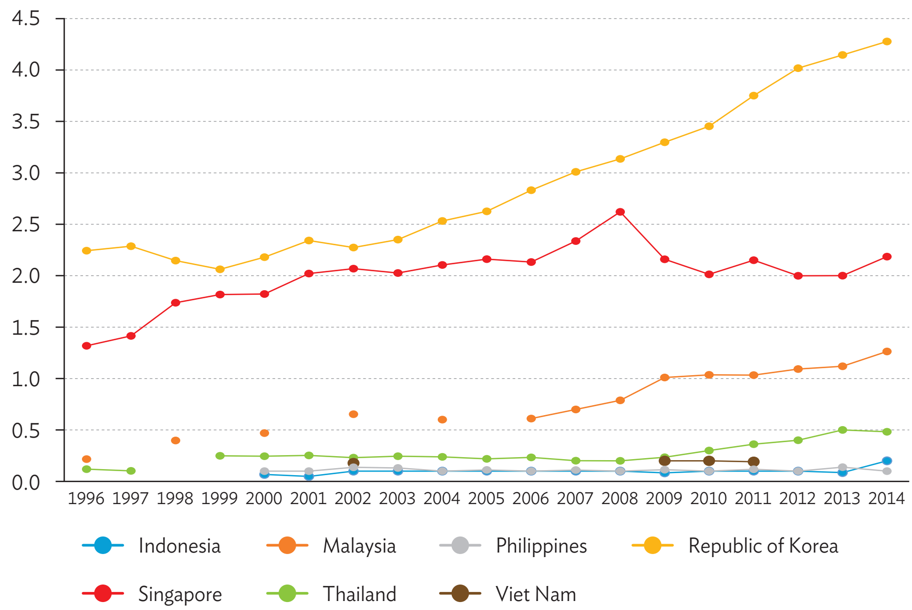
10.5 | Innovation Inputs

As explained earlier, measuring innovation inputs is difficult, and any attempt to do so will only yield rough estimates, especially when considerable inputs, such as the non-pecuniary ones, are not captured. Nevertheless, it is important to track rough estimations of them to assess their efficiency and effectiveness. In this section we examine R&D expenditure in GDP, including the business- and government-financed shares, R&D scientists and engineers in the population, and payments made to import intellectual property from abroad. The discussion on Viet Nam is limited owing to a lack of data.

10.5.1 Gross expenditure on research and development

Singapore enjoyed the highest GERD share in GDP among the five countries during 1996–2014 (Figure 10.6). Its GERD share in GDP rose from 1.3% in 1996 to 2.6% in 2008. It fell slightly owing to the global financial crisis to 2.0% in 2012–2013 before rising again to 2.2% in 2014. Malaysia had the second-highest performance with a rise in its GERD–GDP ratio from 0.6% in 2006 to 1.3% in 2014. Thailand placed third among the five countries as its share of R&D expenditure rose slowly from 0.2% of GDP in 1999 to 0.5% in 2013–2014. While significant expansion has taken place since 2006, Malaysia and Thailand's R&D expenditures are still low compared with the newly developed economies. The contribution of Malaysia's business sector is low as its share of R&D expenditure was only 0.6% of GDP in 2011 compared with the much higher percentages enjoyed by Singapore (1.3%), Korea (2.8%), and Taiwan (2.1%) (UNESCO, 2015). Indonesia (0.2% in 2014), the Philippines (0.1% in 2014), and Viet Nam (0.2% in 2011) showed the lowest GERD share in GDP, demonstrating that these countries are still heavily focused on infrastructure development.

Figure 10.6: Research and Development Expenditure Share of Gross Domestic Product for Selected Economies, 1996–2014 (%)

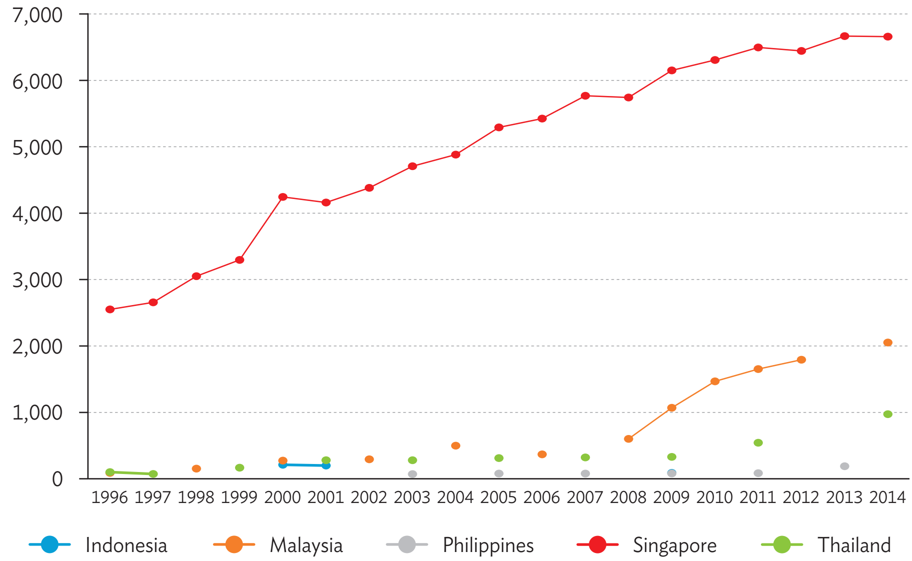


Source: World Bank (2016).

R&D researchers. As with GERD, the intensity of R&D researchers in the population of the five countries has remained similar, with Singapore enjoying the highest share followed by Malaysia and Thailand (Figure 10.7). The number of R&D researchers per million people in Singapore rose from 2,551 in 1996 to 6,659 in 2014. Malaysia's figure rose from 601 in 2008 to 2,052 in 2014 following the government's increased focus on STI policies. Thailand's commensurate figure rose from 332 in 2009 to 974 in 2014. The figure for the Philippines was extremely low at 189 in 2013. Indonesian data were largely unavailable, and the last reported figure was 199 R&D researchers per million people in 2001.

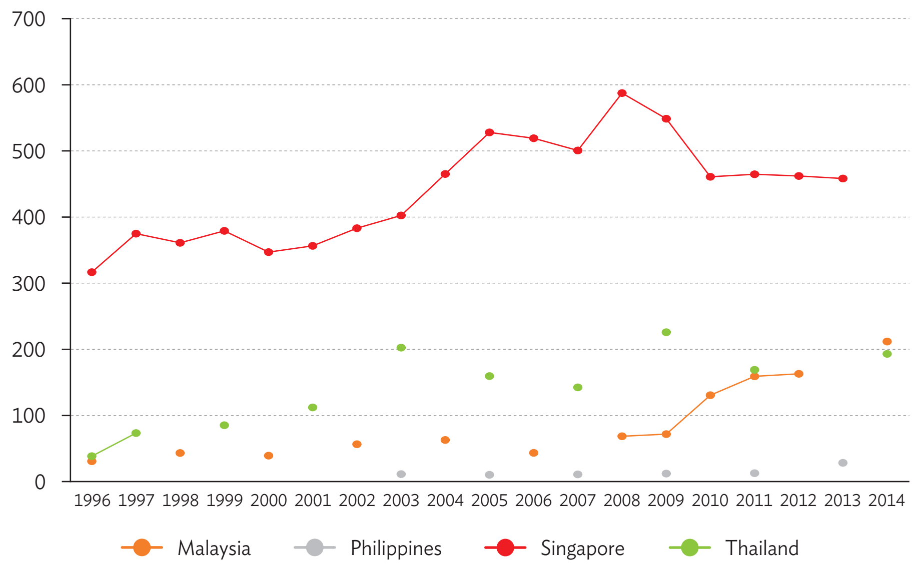
R&D technicians. Singapore also led in the share of R&D technicians per million people among the five countries (Figure 10.8). However, after rising from 317 in 1996 to 588 in 2008, the figure fell to 458 in 2014. Although Malaysia ranked second in 2014 with 212 R&D technicians per million people compared to Thailand's 193, Thailand's figure was consistently ahead of Malaysia's for much of 1996–2014. The Philippines had only 28 R&D technicians per million people in 2013. We could not locate data for Indonesia or Viet Nam.

Figure 10.7: Research and Development Researchers in the Populations of Selected Economies, 1996–2014 (number per million people)



Source: World Bank (2016).

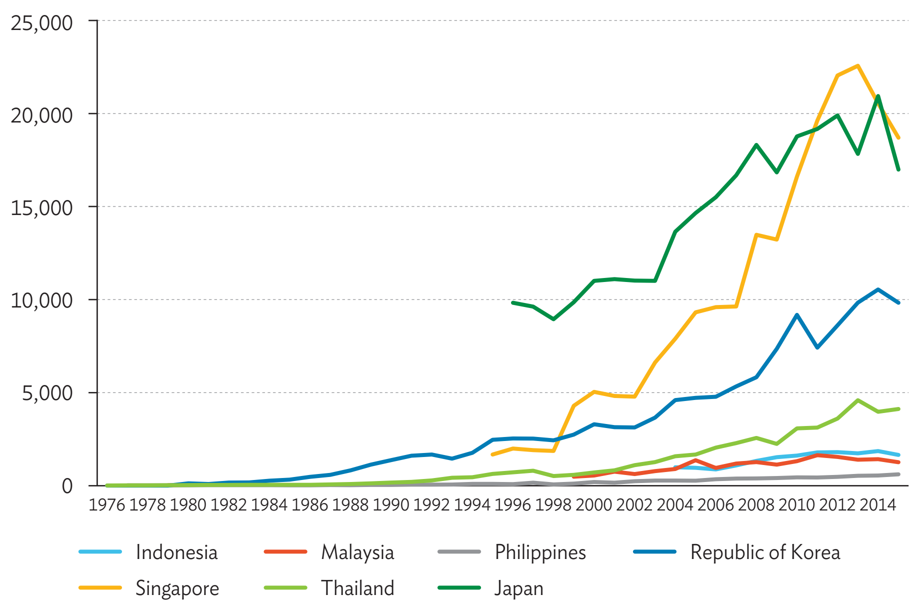
Figure 10.8: Research and Development Technicians in the Populations of Selected Economies, 1996–2014 (number per million people)



Source: World Bank (2016).

Intellectual property payments. Royalty payments for imports of intellectual property are an indicator of purchases of technology from abroad. However, as with public goods, a significant proportion of them diffuse through countries without any pecuniary payments. We included Japan and Korea in Figure 10.9 to locate the five economies against the technologically sophisticated countries in East Asia. In 2015, Korea was in second place after Japan, followed by Singapore. Thailand was the next-highest importer of intellectual property followed by Indonesia, Malaysia, and the Philippines.

Figure 10.9: Intellectual Property Payments of Selected Economies, 1976–2014 (US$ million)



Source: World Bank (2016).

The strong policy focus on stimulating innovative activities is reflected in Singapore's high intensity of innovation inputs, including imports of intellectual property from abroad. Malaysia and Thailand have also started to enjoy fairly strong innovation inputs after their governments began to raise R&D expenditure in GDP and launch STI strategies starting in 2006–2008. Indonesia and the Philippines show the least emphasis on innovation inputs, which is largely a consequence of their heavy focus on infrastructure development.

10.6 | Innovation Outputs

As with innovation inputs, innovation outputs are difficult to measure for the same reasons. Nonetheless, we examine innovation outputs by analysing proxies of the share of high-tech exports in manufactured exports, patents, scientific publications, intellectual property receipts from exports, and the trade balance.

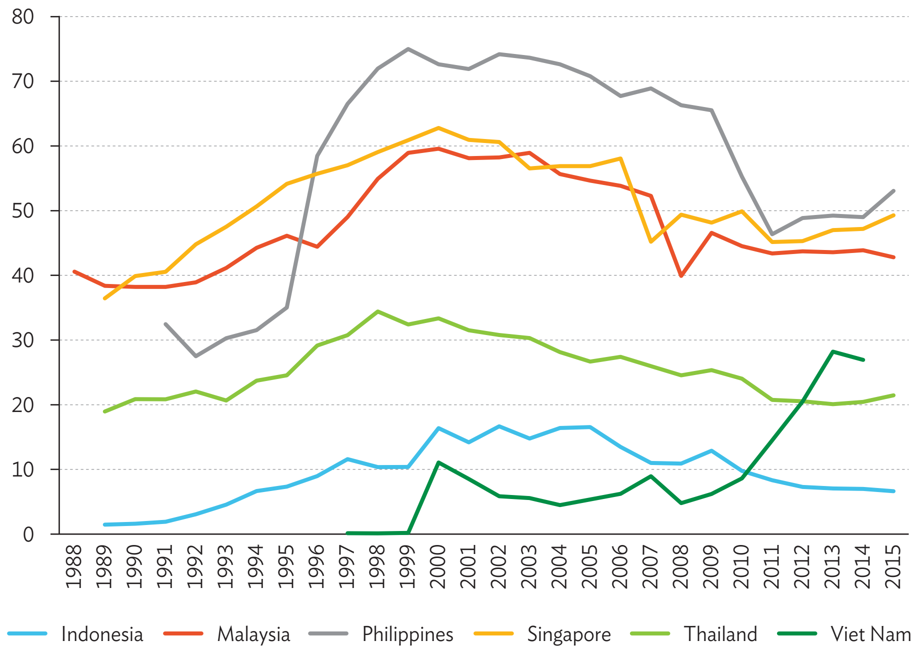
10.6.1 High-tech exports in manufacturing

Exports of high-tech manufactured products have gradually become an indicator of the participation of firms in innovative activities in developing economies. However, the specialisation of firms in these economies in assembly-type activities often masks the innovation intensities involved as they are often limited to assembly and processing activities. Nevertheless, we discuss this as it features in leading reports on innovative activities (e.g. World Bank, 2016; WIPO, 2016; UNESCO, 2015).

Export manufacturing promotion policies involving the relocation of multinational corporations have been the prime driver of expansion in high-tech exports from Singapore since the mid-1960s, Malaysia since the 1970s, the Philippines since the 1980s, and Thailand and Indonesia since the 1990s (Rasiah, 2009). The subsequent extension of incentives helped sustain such exports. Singapore managed to retain high levels of high-tech exports despite its small labour force and rising wages by successfully stimulating the transformation of such activities to design-based, high-value-added activities.

The Philippines' intensity of high-tech exports in manufactured exports gradually rose to lead the other four economies (Figure 10.10). Singapore and Malaysia followed next. Indonesia showed the lowest high-tech intensity in manufactured exports, below Thailand. Viet Nam overtook Indonesia in 2010 and Thailand in 2012. However, it must be noted that electronics and automotive component exports from the Philippines and Viet Nam are dominated by low-value-added assembly activities, whereas exports from Singapore have increasingly been dominated by design-based, high-value-added activities (Rasiah and Yap, 2016).

Figure 10.10: High-tech Exports in the Manufactured Exports of Selected ASEAN Countries, 1988–2015 (%)



ASEAN = Association of Southeast Asian Nations.
Source: World Bank (2016).

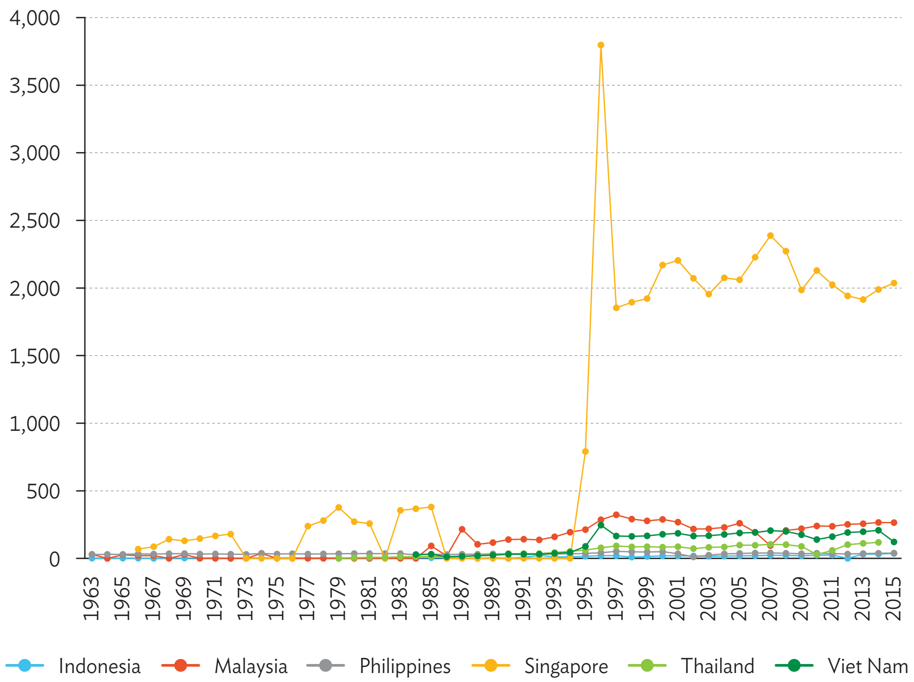
10.6.2 Patents

Although not comparable with the achievements of Korea and Taiwan, patent applications[5] by national authorities rose in all five countries, especially since the increase in government funding for R&D. After initially having extremely low numbers of applications per million people, patenting in Singapore rose sharply from 1995 to lead the five countries in this indicator as government emphasis resulted in a massive rise in patenting (Figure 10.11). The ratio fell sharply in 1997 but remained significantly higher than the remaining ASEAN countries. Malaysia rose to second place in 2012, with 25 patent applications per million people compared with Singapore's 1,942, after enjoying the highest patents per million ratio during 1987–1994. The Philippines' ratio was relatively high during 1963–1986 owing to its focus on resource-based research,

5 This refers to patents granted and applied for at national patent offices. See Chandran and Wong (2011) for more details.

including rice. This was also the period when STI policies were not yet in place in these countries. Viet Nam has taken third place among the six countries since 1995, largely with the support of government research institutes. All six countries have seen a rise in patent activities since 1995, albeit with sharp falls in certain years. The major drivers of the increase in patent applications are the introduction of STI policies, technological upgrading in multinational corporations, and the provision of incentives and grants (UNESCO, 2015).

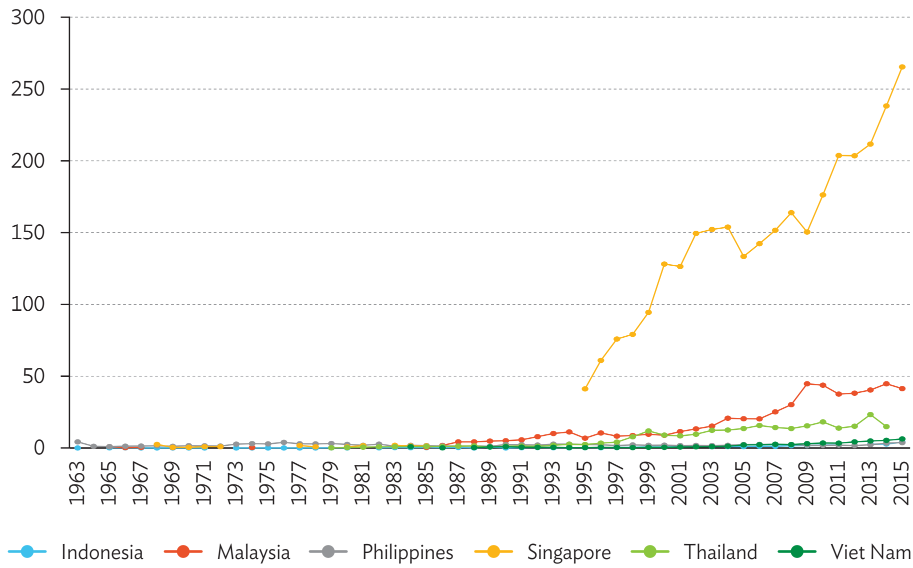
Figure 10.11: Patent Applications of Selected ASEAN Countries, 1963–2015 (number per million people)



ASEAN = Association of Southeast Asian Nations.
Source: World Bank (2016).

The evidence also shows that domestic firms have done little patent filing in the six countries (Figure 10.12). The trend of patent registration has remained similar to that of overall patents filed, with the period after 1995 recording a big jump. Overall, Singapore has dominated the ratio of patents per million people since 1995. In contrast to general views about the relative importance of FDI in Singapore (see, for example, Rasiah and Yap [2016]), its residents filed the highest share of patents in total patents among the six countries in 2015 at 13.6%, followed by Thailand (12.7% in 2014), Indonesia (11.6%), the Philippines (10.0%), Viet Nam (5.4%), and Malaysia (2.6%) (World Bank, 2016).

Figure 10.12: Resident Patent Applications of Selected ASEAN Countries, 1963–2015 (number per million people)

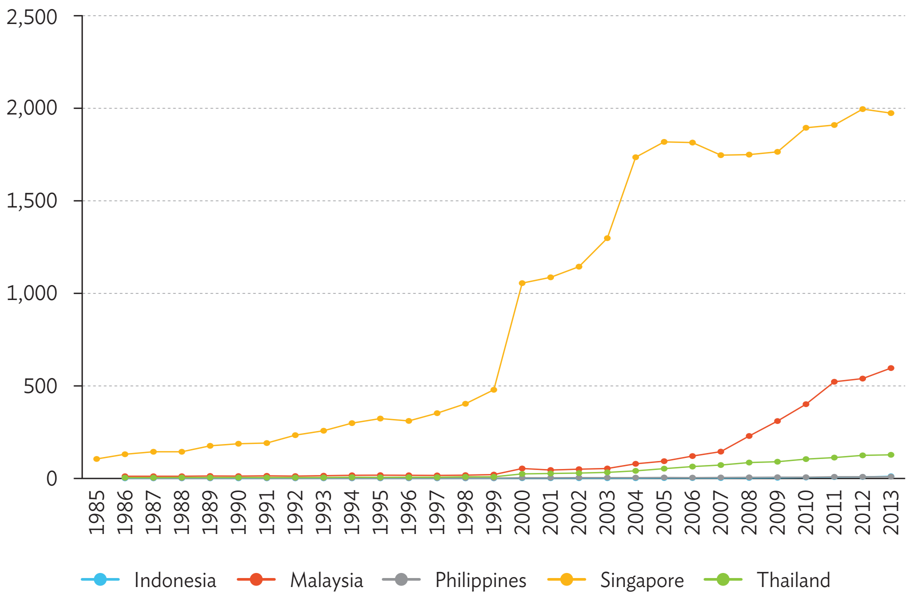


ASEAN = Association of Southeast Asian Nations.
Source: World Bank (2016).

10.6.3 Scientific publications in journals

The strong focus on funding research at universities has translated into a big jump in publications in scientific journals in the five countries. Singapore enjoyed the highest number of publications in scientific journals per million people, followed by Malaysia and Thailand (Figure 10.13). Malaysia has closed the gap slightly since 2007. Singapore enjoyed a significant leap in publications in 2000, while Malaysia experienced a major jump from 2007, all of which were driven by increased funding and universities' emphasis on publications and global university rankings. Data on Viet Nam were not available, and, hence, the analysis of scientific publications for the country was excluded.

Figure 10.13: Scientific Journal Publications of Selected ASEAN Countries, 1996–2015 (number per million people)



ASEAN = Association of Southeast Asian Nations.

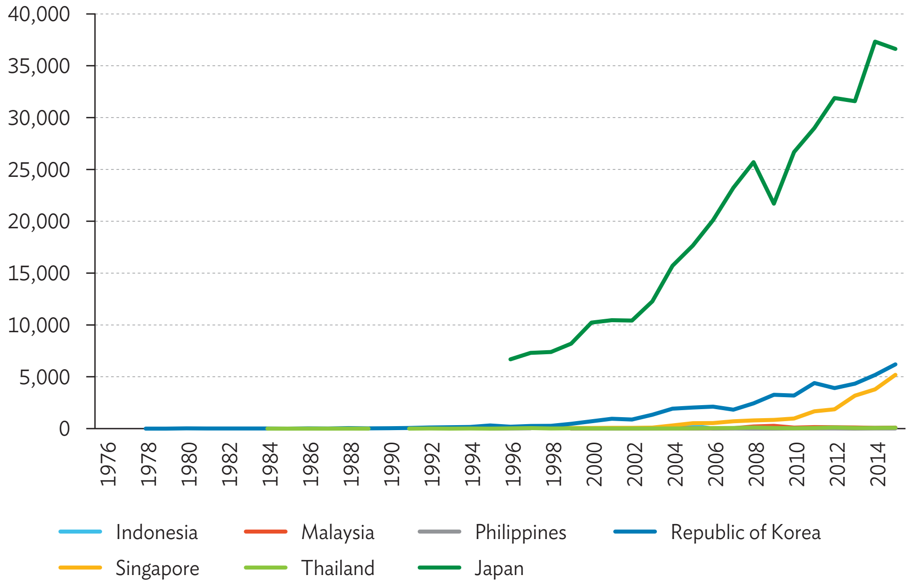
Source: World Bank (2016).

10.6.4 Intellectual property

Japan's receipts from intellectual property exports dominated East Asian intellectual property exports, with Korea and Singapore following at a distant second and third (Figure 10.14). Clearly, Singapore has managed to export intellectual property successfully abroad to compete with Korea. In contrast, Indonesia, Malaysia, the Philippines, and Thailand lag far behind with low exports.

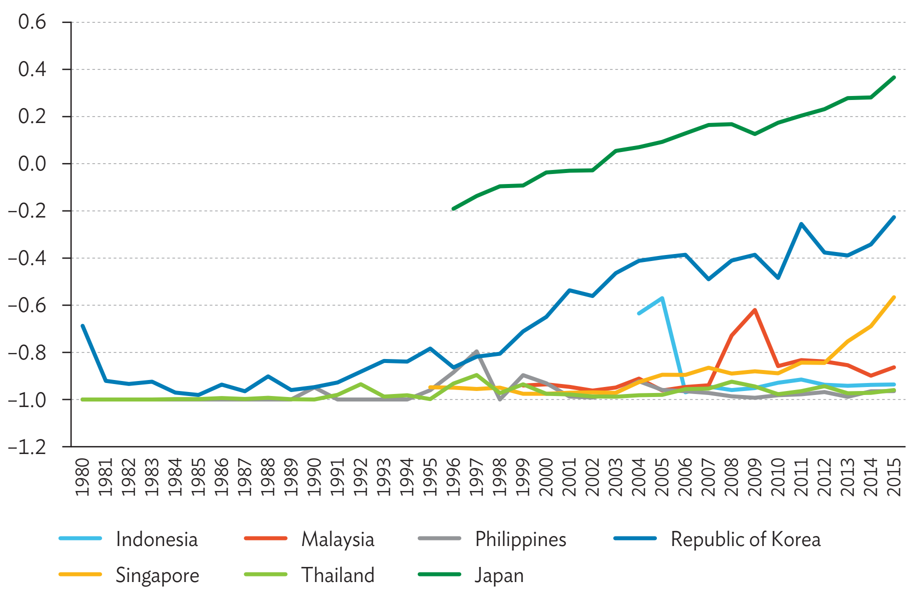
We used the formula: (exports – imports)/(exports + imports), to measure intellectual property dependence on foreign sources. Japan has enjoyed a massive surplus in its net intellectual property trade balance since 2003 (Figure 10.15). In 2014, Japan enjoyed an intellectual property trade balance of 0.37. Korea and Singapore have reduced their dependence on foreign intellectual property to −0.23 and −0.57, respectively, in 2015. Although there were improvements in some years, Indonesia, Malaysia, the Philippines, and Thailand have remained strongly dependent on foreign intellectual property. The intellectual property trade balance figures for Malaysia, Indonesia, Thailand and the Philippines in 2015 were −0.86, −0.94, −0.96, and −0.96, respectively.

Figure 10.14: Intellectual Property Receipts of Selected Economies, 1976–2015 (US$ million)



Source: World Bank (2016).

Figure 10.15: Intellectual Property Trade Balance of Selected Economies, 1980–2015



Source: World Bank (2016).

10.7 | Conclusion

The GDP per capita performance of the six ASEAN countries examined in this chapter is reflected in their innovation indicators. While Singapore has benefitted strongly from its entrepôt trade, institutional change has continued to promote the upgrading of its innovation inputs and outputs through proactive support from the government. The resulting innovation inputs and outputs compare favourably with those of developed countries. However, Singapore has not managed to stimulate the leapfrogging in the critical high-tech industries that it had expected following the launching of its science parks and the provision of cutting-edge R&D facilities and grants. Although Malaysia moved earlier than Thailand to launch formal policies to strengthen its regulatory framework and meso-organisations to stimulate innovation, because of coordination and leadership problems, it has not closed the gap with Singapore. Instead, Malaysia has remained closer to Thailand in terms of innovation inputs and outputs generated. In Indonesia and the Philippines, despite initiatives to spearhead innovative activities, especially in essential sectors, innovation inputs and outputs have remained small. Although Viet Nam began to integrate with the world economy in 1986 and has since experienced significant growth, its innovation capabilities have only now reached those of Indonesia and the Philippines.

What policy implications can be drawn from the foregoing analysis for the six ASEAN economies, as well as for other emerging economies in the world? Clearly Singapore's innovation system – with its policies, organisations, science and technology infrastructure, and connectivity and coordination between knowledge nodes, users, and producers – and innovation outputs are the most advanced among the ASEAN countries. Its sophisticated innovation system has helped sustain rapid economic growth. However, Singaporean firms have yet to leapfrog the incumbents in the high-tech industries that Korean and Taiwanese firms, such as Samsung and the Taiwan Semiconductor Manufacturing Company, have achieved. If Singapore seeks to achieve this goal, the government will have to deepen further basic research on semiconductors and a wide range of digital technologies, and attract human capital endowed with frontier tacit and experiential knowledge to spearhead such a catch-up strategy.

Malaysia and Thailand come in a distant second with regard to both innovation inputs and outputs. Malaysia leads the other countries only in the total output of scientific journal publications. Even here, Malaysia falls far behind Singapore when publications are measured in per capita terms. Also, given the higher inputs financed by the Government of Malaysia compared to Thailand, the returns do not appear to be effective. Both countries seriously lack R&D human capital. Malaysia, in particular, requires better innovation management policies and leadership by experts with experiential and tacit knowledge. While Malaysia has spent heavily on R&D funding, the returns have only been visible in scientific publications as it still faces the serious problem of commercialising its innovation outputs. Indonesia and the Philippines are far behind the other countries owing to a lack of innovation finance. Although both countries have launched STI policies, they have devoted too little funding to R&D and have not stimulated sufficient innovation output. Without greater R&D funding and stronger support for stimulating R&D activities, it is unlikely that they will be able to reverse the existing heavy dependence on foreign intellectual property.

Innovation activities are associated with public goods characteristics.[6] As such, their dissipation can be damaging. Thus, it is pertinent that incentives and grants are provided and are governed stringently to prevent rent dissipation. While the leveraging strategy has worked well in Singapore, the lack of it has restricted the FDI route to technological upgrading in the remaining ASEAN economies. Therefore, there is a need to form an evaluation, monitoring, and appraisal committee of experts with experiential and tacit knowledge and professional auditing qualifications to ensure that innovation inputs are targeted at producing innovation outputs and directed to commercialisable activities. This is the route that should be taken by Indonesia, Malaysia, the Philippines, Thailand, Viet Nam, and the remaining ASEAN economies to stimulate FDI-driven innovation synergies.

Given that ASEAN economies are profoundly engaged in collaborating to stimulate cross-regional economic, social, cultural, and political synergies, the six countries in the study should also consider the following ASEAN initiatives to promote innovation. First, as has been carried out by the European Union and the Organisation for Economic Co-operation and Development, the ASEAN-wide collaboration initiative should start with the coordination of annual innovation surveys with proper sampling of the same firms over a period of time. There should also be an innovation census every five years. The ASEAN Secretariat should coordinate this for its use by researchers and policymakers to assist evaluation and the building of innovation infrastructure in all member countries. Second, since public goods are non-rivalrous and non-excludable, the collaborative sharing of knowledge and access to public utilities will be beneficial to stimulate innovation synergies across society at large in ASEAN. Third, there should

[6] Public goods are non-excludable and non-rivalrous (Samuelson and Nordhaus, 2001).

be coordination of R&D grants across ASEAN Member States to ensure that their provision is rationalised. Fourth, since incremental innovation is the prime route by which firms (especially SMEs) access appropriate innovation synergies, ASEAN Member States should coordinate their efforts to upgrade vocational and technical education and training programmes. Fifth, there should be a mechanism to appraise all innovation policies in the region to ensure they are calibrated, taking account policy errors, government and market failures, and random future developments. Finally, efforts must be taken at the ASEAN level to share R&D findings and disseminate knowledge on poverty alleviation and environmental protection to strengthen sustainable development programmes across the region.

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