



INNOVATION POLICY IN ASEAN

EDITED BY:
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FOREWORD

Innovation has strongly promoted the development and prosperity of humankind, particularly in the modern economy, by introducing new ideas and technologies to create a shift in both daily life and society. Since the pioneering works of Joseph A. Schumpeter, economics has paid much attention to the process of technological development and innovation. Theoretically and empirically, economic studies have made it clear that research and development and innovative activities are vitally important for modern countries, industries, and firms to achieve growth and sustainable development. There have not been many studies focusing on innovation in the Association of Southeast Asian Nations (ASEAN), however, one exception being the previous ERIA study project, ‘Globalisation and Innovation in East Asia’, published in 2011.

This scarcity of relevant innovation studies for ASEAN may be an indication that the interest in or expectation of facilitating innovation policies has not always been high amongst stakeholders in the region. But times have changed. Developing countries outside of ASEAN, especially China, have increasingly strengthened their innovation ability, while ASEAN Member States (AMS) such as Indonesia, Malaysia, and Thailand are facing the difficulty of having to depend solely on the development strategy of combining manufacturing with low-wage workers. Given that ASEAN is engaged in fierce competition with other emerging countries, creating innovation independently is an urgent issue for ASEAN to achieve sustainable development, and in particular escape from the middle-income trap.

Innovation Policy in ASEAN is the culmination of ERIA studies in fiscal year 2017. It is the first comprehensive innovation study of ASEAN, in that it includes not only a theoretical framework specified for ASEAN, but also individual country analyses based upon detailed data, empirics, and case studies including cases of both success and failure. One of the book’s key messages is that for ASEAN it is important not only to increase investment in research and development and innovative activities, but also to enhance innovation capability and improve the environment where innovation tends to take place. I believe that the book will provide insights for all stakeholders who want to examine innovation policies in the region.

ERIA has dedicated tremendous efforts to the study of connectivity enhancement in East Asia, which was embodied in the *Comprehensive Asia Development Plan (CADP)* and the *CADP 2.0*. As indicated in these ERIA studies, physical, institutional, and people-to-people connectivity constitute an essential foundation for nurturing innovation because AMS are likely to benefit from technology diffusion and knowledge spillovers through integrating with production networks that have been developed in East Asia. Hence, the book suggests a basic strategy of enhancing innovation by further strengthening economic integration, which is also suggestive for trade policy issues. In light of this, the book will contribute to determining the direction of connectivity and innovation in ASEAN.

The co-authors played an important role in the development of this project. I would like to particularly thank Jose Ramon G. Albert, Haryo Aswicahyono, David Christian, Yose Rizal Damuri, Thu Hang Dinh, Nobuya Fukugawa, Yanfei Li, Hank Lim, Gilberto M. Llanto, Suresh Narayanan, Anh Duong Nguyen, Francis Mark A. Quimba, Rajah Rasiah, Saowaruj Rattanakhomfu, Somkiat Tangkitvanich, Vo Tri Thanh, Lai Yew-Wah, and Dayong Zhang. I would also like to thank Masahito Ambashi. He completed the whole book report to near perfection. I am very grateful to Nobuya Fukugawa, who stimulated our research during his sabbatical leave spent at ERIA. Lastly, I would like to express my gratitude to Chrestella Budyanto, Maria Priscila del Rosario, Fadriani Trianingsih, and Stefan Wesiak for their editorial and publishing support.

I hope that *Innovation Policy in ASEAN* will be useful guidance to all of you for promoting innovative activities in ASEAN.



Professor Hidetoshi Nishimura

President

Economic Research Institute for ASEAN and East Asia

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Executive Summary

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ECONOMIC RESEARCH INSTITUTE FOR ASEAN AND EAST ASIA

Innovation Policy in ASEAN is an outcome of the new ERIA research project conducted during fiscal year 2017. As is well known, innovation is a primary source of sustainable economic development and inclusive growth, not only through improving productivity in firms, industries, and macroeconomies but also through stimulating consumption, investment, and exports. It is also widely recognised that innovation, in addition to capital investments and skilled human resources development, is indispensable for propelling modern economies.

Economic growth in most member states of the Association of Southeast Asian Nations (ASEAN) has been driven by manufacturing industries in conjunction with a low-wage labour force, and labour-intensive manufacturing remains the basis for economic development in ASEAN. However, the economic management of ASEAN Member States (AMS) will run into obstacles if AMS remain dependent on this model in the long term. Wage levels in some AMS, such as Malaysia and Thailand, have been rising sharply, and other AMS will witness wage increases before long. This will harm the competitiveness of ASEAN's manufacturing industries compared with those of other emerging countries. In the face of this challenge, innovation can help ASEAN improve the sophistication of its economies as it enhances the attractiveness of its single market and production base. Although it may not be easy for AMS to quickly achieve a significant level of innovation capability, they have much potential for improvement in future years.

The objective of the study is to (i) review the past and present innovation policies of the more developed countries of ASEAN and East Asia – China, Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam – and present them with reasonable future innovation policies; (ii) analyse successful and failed national innovation systems (NIS) using country case studies and empirical data, and derive policy implications for AMS; and (iii) examine the ASEAN-wide innovation policies needed to promote regional innovation and provide suggestions for carrying out the ASEAN Economic Community Blueprint 2025.

Chapter 1: Introduction to Innovation Policy in ASEAN (by Masahito Ambashi) provides a general introduction to the book by describing the innovation policies that should be introduced in each AMS and for ASEAN as a whole. While existing studies have highlighted the importance of enhancing each country's innovation capability, the limited development of innovation to date has heightened concerns that some AMS, such as Malaysia and Thailand, have succumbed to the middle-income trap. It is important for AMS to steadily accelerate innovation development by formulating and implementing appropriate policies in accordance with the typology of innovation development stage. To this end, NIS, which organise innovation policy in a systematic manner and emphasise active coordination by governments, could be effective policy tools for home-made innovation. It is also important to examine ASEAN-wide innovation policies formulated to enhance the region's presence and competitiveness in the global economy.

Chapter 2: Theoretical Framework for Innovation Policy in ASEAN (by Nobuya Fukugawa) presents a theoretical framework for the design of innovation policy in ASEAN. AMS are diverse in their economic and industrial structures as well as their ethnic and political aspects. For this reason, Chapter 2 pays particular attention to devising a theoretically desirable approach to innovation policy according to the development phase and industrial characteristics. The chapter emphasises that innovation creation should first be considered from the viewpoint of how knowledge diffusion works among private firms, public institutes, and universities. A review of the theories and facts on economic growth also indicates that innovation policy matters at any stage of development. The chapter next identifies the determining factors of innovation from a theoretical perspective. These include appropriability conditions (i.e. private ownership), technological opportunities (i.e. public access), and knowledge spillovers, all of which need to be integrated appropriately into the framework of sectoral, national, and regional innovation systems. The policy implication is that multi-frameworks encompassing innovation intermediaries, entrepreneurship, and a whole-of-government approach should be built to produce knowledge spillovers and innovation diffusion in and across ASEAN.

Chapters 3 to 9 are devoted to detailed country studies. **Chapter 3: Innovation Policy in China** (by Yanfei Li and Dayong Zhang) comprehensively reviews China's past, current, and possible future innovation policy and technological catch-up strategy to provide a valuable reference for AMS that intend to accelerate economic growth by taking advantage of innovation as China has done. China remains a developing economy, and most of its industries are still in the technological catch-up phase.

However, since the 2000s, innovation, especially incremental innovation, has become more prevalent in the Chinese economy. Government innovation policies have shifted from focusing on catching up to strengthening innovation in all sectors and recognising that innovation should be seen as essential for raising productivity and avoiding the middle-income trap. Supported by empirical analysis and case studies, new theoretical frameworks, such as the life-cycle theory and the S or inverted-S curve theories, explain the dynamism of the phenomenal catching up – and even lead taking – of technologies and innovations by Chinese industries in recent decades. The chapter identifies several key factors, including risk, financing, entrepreneurship, and supply chain and component technologies. It also analyses the cases of China General Nuclear and Huawei to show how these factors work together to create the pathways for catching up.

Chapter 4: Innovation Policy in Indonesia (by Yose Rizal Damuri, Haryo Aswicahyono, and David Christian) takes stock of past and present innovation policies implemented in Indonesia. The chapter begins by revealing the absence of a formal, integrated NIS until recently and the corresponding lack of significant innovations in Indonesia compared with its regional peers. It then draws lessons for frameworks of governance with respect to the government's innovation initiatives, programmes, and platforms that are intended to stimulate knowledge diffusion, by exploring the interactions between the innovation actors. The discussion finds that Indonesia's approach to innovation has been generally too government-centric and has lacked good coordination, continuity, and implementation and, consequently, has failed to produce the desired knowledge diffusion. The chapter concludes with suggestions for the future Indonesian innovation system. It proposes that the government should assume the role of an innovation facilitator by creating a conducive environment at the macro level. Improving the investment climate, establishing basic innovation enablers, and encouraging local-level initiatives must also be prioritised in the short run to promote knowledge diffusion. On the other hand, adopting the more explicit and advanced innovation policies commonly observed in developed countries is unlikely to succeed at the current stage of development unless they are accompanied by significantly greater foreign direct investment, which has been the major channel of knowledge diffusion in Indonesia.

Chapter 5: Innovation Policy in Malaysia (by Suresh Narayanan and Lai Yew-Wah) states that despite a late start in formulating its policies to nurture innovation, there is encouraging evidence that firm-level innovation in Malaysian manufacturing has been growing and that macro indicators of research inputs and outputs have been increasing. However, despite this evidence of innovation development, Malaysia's rankings in key global innovation indices fell during 2014–2016. The chapter sets out to account for

this poor performance by considering the nature of innovation. First, whereas most of the innovation undertaken by large firms and small and medium-sized enterprises (SMEs) occurred in relatively low-tech sectors, little or none was reported from SMEs in the more sophisticated electrical and electronics sectors despite their long links with multinational corporations (MNCs). Second, most firms were engaged in adaptation rather than patent-generating creation. Third, collaborative research with publicly created entities and technology gained from parent plants produced most of the innovation, but the technology gained through supplier links with MNCs contributed little to firm-level innovation. Fourth, while foreign firms appear to have generated horizontal and vertical spillovers, principally including forward and backward spillovers, the vertical spillovers were limited to backward ones. Weaknesses in the implementation, monitoring, and application procedures of well-intentioned innovation policies and schemes compounded the problem. The chapter, therefore, concludes that no new policy initiatives are required to increase the momentum of innovation; rather, a fine-tuning of existing innovation policies and delivery systems is urgently needed to increase their efficiency.

Chapter 6: Innovation Policy in the Philippines (by Francis Mark A. Quimba, Jose Ramon G. Albert, and Gilberto M. Llanto) recognises that now, more than ever, Philippine industries are facing new demands that require more innovations if firms are to remain competitive across the rapidly changing global marketplace. The 2015 Philippine Institute of Development Studies Survey on Innovation Activities suggests that about 43% of establishments in the Philippines were innovation-active, and, strikingly, the business process outsourcing sector spent the most on innovation activities. Intellectual property applications have been very low across all industries and all types of intellectual property, which implies that firms tend to view their product innovations as trade secrets to maintain their competitive edge against rivals. The chapter finds that knowledge management activities are positively correlated with firm size and that larger firms tend to rely on internal sources for their information and innovation, as is the case with the food processing and automotive sectors. The 2015 survey found that firm size and the practice of knowledge management were adequate determinants of innovation. Considering the survey results, the chapter argues that innovation policy should veer away from a linear innovation model focusing only on research and development (R&D) and move towards one that is grounded on consultations with all stakeholders in the innovation ecosystem. In addition, it maintains that stronger intellectual property rights would provide a more enabling business environment to encourage larger numbers of firms to innovate, especially among wary MNCs.

Chapter 7: Innovation Policy in Singapore (by Hank Lim) conducts an elaborate analysis of knowledge diffusion over successive phases of economic restructuring and technological development in Singapore. The diffusion process can be observed not only through the change in and upgrading of existing industrial clusters, such as the offshore marine engineering cluster, but also in the establishment of a biomedical science cluster. Throughout the process, the Government of Singapore has played an instrumental and crucial role in strategic planning, infrastructure building, and human resources development. The chapter stresses that the remarkable success of Singapore's innovation policy has been characterised by and is attributable to both its strategic and long-term planning and the meticulous coordination and execution of different innovation components and teamwork with various stakeholders in a single, seamless process. Such success in implementing cohesive and integrated innovation policies and measures has been made possible by effective and efficient public officials, necessary institutions, and competitive market environments. The chapter points to three core elements for the process of innovation policy: research, innovation, and enterprises. It asserts that in the next phase of innovation progress, Singapore will be increasingly dependent not only on its own research intensity and deeper pools of world-class research but also on attracting scientific and entrepreneurial talent that can translate the innovations produced into value creation and marketable services. The two case studies of the offshore marine engineering and biomedical science clusters illustrate the complexities, characteristics, and processes of Singapore's innovation policy experience as well as the resultant policy outcomes.

Chapter 8: Innovation Policy in Thailand (by Saowaruj Rattanakhomfu and Somkiat Tangkitvanich) takes note of Thailand's remarkable economic development. An average gross domestic product (GDP) growth rate of more than 6% per year from the 1960s to the mid-1990s and the diversification of export products and markets reflect Thailand's success in transforming itself from a traditional agricultural economy into modern one based on manufacturing and services. But despite these accomplishments, Thailand has been unable to regain the high growth rates achieved before the 1997 Asian financial crisis. This shows that without upgrading its R&D and innovation capabilities, the country will be unable to escape the middle-income trap. This chapter makes it clear that Thailand needs to increase its investment in R&D, produce more R&D personnel, and, more importantly, manage its total R&D system to achieve greater economic efficiency. To improve the Thai R&D system, the chapter suggests that the government should (i) increase public investment in R&D, especially applied R&D, to the target of 2% of GDP; allocate the R&D budget through capable research granting agencies; and use public money to encourage

private investment; (ii) create accountability in publicly funded research; (iii) establish a specialised government research institute with the sole mission of conducting R&D for commercialisation; (iv) improve R&D human resources policies by reforming the current government scholarship systems; and (v) make technology transfer an explicit objective of government procurement for megaprojects, such as railway and water management projects.

Chapter 9: Innovation Policy in Viet Nam (by Tri Thanh Vo, Anh Duong Nguyen, and Thu Hang Dinh) provides a comprehensive review of innovation policy in Viet Nam since 1986. In tandem with economic reforms and integration, Viet Nam has gradually expanded and amended its innovation policy. The chapter demonstrates that science and technology (S&T) achievements have contributed to economic development in Viet Nam through their impacts on labour productivity and economic structure. However, there are obstacles to more effective S&T innovation-led growth. Viet Nam's innovation capability and policy environments, namely the NIS, are insufficiently pro-innovation in both the public and private sectors due to overlapping and inconsistent policy design and implementation, and inadequate financing and human resources for S&T. It is also notable that the policy space for supporting S&T development and innovation has become narrower due to an array of international economic commitments associated with membership of the World Trade Organization and economic partnership agreements. To bring about more sustainable economic development, the chapter insists that Viet Nam's innovation policy should be amended towards (i) improving the institutional and policy framework for S&T and innovation, (ii) strengthening human resources development for S&T, (iii) enlarging the engagement and role of the private sector in innovation, (iv) enhancing the contribution of public research organisations to innovation, and (v) reinforcing links between S&T and innovation.

Chapter 10: Innovation Policy, Inputs, and Outputs in ASEAN (by Rajah Rasiah) provides an overview of innovation policy by the governments of Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam and their impacts on innovation inputs and outputs. The evidence shows that Singapore is by far the most innovation-intensive of the six AMS, followed by Malaysia and Thailand, and there is little difference between Indonesia, the Philippines, and Viet Nam, which are by far the least innovation-intensive countries. While Singapore has led the other countries on both innovation inputs and outputs and has reduced its dependency on foreign intellectual property, despite aggressive promotion, the country still lacks strong research-based universities and the human capital to support the kind of radical,

global-scale innovation that can stimulate technological leapfrogging. Malaysia and Thailand have implemented innovation policies since the 1990s and 2000s, respectively, by increasing R&D expenditure and focusing on augmenting R&D personnel to stimulate patent filing and intellectual property exports. In contrast, Indonesia, the Philippines, and Viet Nam have invested little in R&D, and, as a result, their innovation inputs and outputs have remained relatively low. The chapter also argues that ASEAN regional innovation policies, such as ASEAN initiatives for promoting innovation, should be seriously considered; collaborative sharing of and access to knowledge should be promoted to stimulate innovation synergies; and R&D grants and efforts to upgrade vocational and technical training programmes should be coordinated across AMS.

Finally, **Chapter 11: Conclusion and Policy Recommendations** (by Masahito Ambashi) summarises the discussions developed in individual chapters and provides policy recommendations for innovation policy in ASEAN. The chapter's key message is that it is important for ASEAN not only to increase investment in R&D and innovative activities but also to enhance the region's innovation capabilities and improve the environment in which innovation tends to take place. The chapter goes on to present innovation policy for individual AMS and for ASEAN as a whole. With respect to AMS innovation policy, it argues that the fundamental strategy should be reaffirmed; that is, AMS need to continuously attract foreign direct investment from MNCs to benefit from the knowledge spillovers of process innovation in the use of production networks or the 'second unbundling'. The region's economic integration should be further strengthened to realise an efficient and effective division of labour through measures such as infrastructure enhancement, the removal of non-tariff barriers, and economic partnership agreements, such as the Regional Comprehensive Economic Partnership Agreement. In doing so, it is important to (i) strategically drive and implement harmonised innovation policies; set priorities over measures, plans, and programmes; and monitor and evaluate them; (ii) encourage the private sector, including both domestic and foreign firms, to invest more in R&D and innovative activities; and (iii) elaborate on a conducive innovation ecosystem for the NIS. The chapter goes on to consider policies for ASEAN, recommending that it should (i) formulate initiatives for promoting innovation with more cross-regional synergies and positive feedbacks across AMS; (ii) accelerate goods, investment, and service trade liberalisation and deregulation; and (iii) promote the freer movement of natural persons, especially of highly skilled immigrants.

SUMMARY OF POLICY RECOMMENDATIONS

The following policy recommendations aim to provide possible directions for the innovation policies of ASEAN Member States and ASEAN to promote their own innovation creation.

I. Innovation Policy for Individual ASEAN Member States

Fundamental strategy: Continuously attract foreign direct investment from multinational companies and receive the benefits of knowledge spillovers from them to promote process innovation, particularly in the use of production networks or the ‘second unbundling’.

Strengthen economic integration to realise efficient and effective production networks (e.g. infrastructure enhancement, the removal of non-tariff barriers, and economic partnership agreements, such as the ASEAN-plus-one free trade agreements).

1. **Strategically drive and implement harmonised innovation policies; set priorities over measures, plans, and programmes; and monitor and evaluate them.**
 - Establish or reinforce a government organisation responsible for holding unified authority with strong leadership under government control to lead and coordinate innovation policies across various departments.
2. **Encourage the private sector, including both domestic and foreign firms, to invest more in research and development (R&D) and innovative activities.**
 - Provide subsidy and tax credits for R&D and human resources development, grants for targeted innovative activities, and patent grants.
 - Create specialised public research institutes with the primary mission of conducting R&D and providing technical support related to the commercialisation of innovation achievements modelled after other countries (e.g. Exploit Technologies Pte Limited of A*STARS in Singapore).
3. **Elaborate on a conducive innovation ecosystem for the national innovation system.**
 - Nurture university–industry collaboration to enhance university-launched innovations and to disseminate and commercialise them for private industrial sectors (e.g. by introducing laws analogous to the ‘Basic Act on Science and Technology’ in Japan and the ‘Technology License Organization Law’ and ‘Bayh-Dole Act’ in the United States).
 - Organise public institutes or programmes, such as local public technology centres, as innovation intermediaries to help private manufacturing firms, particularly small and medium-sized enterprises, innovate.

II. Innovation Policy for ASEAN as a Whole

1. **Formulate initiatives for promoting innovation with more cross-regional synergies and positive feedback across ASEAN Member States.**
 - Innovation surveys and censuses for innovation infrastructures; databases and platforms for R&D findings and innovation for collaborative knowledge; and optimised coordination of R&D grants and subsidies, and education programmes.
 - Compare ASEAN Member States’ innovation policies by introducing peer reviews.
2. **Accelerate goods, investment, and services trade liberalisation.**
 - Consider, in particular, further eliminating services trade restrictions in the ASEAN Framework Agreement on Services and the ASEAN Trade in Services Agreement.
3. **Promote the freer movement of natural persons, especially of highly skilled immigrants.**
 - Enhance the free movement of engineering service providers and make it easier for certified engineers in the mutual recognition agreement to work overseas.
 - Strengthen collaboration among ASEAN universities through harmonising their curricula and degrees to create new, university-based innovation.

Introduction to Innovation Policy in ASEAN

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1.1 | Is Innovation Indispensable for ASEAN?

Innovation is widely acknowledged as a primary source of sustainable economic development and inclusive growth, not only through improving productivity in firms, industries, and macro economies but also through stimulating the expansion of consumption, investment, and exports. Innovation, in addition to capital investments and human resources, is regarded as indispensable for propelling modern economies. It should also be noted that innovation frequently brings about spillover effects via research and development (R&D) activities and patents to other economic agents. In other words, the social returns of innovation could be much higher than the private ones because of positive externalities.¹

Moreover, recently, the economic impacts of innovation have been emphasised in relation to the emergence of information and communication technology (ICT), especially the Internet, since the 1980s. ICT has affected the technology levels, business investments, and management systems of both manufacturing and service industries through computers and networks enabled by the Internet, the speed of which has been increasing rapidly. With respect to manufacturing industries, ICT facilitates production processes and systems in, for example, automobile industries. In the currently prevailing fragmented production system, factories and facilities (including goods, know-how, ideas, capital, investment, and workers) are unbundled within global value chains with the support of ICT by the trading of raw materials, final goods, and production services, which promotes new types of manufacturing innovation.²

¹ Hall and Lerner (2010) conclude that the social returns of R&D activities, which they estimate as 20%–30% in developed countries, are higher than those of capital investments overall.

² Baldwin (2011) represents this global division of production at the task level as the ‘second unbundling’, while the ‘first unbundling’ indicates the division of production based on the trade theory of comparative advantage.

Moreover, the latest technologies, such as the Internet of things or artificial intelligence, produce business opportunities for services companies that heavily depend on the Internet, such as Amazon, Alphabet (the holding company of Google), and Uber.

This recognition of the efficacy of innovation has, no doubt, been prevailing in developed countries for some time, but there still seems to be some scepticism in developing countries (Fagerberg et al., 2010). Questions such as ‘Is innovation a significant factor for the economic development of developing countries?’ or ‘Is it beneficial to consider innovation as an important policy target for developing countries?’ are frequently answered negatively on the grounds that high-tech firms and high-tech industries would emerge only in advanced economies. So far, the member states of the Association of Southeast Asian Nations (ASEAN) have not on the whole been exceptions to this sceptical point of view.

This scepticism may stem from a high ideal of what innovation should be. The current popular definition of innovation was affected by Schumpeter (1934), who advocated the concept of ‘new combination’.³ Influenced by Schumpeter’s work, the *Oslo Manual* (OECD, 2005), which is the source of guidelines for the collection and interpretation of data on innovation, defines innovation as ‘the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations’. Although this definition of innovation excessively emphasises the element of ‘new’, it is highly likely that most actual innovation steps start with imitation. For example, Japan and the Republic of Korea (henceforth, Korea), when they were less developed countries that possessed only infant technologies, were eager to imitate superior Western technologies through licensing and reverse engineering. This suggests that there is much room for developing countries to advance their technologies through diverse activities, including learning-by-doing, imitation, and technology transfer, and not just through original inventions or innovations at the initial development stage.

Innovations diffuse from developed to developing countries like water flowing from high to low places and, as a result, countries’ development levels converge.

³ Schumpeter (1934) employed the term ‘new combination’, rather than innovation, in his early writings. He categorises new combination into five types: (1) the launch of a new product or a new quality of an already known product, (2) the application of new methods of production or sales of a product, (3) the opening of a new market, (4) the acquisition of new sources of supply of raw materials or semi-finished goods, and (5) the formation of a new industry structure, such as the creation or destruction of a monopoly position. Thus, he stresses that innovation in the economy is not led by consumers but by producers.

But this discreet, passive, neoclassical view captures only one aspect of innovation in developing countries. Another more important aspect highlights innovation policies or systems for proactive, provocative technological development, undertaken or put in place by the governments of developing countries. This approach could be conducive to innovation in contrast to laissez-faire market approaches (Fagerberg et al., 2010). Successful examples are observed in East Asian countries, such as China, Japan, Korea, and Singapore, which have achieved their own innovation to varying degrees. It has been demonstrated that they systemically formulated and implemented innovation policies not only to carefully address market failure⁴ but also to aim to audaciously close innovation gaps with developed countries. It is, therefore, indispensable for ASEAN Member States (AMS) and ASEAN to develop their own effective innovation policies.

1.2 | Innovative Activities in ASEAN

Before investigating in detail possible innovation policies for ASEAN, it is useful to review the current status of innovative activities conducted in the region. Although, in general, it is difficult to accurately evaluate the level of innovative activities, the following measures provide some approximations. Subsequent chapters in this book provide details of innovative activities in individual countries.

1.2.1 Innovation capability

How innovation is achieved by countries depends on their intrinsic capability, which is frequently referred to as ‘innovation capability’ in the literature. Intuitively, innovation capability provides a country with the foundation for creating innovation by itself, and thus, it can take on physical, intangible, and institutional characteristics.

AMS need to enhance their innovation capability to achieve autonomous and sustainable economic development based on innovations so as not to be over-dependent only on foreign direct investment (FDI) and official development assistance. Innovation capability also matters if AMS are to escape the so-called ‘middle-income trap’, where developing countries that attain middle-income status owing to given advantages, such as abundant natural resources, stagnate at that development level.

⁴ It is typically difficult for innovators to appropriate their innovation outcomes except for intellectual property rights, such as patents, because of externalities (spillovers). Hence, market failure caused by the free rider problem is inevitable (Arrow, 1962).

For ASEAN to be competitive, dynamic, and innovative, and for it to maintain its centrality in the global economy, developing AMS' innovation capability through effective policies is its key challenge.

To make the concept of innovation capability more concrete, Fagerberg and Srholec (2008) presented comprehensive measures that can be categorised into four types of capabilities: innovation system, governance, political system, and openness. The innovation capability we now discuss mostly corresponds to the innovation system they proposed. According to the results of the factor analysis they undertook to identify effective measures for innovation achievement, innovation systems include measures such as the United States Patent and Trademark Office patents, science and engineering articles, the International Organization for Standardization (ISO) 9000 certification, fixed line and mobile phone subscribers, Internet users, and secondary and tertiary school enrolment. Using the score of the innovation system specifically calculated by the above-mentioned innovation-related measures, the authors observe a clear positive relationship between the innovation system and the level of economic development expressed as gross domestic product (GDP) per capita across countries. Based upon a regression analysis of 115 countries from 1992 to 2004, the authors also find that the degree of sophistication of innovation systems is positively associated with and of particular importance for economic development.

From this finding, clearly, having better innovation capability, strengthened by various tangible and intangible factors, is of significant importance in enabling developing countries to move ahead with their economic development agendas. The following sections consider data on innovative activities in ASEAN and provide an assessment of AMS' innovation capability. They argue that most AMS are still building their innovation capability.

1.2.2 Data on innovative activities in ASEAN

Research and development intensity. R&D expenditure should be a main indicator of innovation progress in a country. Table 1.1 presents R&D intensity per GDP for AMS, China, India, Japan, and Korea. It shows that most AMS, except Singapore, have maintained quite low investments in R&D compared with Japan and Korea, which have recorded an R&D intensity in excess of 3% since 2000 (Japan) and 2008 (Korea).⁵

⁵ In 2000, the European Union formulated the Lisbon Strategy, which aimed to leverage R&D investments to boost its economies. This strategy was followed in 2003 by an action plan, 'Investing in Research', which laid out an ambitious goal of investing 3% of GDP in R&D by 2010 (the so-called '3% objective', set in Barcelona). This goal is regarded as a numerical criterion that developed countries are encouraged to achieve.

Table 1.1: Research and Development Intensity
(% of gross domestic product)

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Brunei Darussalam	...	...	0.02	0.02	0.04	...	...	...	...	...	...	...	...	...	...
Cambodia	...	...	0.05	...	...	...	...	...	...	...	...	...	...	...	...
Indonesia	0.07	0.05	...	...	...	...	...	...	...	0.08	...	...	...	0.08	...
Lao PDR	...	...	0.04	...	...	...	...	...	...	...	...	...	...	...	...
Malaysia	0.47	...	0.65	...	0.60	...	0.61	...	0.79	1.01	1.04	1.03	1.09	...	1.26
Myanmar	0.11	0.07	0.16	...	...	...	...	...	...	...	...	...	...	...	...
Philippines	...	...	0.14	0.13	...	0.11	...	0.11	...	0.11	...	0.12	...	0.14	...
Singapore	1.82	2.02	2.07	2.03	2.10	2.16	2.13	2.34	2.62	2.16	2.01	2.15	2.00	2.00	2.19
Thailand	0.24	0.25	0.23	0.25	0.24	0.22	0.23	0.20	...	0.23	...	0.36	...	...	0.48
Viet Nam	...	...	0.18	...	...	...	...	...	...	...	...	0.19	...	...	...
China	0.90	0.95	1.06	1.13	1.22	1.32	1.38	1.38	1.46	1.68	1.73	1.79	1.93	2.01	2.05
India	0.74	0.72	0.71	0.71	0.74	0.81	0.80	0.79	0.84	0.82	0.80	0.82	...	...	...
Japan	3.00	3.07	3.12	3.14	3.13	3.31	3.41	3.46	3.47	3.36	3.25	3.38	3.34	3.47	3.58
Republic of Korea	2.18	2.34	2.27	2.35	2.53	2.63	2.83	3.00	3.12	3.29	3.47	3.74	4.03	4.15	4.29

... = no data, Lao PDR = Lao People's Democratic Republic.

Sources: United Nations Educational, Scientific and Cultural Organization Institute for Statistics, dataset obtained from Science, Technology & Innovation: Research and Development.

Malaysia's R&D expenditure has been rising rapidly and has exceeded 1% since 2009. Thailand's has been low at 0.2%–0.5% despite a recent upward trend, while the 'CLMV' countries (Cambodia, Lao PDR, Myanmar, and Viet Nam) have made minuscule investments in R&D. China's R&D expenditure, on the other hand, has skyrocketed since the 2000s, in line with its strong economic development. In 2014, it reached 2.05%, which is comparable to Singapore's 2.19%. (Note that the absolute amount of R&D in China is far greater than that of Singapore given the relative sizes of their economies.)

Patent applications. The same trend can be observed with respect to the number of patent applications in each country (Table 1.2). As research has generally affirmed, most patent applications are associated with innovative activities, especially inventions. Table 1.2 indicates that although the number of direct patent applications has tended to increase in all AMS, it is still smaller than in the developed

Table 1.2: Direct Patent Applications
(number per million population)

Country	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Brunei Darussalam	5.53	0.00	26.71	5.25	5.17	83.90	25.03	64.12	75.33	88.65
Cambodia	0.00	0.00	0.00	0.00	0.07	0.07	0.07	0.00	0.07	0.33
Indonesia	1.12	1.32	1.31	1.67	1.83	2.21	2.31	...	2.77	2.92
Lao PDR	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Malaysia	34.11	36.40	40.29	42.61	58.46	59.92	50.33	51.62	56.91	66.28
Myanmar	...	...	...	...	...	...	...	...	...	...
Philippines	3.09	3.19	3.53	3.24	2.48	2.72	2.95	2.87	3.16	4.91
Singapore	326.55	372.84	490.35	471.75	412.63	469.59	501.19	524.05	548.23	609.17
Thailand	15.11	17.18	16.68	16.12	17.37	20.06	15.96	17.26	18.16	17.70
Viet Nam	2.21	2.42	2.72	2.50	3.06	3.61	3.49	4.41	5.14	5.71
China	73.55	96.66	119.45	150.72	177.40	224.51	314.65	402.86	526.96	597.39
India	5.30	6.24	7.12	7.49	8.12	9.81	10.21	11.60	12.97	14.40
Japan	3,721.06	3,541.24	3,423.09	3,388.88	2,997.56	2,936.34	2,954.83	2,950.25	2,758.97	2,685.61
Republic of Korea	3,244.67	3,410.01	3,415.54	3,296.41	3,203.18	3,339.24	3,484.29	3,728.97	4,068.01	4,152.37

... = no data, Lao PDR = Lao People's Democratic Republic.

Sources: World Intellectual Property Organization Global Brand Database and World Bank Database.

Asian countries. Even Singapore does not produce sufficient patent applications compared to other developed Asian countries. This suggests that AMS have much room to increase their patents as facilitators of innovation capability.

Number of researchers. Table 1.3 presents the number of R&D researchers per million people in major AMS. Educated human resources, especially engineers and scientists, are without doubt a fundamental driving force of innovation. Excluding Singapore, which has focused its limited human resources on R&D and had 6,658.5 researchers per 10,000 population in 2014, Malaysia had the highest number of the AMS (2,051.7) in the same year, although the number is small relative to Japan's 5,386.2 and Korea's 6,899.0. The figures suggest that the quantity of R&D researchers is not sufficient in most AMS. Hence, countries need to exert greater efforts to produce more R&D researchers who excel in science and technology (S&T) through their higher education systems (e.g. universities and national research laboratories) to achieve higher levels of home-grown innovation.

**Table 1.3: Number of Research and Development Researchers
(full-time equivalent per 10,000 population)**

Country	2000	2001	2002	2003	2004	2005	2006	2007
Brunei Darussalam	...	...	288.3	280.4	286.5	...	...	...
Cambodia	...	...	17.6	...	...	...	...	...
Indonesia	212.6	199.2	...	...	...	...	...	...
Lao PDR	...	...	15.8	...	...	...	...	...
Malaysia	274.2	...	293.3	...	500.1	...	369.1	...
Myanmar	...	11.9	17.2	...	...	...	...	...
Philippines	...	...	...	70.6	...	80.1	...	78.2
Singapore	4,245.0	4,160.9	4,381.0	4,706.5	4,881.9	5,291.8	5,424.8	5,768.6
Thailand	...	279.3	...	279.5	...	311.3	...	322.4
Viet Nam	...	...	113.9	...	...	...	...	...
China	547.3	581.5	631.1	667.5	713.3	856.8	932.3	1,078.6
India	110.1	...	...	...	...	135.3	...	...
Japan	5,151.1	5,183.8	4,934.9	5,156.1	5,156.8	5,360.2	5,387.0	5,377.7
Republic of Korea	2,345.4	2,932.5	3,034.4	3,215.2	3,301.3	3,777.1	4,175.0	4,603.8
Country	2008	2009	2010	2011	2012	2013	2014	
Brunei Darussalam	...	...	...	...	...	...	...
Cambodia	...	...	...	...	...	...	...
Indonesia	...	89.5	...	...	...	...	...
Lao PDR	...	...	...	...	...	...	...
Malaysia	601.0	1,070.4	1,467.1	1,653.4	1,793.5	...	2,051.7	
Myanmar	...	...	...	...	...	...	...
Philippines	...	81.9	...	85.1	...	189.4	...	
Singapore	5,740.8	6,149.0	6,306.5	6,496.0	6,442.3	6,665.2	6,658.5	
Thailand	...	330.6	...	543.5	...	...	974.0	
Viet Nam	...	...	...	...	...	...	...
China	1,200.3	863.9	903.0	977.7	1,035.9	1,089.2	1,113.1	
India	...	...	156.6	...	...	...	...
Japan	5,157.8	5,147.8	5,152.6	5,160.2	5,083.7	5,201.3	5,386.2	
Republic of Korea	4,867.8	5,000.9	5,380.3	5,853.3	6,361.6	6,456.6	6,899.0	

... = no data, Lao PDR = Lao People's Democratic Republic.

Sources: United Nations Educational, Scientific and Cultural Organization Institute for Statistics.

1.2.3 Empirical observations of existing studies

Several empirical studies examine how innovation in ASEAN has progressed and what impact innovation has had on the economic environment. Hahn and Narjoko (2010) published a pioneering study with the Economic Research Institute for ASEAN and East Asia (ERIA) that investigated innovation issues based on unique micro firm- and establishment-level data across East Asian countries.

As part of the research project, a prominent study by Kuncoro (2010) examined the relationship between globalisation and innovation through a study of Indonesian medium and large manufacturing firms. Somewhat surprisingly, no clear-cut upward trends in the percentage of Indonesian firms that conducted R&D investments could be observed in his dataset during 1995–2006 (7.4%–8.8%). Furthermore, the R&D intensity of firms (R&D expenditure as a share of the value of total inputs), regardless of their enterprise characteristics, decreased during 2000–2006 (from 1.1% to 0.5% for all firms). Although these data should be interpreted carefully, Ito (2013) develops an insightful argument that Indonesian firms may have changed their production from high-end (R&D intensive) products to low-end (primary, such as mining and mineral) products. As for other AMS, there do not seem to be any robust findings to suggest that the R&D intensity of domestic firms greatly increases through investing more in R&D and innovative activities, in tandem with increasing globalisation.

These empirical observations may indicate that AMS are caught in the middle-income trap (Griffith, 2011). This may be because of the absence of industrial competitiveness, particularly in manufacturing. As these studies suggest, domestic firms in AMS are likely to have transformed their business structures to improve their comparative advantage in low-end products in primary industries rather than concentrating on high-end products that require greater innovative activities (Ito, 2013). The resource boom that has occurred since the beginning of the 21st century, as observed in the price hikes of oil, gas, and commodities, induced many AMS to invest in these products. This raises a serious concern that such biased investments in and orientation towards primary industries and products and away from innovative activities could cause the so-called ‘Dutch disease’ in some AMS.⁶

⁶ Dutch disease suggests the causal relationship in which an expansion in the resource sector weakens the manufacturing sector. This occurs because as the resource sector grows, the national currency appreciates, and the domestic wage of the workforce rises, reducing the competitiveness of manufacturing industries.

This suggests that exports of resources and resource-related products may further weaken the competitiveness and innovativeness of AMS manufacturing industries in international markets.

The industry shift to less-innovative activities seems to be simply firms optimising their behaviour. More precisely, firms seek to short-sightedly accommodate their businesses activities to given market environments (the resource boom in this case) by producing and exporting more low-end primary products based on the free trade mechanism (that is, specialisation of production based on the principle of comparative advantage). However, an overdependence on resources is likely to unintentionally undermine the foundation of firms in AMS for producing innovation in the long run (Ito, 2013). Strenuous efforts to nurture innovation capability are, therefore, of paramount importance for AMS to avoid the middle-income trap and Dutch disease. To this end, it would be sensible to allocate government financial surplus obtained from exporting primary products to the budgets for innovation policies to support public and private innovative activities.

1.3 | Efforts towards Innovation in ASEAN

Despite a prolonged stagnation in innovative activities, ASEAN has recognised the importance of improving its members' ability to develop S&T. The organisation has made many efforts to produce innovation and address the challenges on the way to becoming an 'innovative ASEAN' (ASEAN Secretariat, 2015). The following paragraphs review ASEAN's efforts to promote innovation.

Science, technology, and innovation (STI) policies in ASEAN have progressed along with a set of frameworks developed within ASEAN. In 1971, the ASEAN Permanent Committee on Science and Technology was reorganised to enhance the work of promoting and intensifying cooperation in S&T activities. Subsequently, in 1978, the ASEAN Committee on Science and Technology (ASEAN COST) was officially established as a primary headquarters of ASEAN S&T policies, guided by the ASEAN Summits and the ASEAN Ministerial Meetings on Science and Technology. Roughly speaking, the objective of ASEAN COST is to promote cooperation towards developing S&T and related human resources and to encourage technology transfer within and outside ASEAN. In addition, ASEAN COST organises nine sub-committees, including food S&T, biotechnology, and space technology and applications. Since the establishment of ASEAN COST, ASEAN has reinforced its ability to develop STI.

For example, the ASEAN Ministerial Meetings on Science and Technology and ASEAN COST have been held once and twice a year, respectively, to discuss STI-related issues. One of the achievements of ASEAN COST has been the design of the first ASEAN Plan of Action on Science and Technology, which was adopted in 1985. ASEAN COST holds periodic meetings with China, the European Union, Japan, Korea, the United States, and others, and discusses cooperation issues on STI through a multinational interlocutory framework of Japan–China–Korea.

STI has recently been positioned as a major foundation for attaining the ASEAN Vision 2020 that was set out in 1997.⁷ The goal is to transform ASEAN into ‘a technologically competitive ASEAN, competent in strategic and enabling technologies, with an adequate pool of technologically qualified and trained manpower, and strong networks of scientific and technological institutions and centres of excellence’. In October 2016, the ASEAN Plan of Action on Science, Technology and Innovation (2016–2025) was formulated, together with vision, goals, and thrusts, after the launch of the ASEAN Economic Community (AEC) in 2015.⁸ This new comprehensive action plan aims to promote ‘a science, technology and innovation-enabled ASEAN, which is innovative, competitive, vibrant, sustainable and economically integrated’ towards 2025. The goals underline the active involvement of and collaboration between the public and private sectors (especially small and medium-sized enterprises), mobility of talent, deep awareness of STI, an innovation-driven economy, active R&D collaboration, technology commercialisation, entrepreneurship, and so on. In response to concerns about how to implement a designated vision, goals, and thrusts, the plan puts forward detailed strategic actions.

Another remarkable thing about the framework of STI policy in ASEAN is that the institutional position of ASEAN COST moved from the ASEAN Socio-cultural Community to the AEC, as indicated by the AEC Blueprint 2025. Since ASEAN COST is under the supervision of the AEC, it has been designed to address the economic issues specified by the AEC Blueprint 2025 – ‘productivity-driven growth, innovation, R&D, and technology commercialisation’ (Subsection B.4). This institutional change not only streamlines the organisation of the ASEAN Secretariat but also indicates

⁷ The ASEAN Vision 2020 was issued during the Second ASEAN Informal Summit in Kuala Lumpur on 15 December 1997. It is available at http://asean.org/?static_post=asean-vision-2020

⁸ The ASEAN Plan of Action on Science, Technology and Innovation was published by the ASEAN Secretariat and is available at <http://aseanstforum.net/wp-content/uploads/2016/09/APASTI2016-2025.pdf>

ASEAN's keen interest in improving productivity and reinforcing global industrial competitiveness through innovation, and thereby producing more economic value. In this sense, the development of STI should be further promoted with a particular focus on R&D investment relevant to industries and firms that directly contribute to the aforementioned economic objectives.

Although the discussion so far has stressed innovation policy in the framework of the AEC, the impact of innovation on sociocultural aspects should not be overlooked. Indeed, the ASEAN Socio-cultural Community Blueprint 2025 still refers to S&T in terms of education systems under the common goal of 'a creative, innovative and responsive ASEAN'. Aside from economic impacts, the sociocultural impacts (e.g. the digital divide) that innovation entails remain an important issue in ASEAN.

1.4 | Typology for Innovation Policy in ASEAN

The large discrepancy in the levels of innovative activities among AMS means that innovation policies for individual AMS will also vary. The discrepancy can be seen in the Global Innovation Index published by Cornell University, INSEAD, and the World Intellectual Property Organization. According to the 2016 Global Innovation Index (Dutta et al., 2016), the rankings of AMS range from Singapore's rank of 6th to Cambodia's rank of 95th.⁹ Hence, in drawing up innovation policies for each AMS, a typology of technology and innovation is useful to guide individual AMS.

The Technology Achievement Index (TAI), developed by the United Nations Development Programme, also assesses countries' technological development levels. The TAI provides an indication of how well a country can create and use technology, rather than simply reflecting the value of inputs, such as the number of scientists and R&D expenditure. An analysis by the Asian Development Bank Institute (2014) of the scores of Asian countries, including AMS, from 1999 to 2008 suggests that, in terms of technology and innovation, AMS can be roughly classified into two categories: Singapore (which is comparable to Japan and Korea) and the rest of ASEAN (along with China and India).¹⁰ Another interesting finding of the study is that

⁹ Other AMS rankings in the 2016 Global Innovation Index are as follows: Malaysia, 35th; Thailand, 52th; Viet Nam, 59th; the Philippines, 74th; and Indonesia, 88th. The results for Brunei Darussalam, Lao PDR, and Myanmar are not available.

¹⁰ See Asian Development Bank Institute (2014, p. 116, Figure 3.7).

some AMS, such as Brunei Darussalam, Malaysia, Singapore, Thailand, and Viet Nam increased their TAI scores between 1999 and 2008, meaning that they significantly improved their levels of technological development and innovation during the period. The biggest improvement can be seen for Viet Nam.

Looking at ASEAN as a whole, however, technological development, innovation capability, and the resulting innovation achievements have lagged economic growth. Moreover, AMS are at very different stages of innovation. Following the analyses of Intal et al. (2014) and the Japan Science and Technology Agency (2015), AMS can be roughly divided into the following five groups:

- Singapore is the only ASEAN member in the ‘frontier’ phase of innovation, and its innovation capability, based on solid domestic R&D, is almost at the same level as that of developed Western countries.
- Malaysia is in the ‘catch-up’ phase, and its innovation capability is relatively high, just behind that of Singapore.
- Indonesia, the Philippines, Thailand, and Viet Nam are in the ‘Learning’ phase, which is characterised by the acquisition of innovation capability. These countries are assumed to have significant potential to improve their innovation capability as their economies grow in the future. Thailand is the most likely to catch up with Singapore and Malaysia, which are in the upper development stage. In this regard, Thailand could well be in the ‘catch-up’ phase, like Malaysia.
- Cambodia, Lao PDR, and Myanmar are in the ‘initial condition’ phase, which means they still need to establish nation-building infrastructure and institutions to set up their innovation capability.
- Brunei is difficult to place in any of these categories because the country depends on its natural-resources-driven economic model. But the country is now aware of the necessity for industrialisation through innovation.

Intal et al. (2014) provide a useful matrix table, reproduced in Table 1.4 of this chapter, to illustrate the development stages of each AMS and the policies needed at each innovation phase.¹¹ This kind of typology is quite analogous to ERIA (2015), which proposes development strategies, mainly for manufacturing industries, in relation to the quality of infrastructure and participation in production networks in East Asia.¹²

¹¹ Intal et al.’s Figure 4.5 (p. 199) is substantively built on the idea of Rasiah (2013).

¹² See ERIA (2015, p. 4, Figure 1.1).

ERIA (2015) suggests that developing AMS should steadily advance their development stages at the country, city, and regional levels. The implication of Table 1.4 for AMS is dependent on the same idea as that proposed by ERIA (2015) – that it is important to understand which innovation stages AMS have reached (i.e. what their level of innovation capability is) and to move up the ‘technology ladder’ accordingly, step by step, based on effective strategic and systemic economic policies. In other words, the best way for developing AMS to grow out of conventional industrial structures that depend on low-end products is to nurture their innovation capability at every stage, to achieve basic innovation from the ground up, and to realise steady industrial development through the innovations.¹³

Table 1.4 also suggests a typology of policy frameworks required for AMS in terms of basic and high-tech infrastructure, network cohesion, and global integration. For example, the ‘learning’ phase, where most AMS are situated, emphasises basic approaches to innovation, such as learning-by-doing and imitation, social institutions connected to formal intermediary organisations, and access to foreign sources of knowledge and FDI inflows. It should be noted that the table merely presents a typical framework, and policymakers should formulate actionable and implementable innovation policies. In view of this, it is desirable to add policy recommendations that include concrete elements to Table 1.4 to link academic studies with policies. Rasiah (2013) addresses the problem of intellectual property rights in ASEAN in an interesting case study. But the study needs to be expanded to areas such as competition policies, R&D incentive measures, and university–industry links, all of which are likely to promote innovative activities in ASEAN.¹⁴

¹³ Schumpeter (1942) advocated a concept of ‘creative destruction’ that induces industry dynamics, exemplified by the entry and exit of firms through lively innovative activities. Although activating industries is indispensable for AMS as well, this concept seems more applicable to developed countries. It is open to discussion whether developing AMS can ‘leapfrog’ development stages through revolutionary innovation in the era of ICT.

¹⁴ Intarakumnerd (2013) depicts a very similar conceptual framework to Table 1.4 while proposing policy measures from the perspective of small and medium-sized enterprise innovation and technology transfer according to countries’ development levels. He discusses issues such as grants for targeted activities, R&D tax incentives, and innovation coupons that provide small and medium-sized enterprises with services offered by universities.

Table 1.4: Policy Framework Typology for ASEAN

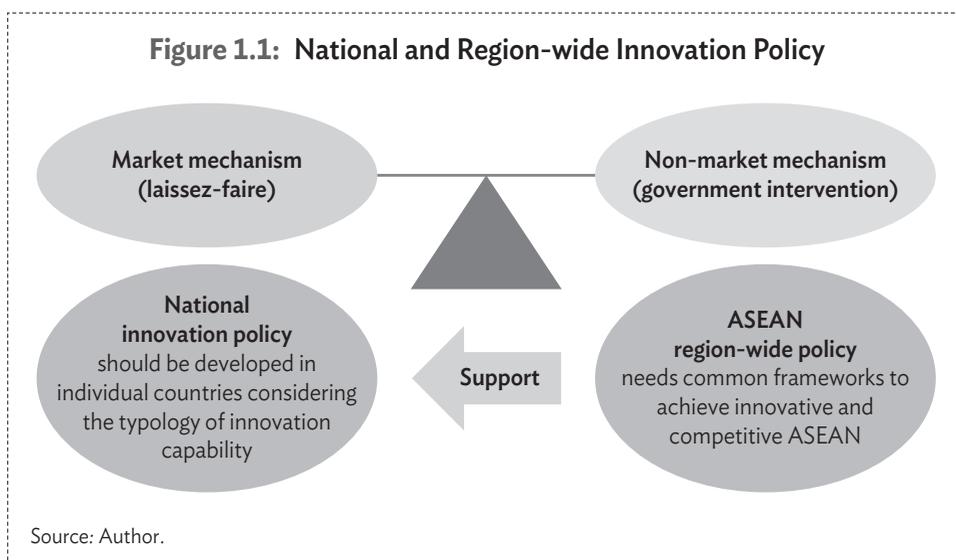
Phase	Basic Infrastructure	High-tech Infrastructure	Network Cohesion	Global Integration
(1) Initial conditions Cambodia, Lao PDR, Myanmar	Political stability and efficient basic structure	Emergence of demand for technology	Social bonds driven by the spirit to compete and achieve	Linking with regional and global markets
(2) Learning Thailand, Philippines, Indonesia, Viet Nam	Strengthening of basic infrastructure with better customs and bureaucratic coordination	Learning-by-doing and imitation	Expansion of tacitly occurring social institutions to formal intermediary organisations to stimulate connections and coordination between economic agents	Access to foreign sources of knowledge, imports of material and capital goods, and inflows of foreign direct investment Integration in global value chain
(3) Catch-up Malaysia	Smooth links between economic agents	Creative destruction activities start through imports of machinery and equipment, licensing, and creative duplication	Participation of intermediary and government organisations in coordinating technology inflows, initiation of commercially viable R&D	Licensing and acquisition of foreign capabilities Upgrading synergies through technology imports Emergence of strong technology-based exports
(4) Advanced	Advanced infrastructure to support meeting demands of economic agents	Developmental research to accelerate creative destruction activities Frequent filing of patents in the United States starts	Strong participation of intermediary and government organisations in coordinating technology inflows, initiation of commercially viable R&D	Access to foreign human capital, knowledge links, and competitiveness in high-tech products and collaboration with R&D institutions
(5) Frontier Singapore	Novel infrastructure developed to save resource costs and stimulate short lead times	Basic research R&D labs to support creative accumulation activities Generating knowledge Technology shapers generate invention and design patents extensively	Participation of intermediary organisations in two-way flows of knowledge between producers and users	Connecting to frontier nodes of knowledge, and competitive exports of high-tech products

Lao PDR = Lao People's Democratic Republic, R&D = research and development.

Sources: Intal et al. (2014) and Rasiyah (2013).

1.5 | National and Region-wide Innovation Policies

From the discussion so far, it seems clear that AMS need to develop their national innovation policies from multifaceted dimensions, such as R&D incentives, human resources development, and industrial and trade policies. Policymakers need to find a balance between market-oriented and government intervention approaches depending on their country's specific situation. This is particularly important for AMS that have just started industrialisation based on innovation. As a regional institution, ASEAN also needs to consider what region-wide policies to implement and how to synergise them with national innovation policies in each member state. This relationship between national and region-wide innovation policy is described conceptually in Figure 1.1.



1.5.1 National innovation system

How did leading Asian countries succeed in building their innovation capability? They did so by formulating effective national innovation policies with the strategic use of foreign technologies and knowledge as a driving force for domestic innovation supported by industrial and trade policies, and thus achieved dramatic economic development. To avoid the middle-income trap and become competitive in the global market, as leading Asian countries did, AMS need to have in place systematic innovation policies to move up through the stages of innovation (Table 1.4).

The experiences of leading Asian countries offer valuable lessons for AMS that aspire to achieve innovation on their own.

One thing leading Asian countries have in common is that they each successfully established their own effective and functional national innovation system (NIS), and their governments functioned as active agents in coordinating these systems to make them work well. According to Soete et al. (2010), an NIS can be defined as a continuous government-controlled process where institutions, learning processes, and networks play a central role in generating technological change and innovation via intentional, systemic interactions between various components.¹⁵ The key point of an NIS is that it is a government-coordinated institutional system that incorporates well-organised interactions among many agents (e.g. public and private institutions and universities) that engage in innovative activities. The NIS approach has a more general purpose than being just a localised market-failure approach, and, hence, a government can be an endogenous positive actor that controls innovative activities within the economy.

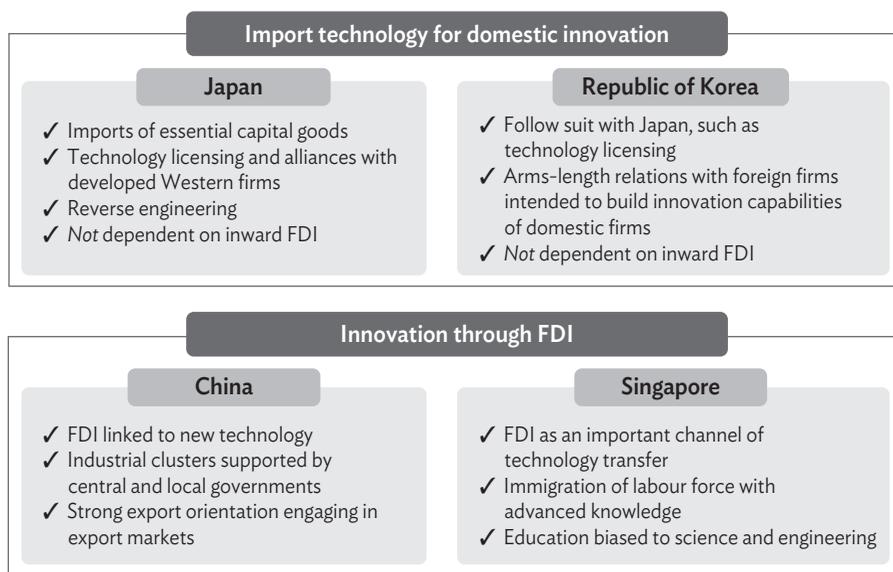
Two prominent types of NISs have been used by leading Asian countries as a strategic way to catch up with Western developed countries. One emphasises domestic industrial resources to be utilised for innovation; the other relies on technologies and skills transferred from foreign countries, including through FDI. The first type of NIS was adopted by Japan and Korea, and the second by China and Singapore (Figure 1.2) as well as many AMS more recently. Although space constraints prevent detailed explanations, the following paragraphs describe the prominent characteristics of NISs in these countries with reference to other studies, such as Fagerberg et al. (2010).¹⁶

Japan. Japan, the leading country of the ‘flying-geese’¹⁷ pattern of economic development in Asia, was the first Asian country to catch up with Western developed countries. Just after World War II, the Government of Japan and Japanese firms formed implicit strategies of importing technologies and knowledge via licensing

¹⁵ In addition to the comprehensive explanation by Soete et al. (2010), a variety of definitions of an NIS have been presented by other authors, such as Nelson (1993). Yet, all these authors stress that the core of a functional NIS is the active and effective involvement of government.

¹⁶ For details of the analyses of innovation in China and Singapore, see Chapter 3 and Chapter 7, respectively.

¹⁷ Akamatsu (1962) argued that a long-term industrial development pattern from imports to exports after import substitution is observed in the industrial dynamics of developing countries that follow developed countries. He likened this to the arrangement of a group of flying geese, where the lead goose is the technologically more advanced developed country.

Figure 1.2: National Innovation Systems of Leading Asian Countries

FDI = foreign direct investment.

Source: Author, with reference to Fagerberg et al. (2010).

agreements and alliances concluded with Western firms, and inventing through reverse engineering. Japanese firms imitated Western products and invented new, but not always unique, products around them. This type of innovation, which was combined with relatively highly educated, low-wage human capital, generated very competitive products. The government did not depend on FDI for technology and knowledge; rather, it implemented several industrial policies, such as domestic industrial promotion, export-incentive schemes, and R&D incentives.

Korea. Korea formulated a catch-up policy as that of Japan. It did not depend too heavily on FDI or multinational foreign firms, but used industrial policies that aimed to accelerate innovation conducted by large domestic firms (home-grown conglomerates, or *zaibatsu*). Like Japan, Korea also succeeded in achieving its own innovation mainly by utilising domestic resources but also by purchasing technologies from developed countries.¹⁸

¹⁸ Fagerberg et al. (2010) pointed out that Taiwan adopted the first type of NSI, which succeeded in changing a main engine of the economy from labour-intensive industries to high-tech ones, such as electric and electronics, based on export-oriented industrial policies.

China. After lengthy isolation from the global economy, China started to transform its economic system into a socialist market economy in the 1970s. Above all, the ‘openness policy’, initiated in 1978, encouraged FDI, and special economic zones and national economic and technological development zones were established with the aim of assimilating foreign technologies.¹⁹ Meanwhile, China made efforts to expand exports of domestic products by prioritising growth and development through a variety of industrial promotion policies. Intal et al. (2014) argue that both central and local governments provided strong support for the formation of industrial clusters that enabled China’s rapid export-led growth. They conclude that the success of Chinese industrial clusters was due in large part to local governments’ institutional, comprehensive, and responsive support systems, which addressed market failures, instituted regulatory reforms, provided monetary incentives for R&D and financial assistance to small and medium-sized enterprises, and promoted innovation research centres in collaboration with local universities and research institutes.

Singapore. Singapore is a distinctive country that has aggressively engaged in the second type of NIS, and FDI has played a critical role as an important channel of technology and knowledge transfer. The country has made a great deal of effort to set up industrial estates and clusters in association with both FDI and innovation-friendly domestic policies. One remarkable example is the Johor electronics cluster, which started in the 1960s as a semiconductor assembly plant and greatly contributed to Singapore’s modern industrialisation (Intal et al., 2014). Another is modern research parks that are represented by biotechnology clusters, where the Government of Singapore, domestic and multinational firms, and universities cooperate to encourage high-value-added innovation in the field of biotechnology (Asian Development Bank Institute, 2014). Moreover, Singapore has willingly accepted high-quality immigrants with a view to profiting from their high skill levels and advanced knowledge. Singapore’s superior higher education system, with its bias towards attracting more domestic and foreign students into science and engineering, also complements its NIS.

1.5.2 Region-wide innovation policies for ASEAN

There is a great need for region-wide innovation policies to enhance ASEAN’s presence and create a competitive and dynamic ASEAN in the global economy, notwithstanding the existing projects of developing STI policies discussed under ASEAN COST.

¹⁹ China was admitted as a member of the World Trade Organization in December 2011. This accelerated the reform and opening-up of its economy, providing access to the global market and attracting more investment.

Chapter 10 of this book investigates in-depth, current innovative activities and the necessary innovation policies to be developed in ASEAN. In addition, Chapter 11 provides policy recommendations from the perspective of (i) initiatives for promoting innovation with more cross-regional synergies and positive feedback across AMS; (ii) goods, investment, and service trade liberalisation and deregulation; and (iii) the freer movement of natural persons, especially of highly skilled immigrants. The final chapter also briefly touches upon the policy requirements of addressing the innovation gaps among AMS.

1.6 | Concluding Remarks

The objective of this chapter is to discuss the innovation policies that are needed for each AMS and for ASEAN. While existing studies point to the importance of enhancing innovation capability of each country to achieve its own innovations, most AMS have made little progress in terms of R&D intensity, patent applications, and the number of science researchers. This heightens concerns that some AMS may be stuck in the middle-income trap. It is important for them to steadily move up through the stages of innovation and to formulate appropriate policies in accordance with the typology of stages. To this end, NISs employed by countries can be an effective policy tool to achieve home-made innovation as such systems organise innovation policy in a systematic manner, emphasising an active coordinating role for governments. Finally, it is also important to examine ASEAN region-wide innovation policies that enhance ASEAN's presence and competitiveness in the global economy.

Economic growth in most AMS has been driven by manufacturing industries in conjunction with a low-wage labour force, and labour-intensive manufacturing remains the basis for economic development in ASEAN. However, if AMS remain dependent on this model in the long term, their economic management will run into obstacles. Wage levels in some AMS, such as Malaysia and Thailand, have been rising sharply and other AMS will also witness wage increases in the near future. This will harm the competitiveness of ASEAN manufacturing industries compared with other emerging countries. In response to this challenge, innovation can help ASEAN take a step forward and improve the sophistication of its economies as it enhances the attractiveness of its single market and production basis. Although it will not necessarily be easy for AMS to immediately achieve a significant level of innovation capability, they have much potential to enhance it in future years. It is not until ASEAN produces its own innovation that it will be able to reach the position in the world that it aspires to, as embodied by the concept of 'ASEAN centrality'.

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Theoretical Framework for Innovation Policy in ASEAN

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2.1 | Introduction

This chapter aims to introduce a theoretical framework for the design of innovation policy in the Association of Southeast Asian Nations (ASEAN). In addition to religious, ethnic, and political diversity, ASEAN Member States (AMS) are diverse in terms of economic status, such as living standards (ranging from low- to high-income countries) and industrial structure (e.g. agriculture, tourism, manufacturing, and finance). Therefore, this chapter pays particular attention to a theoretically desirable approach to innovation policy that takes into consideration the different development phases and industrial characteristics.

The chapter is organised as follows. The first section defines innovation. The second section reviews theories and facts about economic growth to illustrate why innovation policy matters to the government at any development phase. The third section identifies the determining factors in innovation from a theoretical perspective – appropriability, technological opportunities, and knowledge spillovers – and attempts to integrate them into the frameworks of sectoral, national, and regional innovation systems. In the fourth section, policy implications of the effects of knowledge spillovers on innovation are discussed, with a specific focus on the diffusion of innovation. The discussion develops to several frameworks on which innovation policy in ASEAN should be built. These are innovation intermediaries, entrepreneurship, and a whole-of-government approach. The final section concludes the paper.

2.2 | What Is Innovation?

Innovation is defined as new products, processes, and practices created in a society and disseminated within the society. Because of its specific focus on ASEAN, in which many member states are developing countries, this chapter places a greater emphasis

on the latter element – diffusion – for the following reasons. First, innovation is not merely a technical process driven solely by scientific advancement; it is also a social process that inevitably hinges on how receptive users are to the new knowledge embodied in technologies and practices and how responsive providers of knowledge are to social needs. Such recognition has important implications for innovation policy, as will be discussed later. Second, the novelty element associated with innovation defined here does not necessarily mean the innovation must be new to the world. A technology that is entry-level in one society can be regarded as an innovation in another society where the technology has yet to be introduced as long as it brings new solutions to existing problems in the society. Third, the introduction of state-of-the-art technology without taking into account social needs and absorptive capacity is not merely ineffective but also could be detrimental to social welfare. Ample anecdotal evidence demonstrates that the introduction of entry-level technologies could have an immense impact on living standards in developing countries. Typical examples include vaccination against diphtheria, pertussis, and tetanus; the supply of clean water; and improvement in sanitation (World Bank, 2010). The theoretical consequences of the emphasis on the diffusion of innovation will be further discussed in Section 2.5.3 on entrepreneurship.

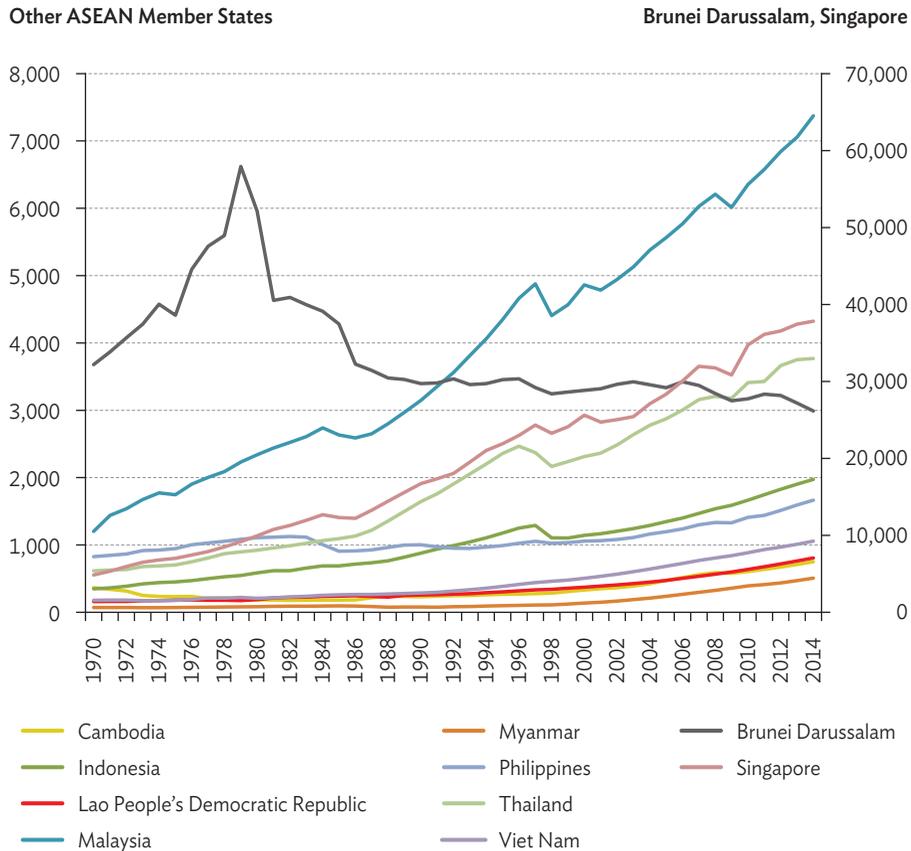
2.3 | Why Innovation?

2.3.1 Welfare improvement

This chapter starts with a discussion of the determinants of welfare, which represents happiness, because improving welfare is the ultimate goal for any government at any development phase. This leads to an understanding that innovation is a critical factor for improving welfare, and that is why innovation policy is of great importance for any government. Assuming wealth can represent welfare, welfare has been evaluated using real gross domestic product (GDP) per capita.¹ Figure 2.1 shows time series variations in the real GDP per capita of AMS. The results show that ASEAN is diverse in terms of the level and growth of living standards, and AMS can be classified into four groups: high-income (Brunei Darussalam and Singapore); middle-income

¹ There has been a rebuttal to the assumption that an increase in income per capita is positively associated with self-reported happiness of a nation (Easterlin, 1974). More fundamentally, empirical studies in the United States show that happiness is one component of (not identical to) utility, and it is possible to give up happiness to increase income, thereby improving utility overall (Benjamin et al., 2011; Glaeser et al., 2016).

**Figure 2.1: Living Standards of ASEAN Member States
(GDP per capita, US\$)**



ASEAN = Association of Southeast Asian Nations, GDP = gross domestic product.

Note: The right-hand axis represents Brunei Darussalam and Singapore, while the left-hand axis represents other ASEAN Member States. GDP per capita is measured in constant 2005 prices.

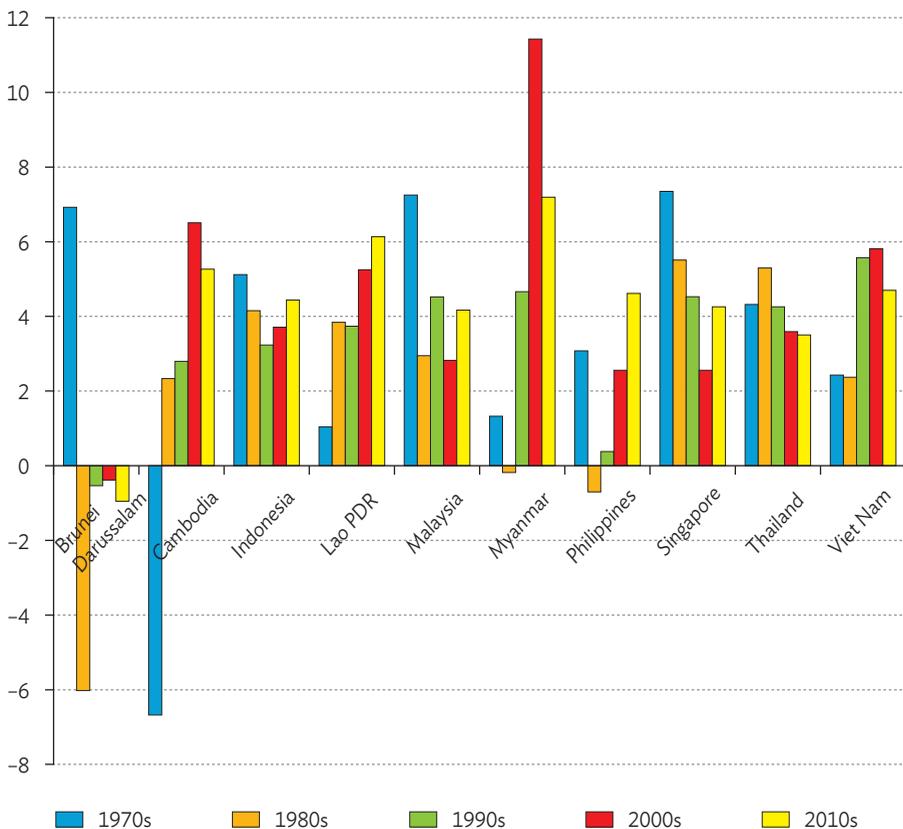
Source: Author's elaboration based on United Nations, National Accounts Main Aggregates Database.

(Indonesia, Malaysia, the Philippines, and Thailand); and low-income (Cambodia, Lao PDR, Myanmar, and Viet Nam). This suggests the need to understand innovation policy in and for ASEAN according to each country's development phase.

Most AMS have experienced remarkable improvements in living standards since the late 1980s. Figure 2.2 shows the rate of improvement in living standards by decade and country. Most member states recorded an annual improvement in living standards of more than 2% since the 1990s. Transitional economies, such as Cambodia, Lao PDR,

Myanmar, and Viet Nam, have demonstrated even better performance than other ASEAN economies since the 1990s, at least partly because they were starting from a lower base. Myanmar recorded an annual improvement of over 11%, which amounts to a 250% improvement in the 2000s. Some countries recorded negative values occasionally (Cambodia in the 1970s, Myanmar and the Philippines in the 1980s) or continuously (Brunei since the 1980s), indicating that people became poorer on average during those periods. The periods of decline appear to be linked to exogenous shocks, such as political turmoil in those countries and major changes in natural resource prices.

Figure 2.2: Improvement in Living Standards in ASEAN Member States (%)

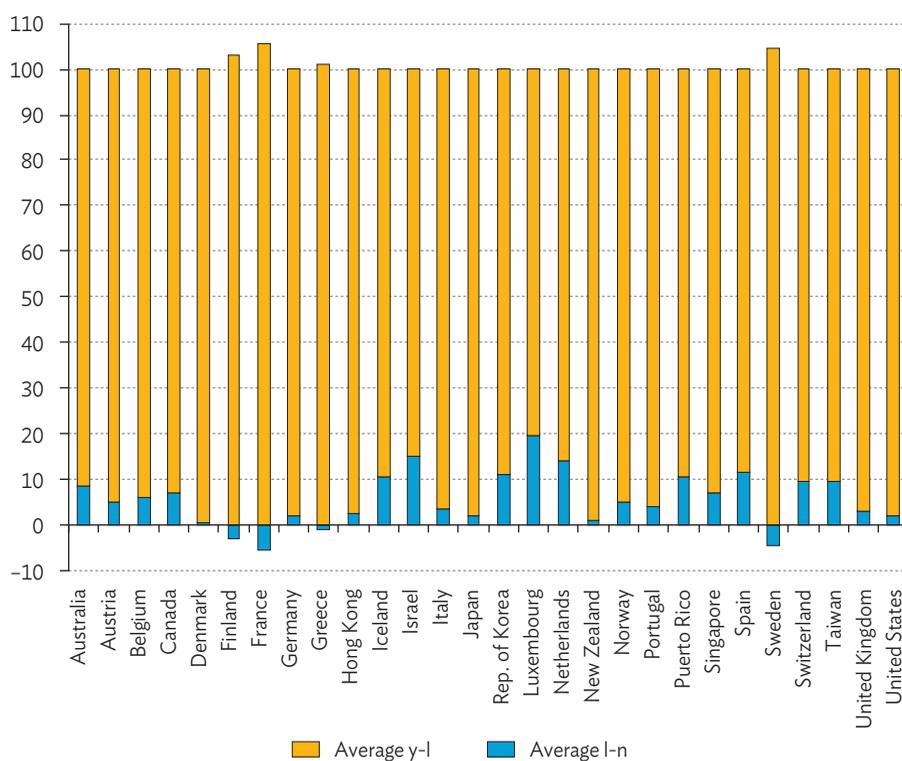


ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.

Source: Author's elaboration based on United Nations, National Accounts Main Aggregates Database.

How can a nation's living standards be steadily improved? A simple mathematical procedure provides an answer to this question. Real GDP per capita is defined as (Y/N) , where Y denotes value-added and N denotes the population. This can be decomposed into labour productivity (Y/L) , where L denotes labour and the labour force participation rate (L/N) . Because $Y/N = Y/L * L/N$, assuming that a lower case variable represents the growth rate of the variable ($Y'/Y = y$, where the apostrophe denotes differentiation with respect to time), then $Y/N = Y/L * L/N$ can be rewritten using logarithmic derivatives as $y - n = (y - l) + (l - n)$. This means that the improvement in living standards is determined by the growth rates of labour force participation and labour productivity. Figure 2.3 shows the contribution of each factor to $y-n$ using data from 1980 to 2010. The results show that in all countries, the annual average growth of labour productivity was far more important than that of labour force participation for improving living standards. This means that labour productivity growth is the key to understanding the reason for steady welfare improvement.

Figure 2.3: Decomposition of the Improvement in Living Standards (%)



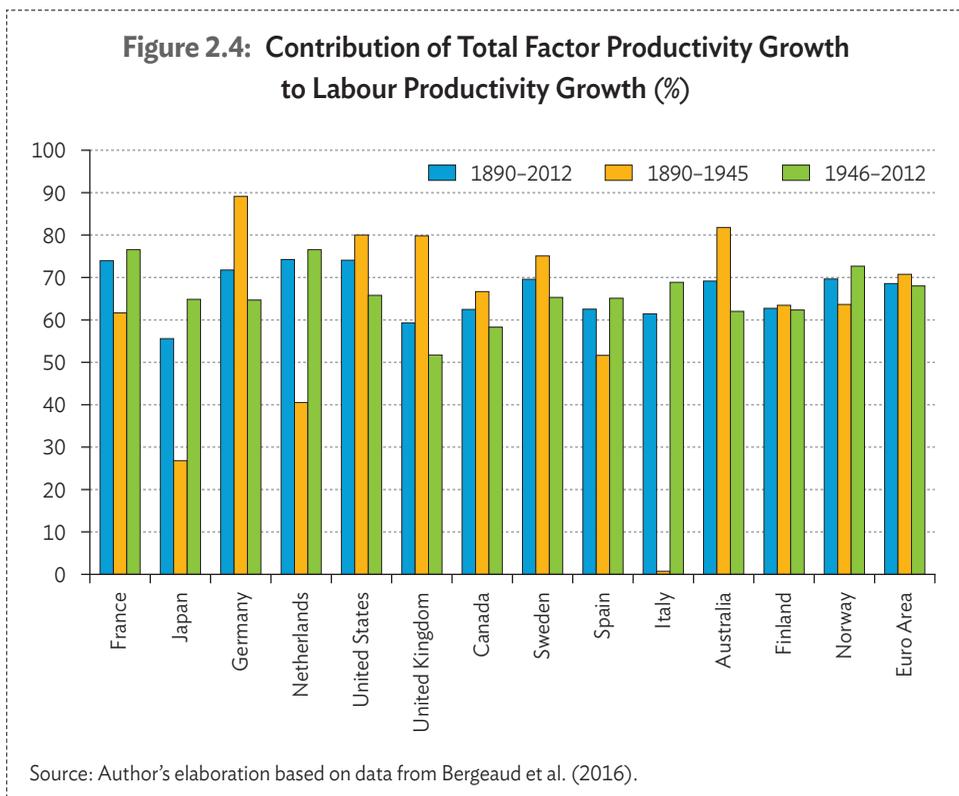
Average l-n = average growth in labour participation rate, average y-l = average labour productivity growth, Rep. of Korea = Republic of Korea.

Source: Author's elaboration based on International Monetary Fund, World Economic Outlook.

2.3.2 Determinants of labour productivity growth

Let us use a simple decomposition again to understand the determinants of labour productivity growth by introducing another indicator of productivity: total factor productivity (TFP). Unlike labour productivity, which assumes labour as a sole input, TFP is the ratio of economic output to all production factors used. Given a competitive market for a final product from labour and capital, the level of TFP can be defined as $Y/L^\alpha K^\beta$, where K denotes the capital stock, α denotes the labour share (proportion of the wage to value-added), and β denotes the capital share ($\alpha + \beta = 1$). The growth rate of TFP is then defined as $y - \alpha l - \beta k$, i.e. the Solow residual, which is the output growth that cannot be attributed to input growth weighted by the cost share (Solow, 1957). This means that labour productivity growth, $y - l$, can be decomposed into TFP growth and capital deepening, which refers to the degree of upgrading of capital intensity (K/L).

Figure 2.4 shows the contribution of TFP growth to $y - l$ using data from 1890 to 2012 in currently advanced economies. The results show that in all advanced economies, TFP growth accounted for more than half of the growth in labour productivity during

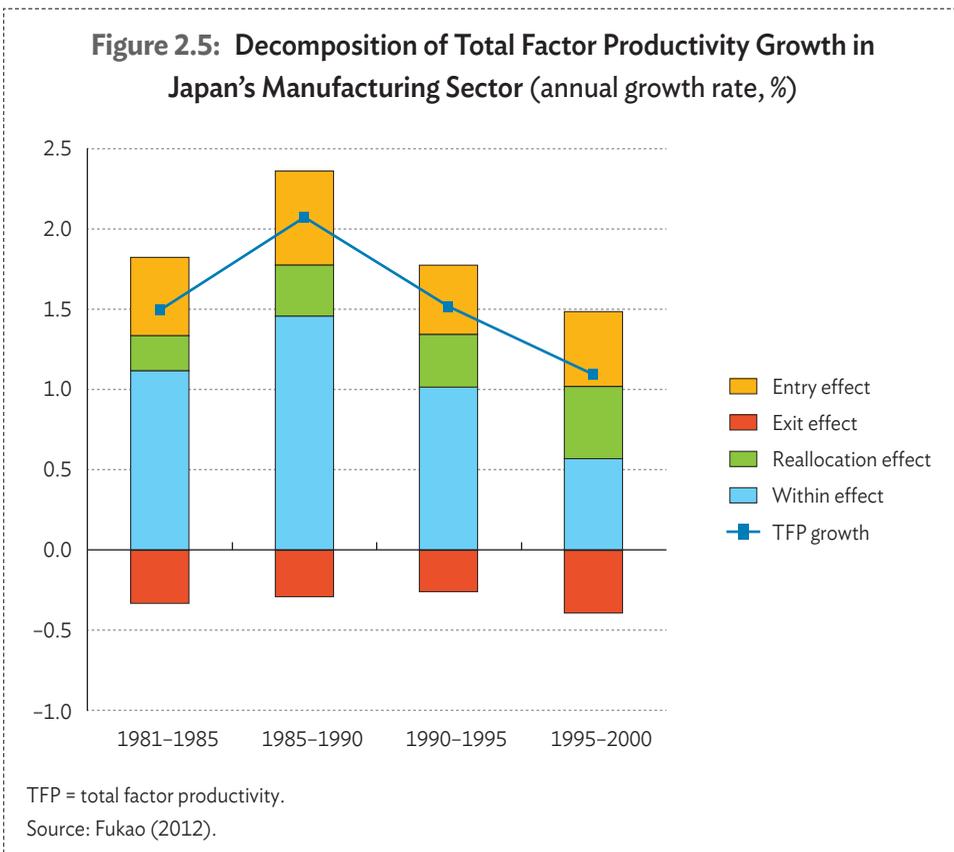


the period. It is no coincidence to find that countries that experienced modern economic growth later, such as Italy and Japan, recorded an even greater contribution from TFP growth in the post-World War II era (1946–2012). This suggests that capital deepening was a critical factor in labour productivity growth before World War II in these economies. This was presumably because they were yet to build a sufficient knowledge stock to create innovation, having had capital deepening play a dominant role in labour productivity growth.

Another study based on the same dataset supports such a notion by illustrating that the contribution of TFP growth to labour productivity growth was particularly salient in the high-growth era (the 1950s and 1960s) in Japan (Cette et al., 2009). One may wonder then what determines TFP growth.² A number of empirical studies have tackled the decomposition of industry-level TFP ($\sum_i s_{it} \omega_{it}$, where s denotes the market share of a firm i , and ω denotes firm-level TFP at time t), thereby identifying and measuring four key factors: (1) the within effect, i.e. the effect of the change in an individual firm's TFP, ($\sum_{i \in S} s_{it} (\omega_{i2} - \omega_{i1})$, where S denotes firms that survive in the market); (2) the between effect, i.e. the effect of the change in market share, ($\sum_{i \in S} (s_{i2} - s_{i1}) \omega_{i1}$); (3) the entry effect ($\sum_{i \in E} s_{i2} \omega_{i2}$, where E denotes firms that enter the market); and (4) the exit effect ($-\sum_{i \in X} s_{i1} \omega_{i1}$, where X denotes firms that exit the market) (Baily et al., 1992; Griliches and Regev, 1995; Foster et al., 2001; Melitz and Polanec, 2015). The policy implications of this decomposition are that the government should promote (or eliminate barriers for) industry research and development (R&D) on which innovations are built; encourage competition in the market, which optimises resource reallocation; and promote entrepreneurship, which accelerates industrial metabolism (exit and entry).

² Endogenous growth theory provides an alternative way of understanding the determinants of TFP growth. It assumes an aggregate production function, $Y = AL^\alpha K^\beta$, where A denotes the technology level. Then labour productivity growth is decomposed into technological progress, $a (= A'/A)$, and capital deepening. Unlike neoclassical theories, which see A' as exogenous (manna from heaven), Romer (1986) argues that knowledge stock created endogenously results in knowledge spillovers, which implies the absence of diminishing marginal returns to capital adopted by neoclassical theories at the social level (note that they work at the firm level). The endogenous growth model assumes that $A' = pLA^\lambda$ where p denotes the probability of discovering a new idea leveraging public knowledge, LA denotes research and development (R&D) staff, LB denotes production workers ($L = LA + LB$), and λ denotes the constant degree of R&D overlapping (the smaller λ is, the more efficient is R&D). Furthermore, it is assumed that $p = p'A^\Phi$, where Φ denotes knowledge spillovers (the greater Φ is, the more ideas come from public knowledge), and p' and Φ ($0 < \Phi < 1$) are exogenous and constant. This means that $a = p'A^{\Phi-1}LA^\lambda = (p'LA^\lambda)/(A^{1-\Phi})$. In a steady state, a is constant, which means that the growth rate of LA^λ is equal to that of $A^{1-\Phi}$. Therefore, $\lambda(LA'/LA) = (1-\Phi)(A'/A)$. Given that the population growth (n) is constant, this can be rewritten as $a = n\lambda/(1-\Phi)$. This implies that the higher the population growth is, the larger the knowledge spillovers are, and the less redundant R&D investment is, the higher TFP growth is.

Figure 2.5 shows the decomposition of TFP growth using data for Japan's manufacturing sector. The results show that the secular stagnation in Japan since the 1990s stemmed from a decrease in the within effect, reflecting decreasing innovation by incumbent firms (those already in the market), a negative exit effect,³ and a low entry effect. This implies that government interventions were needed to increase innovation, foster a pro-market environment for firms to procure and reallocate resources efficiently, and facilitate entrepreneurial activities to increase the entry rate. In sum, from a theoretical perspective, innovation is the most influential factor in the improvement in welfare that any government should aim for. This is why innovation policy is immensely important for governments regardless of the development phase or economic environment.



³ Fukao (2012) argues that the negative exit effect stems from the evacuation of productive establishments (hollowing out of industry) rather than the presence of zombie firms (Caballero, Hoshi, and Kashyap, 2006), which are virtually bankrupt but allowed to survive because of commercial banks' concerns over these firms being 'too big to fail'.

2.4 | What Drives Innovation?

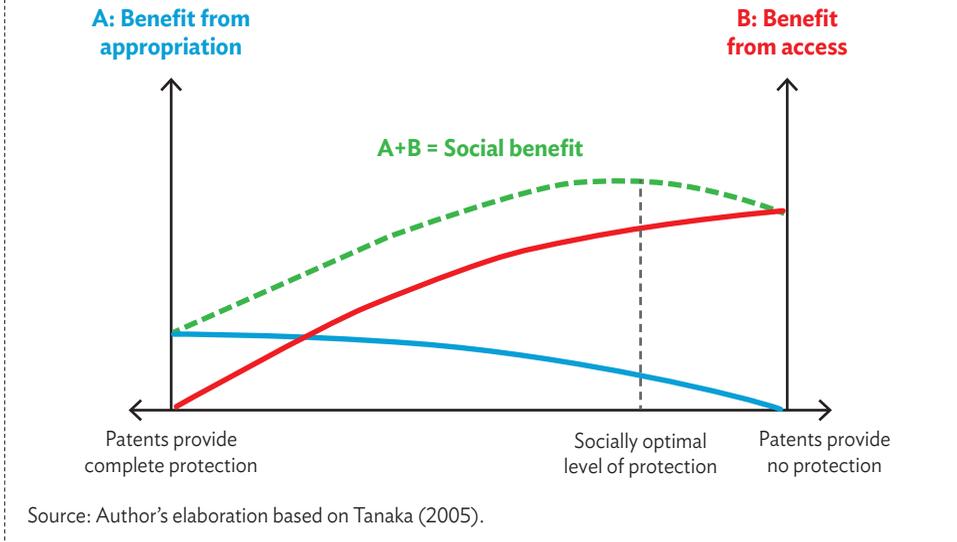
2.4.1 Determinants of innovation

A natural question that follows is, how can the government promote innovation? To answer the question, it is necessary to understand two opposite factors shaping innovative activities: the appropriation of knowledge, which enables current innovators to secure profits from the creation of new knowledge, and access to knowledge, which allows potential innovators to learn from prior knowledge and identify the novelty of their ideas. The former has to do with a demand-side factor of innovation, which is appropriability, while the latter has to do with a supply-side factor of innovation, which is technological opportunity.

Figure 2.6 demonstrates the benefit curves of each factor and the optimal point at which the social benefit (the sum of the two) is maximised. Benefit from the appropriation of knowledge attains its maximum value when patents provide complete protection.⁴ This extreme can be seen in the pharmaceutical industry, where patents are the most effective means to appropriate innovative returns. Previous surveys of R&D managers in the private sector in Europe, Japan, and the United States show that there are three ways for firms to appropriate innovative returns according to industrial characteristics: legal methods, such as utility and design patents; know-how; and first-mover advantage (Levin et al., 1984; Arundel et al., 1995; Goto and Nagata, 1997; Cohen et al., 2000; Nagaoka and Walsh, 2009). Focusing on legal methods, the benefit from the appropriation of knowledge becomes zero when patents provide no protection. On the other hand, the benefit from access to knowledge marks its maximum value when patents provide no protection. It becomes zero when all prior knowledge is privatised through patenting. This extreme is the case where the tragedy of the anti-commons, where the privatisation of upstream knowledge (e.g. research tools, such as mice) through academic patenting deters downstream innovations, becomes a reality (Heller and Eisenberg, 1998; Eisenberg, 2001; Walsh et al., 2003). The social benefit curve is depicted as the sum of the two.

⁴ It is notable that patents act as a means not only of appropriation but also of knowledge diffusion. Patents not only allow applicants to exclude others from using the patented technology but also publicly disclose information about the technology within a specific period of time from application. The latter element acts as an important source of knowledge for followers.

Figure 2.6: Appropriation of and Access to Knowledge as Determinants of Innovation



In general, strong patent protection is conducive to economic growth in developed countries (Lerner, 2002) as developed country firms tend to have accumulated knowledge that can leak out and benefit others. Patent protection that is too strongly enforced in developing countries will make it difficult for these countries to tap into global knowledge and will hamper their economic growth (Maskus, 2000; Boldrin and Levine, 2008; Dutta and Sharma, 2008). It should be noted that factors other than the development phase, such as technologies, regions, and periods, may influence the optimal balance between the two that maximises social benefit. Therefore, arbitrary regulations and initiatives for innovation that do not take into account such factors may be not only ineffective but also detrimental to social welfare.

Another factor associated with both the demand and supply side of innovation is knowledge spillovers.⁵ In the case of investment in physical assets, it is impossible for others to earn revenue from the capital invested by someone else. In the case of R&D

⁵ There are two types of spillovers: knowledge (or pure) spillovers and rent (or pecuniary) spillovers. Unlike knowledge spillovers, rent spillovers take place through market transactions. If suppliers embody their R&D efforts into intermediate goods and the market for them is competitive, then users can procure better inputs at lower prices. A typical example of this can be seen in discrete process industries, such as the automotive industry, where the production process can be divided into many processes and undertaken by various suppliers, including small and medium-sized enterprises (SMEs).

investment, however, knowledge as an outcome of R&D investment may be diffused in a society through various channels, making it difficult for innovators to fully appropriate the returns to their R&D investment. This implies a gap between the private and social rates of return to R&D, which refers to the difference between the marginal products of a firm's own R&D and others' R&D. Economists have measured this gap and found that the social rate of return to R&D is significantly higher than the private rate of return in various regions, industries, and periods (Mansfield et al., 1977; Bernstein and Nadiri, 1988; Goto and Suzuki, 1989). This implies low incentives for the private sector to perform R&D for fear of knowledge leakage, leading to underinvestment where the private sector invests in R&D at a lower level than that which is socially optimal. Such underinvestment justifies innovation policies, such as patent systems, R&D subsidies, and R&D tax credits, which will be discussed later. Thus, knowledge spillovers are a deterrent to private R&D.

There is, however, another important property of knowledge spillovers that relates to the concept of absorptive capacity (Cohen and Levinthal, 1990). This concept builds on the recognition that knowledge spillovers are not manna (a gift) from heaven; rather, they are contingent on the absorptive capacity created through a firm's own R&D efforts. Most of the latecomers in innovation start with imitation, which requires abilities to identify the appropriate sources of knowledge and to understand the contents. This, in turn, requires a certain level of knowledge stock accumulated through continuous own R&D efforts, and the level rises as followers catch up with the technological frontier. In other words, without absorptive capacity, it is impossible to search, select, comprehend, and exploit external sources of knowledge for internal innovative activities. This implies that when knowledge spillovers are large, the incentives for private R&D will be higher because of the greater necessity for firms to build absorptive capacity to learn efficiently from external sources of knowledge.

2.4.2 Systems of innovation

Before discussing the policy implications of theories of innovation, this subsection illustrates a systematic way to understand the relationship among the determinants of innovation (i.e. technological opportunities, appropriation conditions, and knowledge spillovers), leveraging key streams of research on systems of innovation.

The concept of sectoral innovation systems highlights that industrial innovations exhibit distinct sectoral patterns in the following ways (Nelson and Winter, 1982; Pavitt, 1984; Malerba, 2002).

First, regarding technological opportunities, firms innovate not only by exploiting internal resources but also by tapping into external sources of knowledge, such as feedback from customers, better inputs from suppliers, the reverse engineering of competitors' products, and academic research by universities and public research institutes. It has been recognised that different industries rely on different external sources of knowledge. Specifically, the impacts of academic research on industrial innovations are greatest in pharmaceuticals, where advancement in life sciences directly boosts drug discovery (Hicks et al., 2001; Huang and Murray, 2009; Furman and Stern, 2011). Several empirical studies of science-based sectors, such as the pharmaceutical industry, show that interactions with universities improve the R&D productivity of incumbents and promote new firm creation to leverage academic inventions (Deeds and Hill, 1996; Powell et al., 1996; Zucker et al., 1998; Baum et al., 2000; Rothaermel and Deeds, 2004).

Second, regarding appropriability, innovation surveys conducted in various countries show that the effectiveness of patents as a means to appropriate the returns to R&D investment varies significantly across industries, which leads to great variations in patent propensity at the industry level (Levin et al., 1984; Arundel et al., 1995; Goto and Nagata, 1997; Cohen et al., 2000; Nagaoka and Walsh, 2009). Patents are most effective in biotechnology. Biotechnology-related innovations tend to be standalone as opposed to systemic in that a final product can be clearly defined by specific information in patent documents (e.g. chemical equations), which makes it very difficult for followers to invent around, and makes patents particularly effective as appropriation mechanisms for innovators. In other technological fields, lead times and the first-mover advantage are more important than legal protection.

Third, regarding spillover channels, previous studies classify economic activities into three industrial knowledge bases: analytical (science); synthetic (technology); and symbolic (culture), and argue that different industrial knowledge bases require different modes of transfer in a systematic manner (Asheim and Gertler, 2005; Asheim et al., 2007; Martin and Moodysson, 2011). The key components of this framework are the degree to which tacit knowledge is involved and the significance of personal interactions in knowledge transfer. Specifically, the three broad categories are defined as follows.

First, innovations in science-based sectors, such as biotechnology, tend to build on 'analytical knowledge', which is knowledge generated through attempts to explore and explain the universal principles of nature (Asheim and Gertler, 2005).

The production of analytical knowledge refers to encapsulating natural sciences and mathematics, where the key inputs are reviews of scientific articles and the application of scientific principles. Knowledge outputs can be communicated in a universal language, such as mathematical or chemical equations, which are the least tacit and the most likely to be embodied in codified channels (e.g. scientific articles and patents). Therefore, knowledge outputs in analytical knowledge-based industries tend to be disseminated through channels that are less geographically constrained, such as licensing.

Second, innovations in mechanical engineering tend to build on ‘synthetic knowledge’, which is knowledge generated through attempts to design something that works as a solution to a practical and more applied problem. Knowledge is created through a heuristic (learning-by-doing) approach rather than a deductive process, which makes know-how and craft-based skills, both of which contain more tacit knowledge, more important for innovations of this type. Efficient transfer of tacit knowledge requires personal communications among scientists and engineers, which tend to be more active in industrial clusters (Storper and Venables, 2004). Therefore, knowledge outputs in synthetic knowledge-based industries tend to be disseminated through personal interactions, such as technical consultations, which benefit from geographical proximity.

Third, the production of ‘symbolic knowledge’ refers to the creation of cultural meanings embodied in shapes, images, words, sounds, experiences, and cultural artefacts. Symbolic knowledge is the most tacit of the three because the means of production is based on learning-by-doing and observing other creators, such as artists, musicians, industrial designers, and architects. These characteristics strongly affect the spatial configuration of talent because the nature of the valuable knowledge in such occupations particularly favours spatial concentration, which facilitates frequent personal interactions. This implies that talents located in a cluster would be able to receive greater spillovers of locally embedded knowledge from other talents through personal interactions, making them more productive (Gertler, 2003).

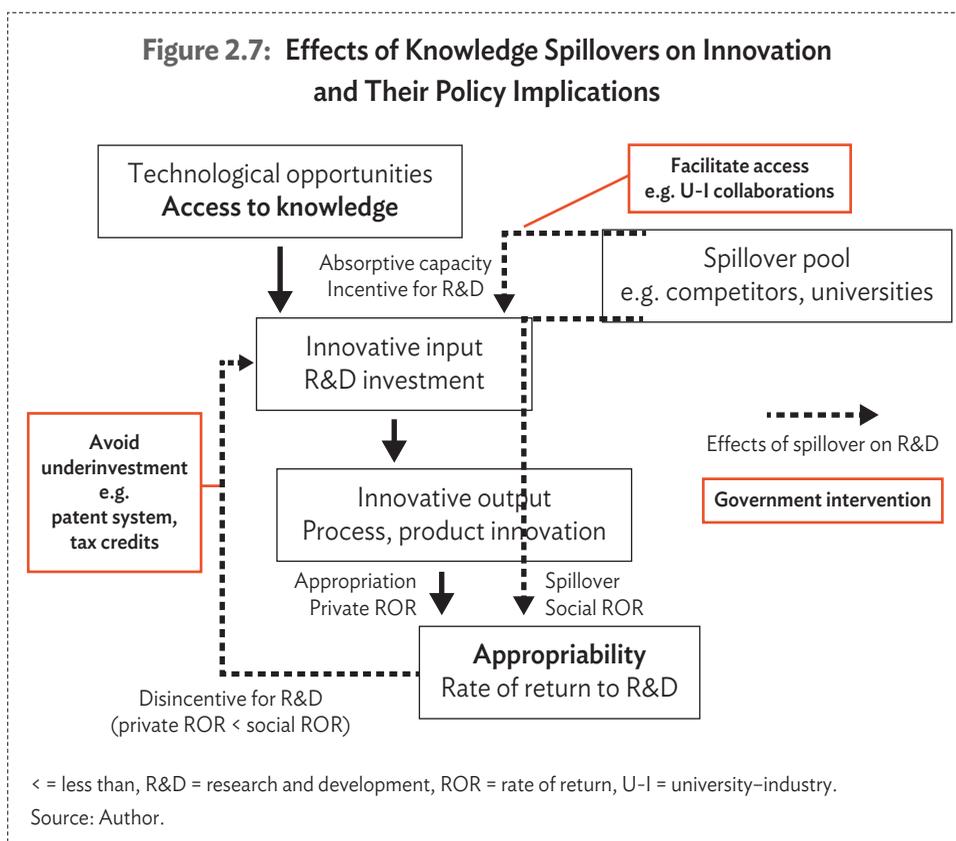
The concept of industrial knowledge bases is closely associated with the significance of geographical distance in knowledge transfer according to the degree of tacitness of knowledge being transferred and the significance of personal interactions in knowledge transfer.⁶ In essence, physical distance does not matter for the transfer

⁶ Another important perspective is the cognitive distance, which will be discussed in the section of innovation intermediaries.

of analytical knowledge, while the transfer of symbolic knowledge tends to be geographically constrained. This notion invokes two important frameworks for understanding the determinants of innovation: national innovation systems and regional innovation systems. The former highlights the creation of knowledge in a nation built on interactions among firms, universities, and public research institutes, rather than relying on independent efforts by each of them (Lundvall et al., 1992; Nelson et al., 1993; Braczyk et al., 1998). This is in contrast to a linear model of innovation, where innovation is supposed to be mechanically derived from scientific advancement. A typical example of such interactions is university–industry collaborations, such as joint research, consultation of firms by university scientists, licensing of academic patents, and academic spin-offs. Figure 2.7, which summarises a national innovation system, illustrates key channels of university–industry knowledge transfer. Efficient university technology transfer is more significant in science-based sectors, where breakthrough innovations tend to build on the advancement of academic research (Nelson and Winter, 1982; Pavitt, 1984). Furthermore, science linkages in patents (i.e. the number or proportion of inventors’ backward citations to non-patent literature, such as academic articles) increase over time, not only in science-based sectors but also in the whole economy (Narin et al., 1997). This implies that academic institutions that create high-impact scientific knowledge (academic articles cited very frequently by subsequent studies) are becoming more significant for the growth of knowledge-based economies.⁷

Rooted in the concept of national innovation systems, the key to understanding regional innovation systems is the localised flow of knowledge. As far as public channels, such as academic articles, are concerned, the geographic range of university spillovers is not deemed to be localised. However, a number of empirical studies show that university spillovers are geographically constrained (Jaffe, 1989; Mansfield,

⁷ It should be noted that efficient university technology transfer calls for a flexible labour market for scientists. If scientists at national universities are not allowed to consult for private firms, formal university–industry collaborations would be limited, as used be the case in Japan before the incorporation of national universities in 2004 (Collins and Wakoh, 2000; Kneller, 2007; Fukugawa, 2017). It also calls for an efficient capital market so that academic spin-offs based on intangible assets, such as valuable academic patents, can grow faster by leveraging initial public offerings (Fukugawa, 2012). The growth of new technology-based firms also depends heavily not only on entry regulations but also on the protection of incumbents, which has to do with the efficiency of the goods market. These notions strongly suggest that innovation policy encompasses a broader range of policies, such as competition, finance, investment, and labour, than science and technology policy with which innovation policy is frequently identified.



1995; Anselin et al., 1997; Autant-Bernard, 2001; Gittelman, 2007; Ponds et al., 2010; Fukugawa, 2013). In other words, university knowledge spills over into private R&D in a region through some channels, but firms in remote regions do not receive the benefits. The key reason behind this is that university research tends to engage in technologies at the embryonic stage, and such knowledge tends to contain more tacit knowledge. This makes it necessary for the firms tapping into academic research for their innovative activities to have face-to-face communications for efficient transfer (Mansfield, 1995; Jensen and Thursby, 2001). This implies that the region is the key unit of analysis in knowledge creation and dissemination because, other things being equal, active face-to-face communication and transfer of tacit knowledge are more likely to occur when there is geographical proximity. This has an important implication for innovation policy in that clusters play a key role in the promotion of innovation, which will be further discussed in the context of entrepreneurship.

2.5 | How to Encourage Innovation?

2.5.1 Theoretical implications for innovation policy

Figure 2.8 summarises two types of government interventions suggested from theories on knowledge spillovers. On the one hand, knowledge spillovers reduce appropriability at the firm level, leading eventually to underinvestment in R&D at the social level. A typical example of a policy instrument for this type of market failure is a patent system, which aims to secure inventors to exclude others from using the patented technology, thereby augmenting appropriation conditions. Other incentives to encourage firms to initiate R&D projects include the outsourcing of government research, preferable interest rates, tax credit, grants, and debt guarantees.

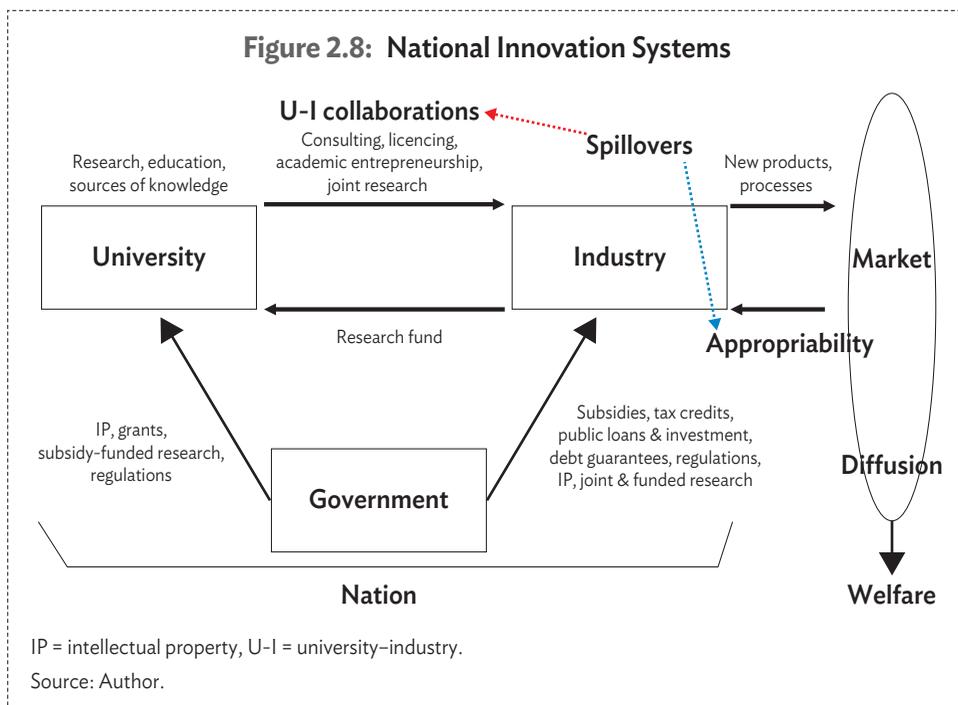


Table 2.1 summarises the advantages and disadvantages of these policy instruments. Table 2.2 illustrates the type of policy intervention the government should adopt according to social and private rates of return to R&D. It is notable that underinvestment refers not to the level of the social rate of return to R&D but to the gap between the social and private rates of return to R&D. 'Input additionality' (private R&D that would have not been performed without public support) is

considered to be negligible in technological fields where both the private and social rates of return are high relative to the opportunity costs (Category B) because the private sector would have invested in R&D in the absence of government support. The impact of underinvestment is the most serious in technological fields where the social rate of return to R&D is high while the private rate of return is low (Category A).

Table 2.1: Government Interventions to Support Private Research and Development

Type	Advantage	Disadvantage
Tax concession	<ul style="list-style-type: none"> — Non-discriminatory, open to all — Arm's length instrument, activities chosen by industry — Maintenance of firms' confidentiality — Speedy processing (where approval is 'automatic') 	<ul style="list-style-type: none"> — Of no benefit to unprofitable or start-up firms — Subsidises 'existing' activity that would have occurred anyway (unless based on incremental performance, which is hard to police)
Repayable loan	<ul style="list-style-type: none"> — Can be targeted widely or focused — Priorities or scope (type, timing, size) set by government — Specific proposals can be made by firms 	<ul style="list-style-type: none"> — Requirements (e.g. collateral) work against small and medium-sized enterprises and start-ups — Procedures are long and cumbersome
Grant	<ul style="list-style-type: none"> — Benefits focused activities, sectors, clusters, and some types of firms — Allows for prioritisation and, therefore, is appropriate for innovative projects — No need to write it off 	<ul style="list-style-type: none"> — May be subject to criticism for being unfair — Government must have the ability to select recipients
Equity participation	<ul style="list-style-type: none"> — Benefits focused activities — Firms get investment money up front, reducing risks and uncertainty and increasing creditability 	<ul style="list-style-type: none"> — May be subject to criticism for being unfair — Government must have the ability to select recipients — Must write-off bad projects

Source: Intarakumnerd (2013, p. 9).

Table 2.2: Rates of Return to Research and Development and Appropriate Government Interventions

		Private Rate of Return to R&D	
		Low	High
Social Rate of Return to R&D	High	A: Large additionality	B: Small additionality
	Low	C: Adverse selection	D: Taxation improves welfare

R&D = research and development.

Note: A high rate of return means that R&D investment is preferable in relation to the opportunity cost of other investments (e.g. interest rate).

Source: Author's elaboration based on Nagaoka et al. (2011).

This is the scenario that best justifies government intervention. A typical example of a technology that falls into Category A is a general-purpose technology that yields tremendous rent spillovers to users in various sectors.⁸ General-purpose technologies include the steam engine, electricity, transistors, scientific instruments, and the Internet. Patents have been used to appropriate innovative returns to R&D investment in these technologies. Furthermore, large-scale government-led research consortia have provided incentives for private R&D in high-tech industries, which has often been associated with public procurement, chiefly from the military sector.

On the other hand, spillovers provide motivation for firms' own R&D because firms need to build richer absorptive capacity to learn from external sources of knowledge (suppliers, customers, competitors, academic institutions, and overseas) more efficiently. Firms can learn through various channels and from various sources, including customer feedback, quality improvements in inputs, technical analysis of competitors' products, licensing of overseas patents, and scientific advancement. The types of spillover channels and pools differ across development phases. University technology transfer is more important in advanced economies, while access to global knowledge, such as having technology transfer from multinational enterprises' foreign direct investment and adapting it to social needs, is more important for less-developed economies. This aspect of knowledge spillovers justifies another policy intervention: securing the wider access of the private sector to external sources of knowledge, thereby augmenting technological opportunities.

2.5.2 Innovation intermediaries

For the government to enhance access to knowledge, it is important to understand the roles played by 'innovation intermediaries'. Innovation intermediaries are individuals or organisations, be they private or public, that connect the constituencies of national, sectoral, and regional innovation systems, which otherwise would have been fragmented, thereby augmenting knowledge spillovers and, thus, innovation (Stankiewicz, 1995; Howells, 2006). According to detailed definitions of innovation intermediaries, as a consultant, they provide clients with solutions to technological

⁸ It is notable that the diffusion of general-purpose technology depends on users' recognition about not only the technological but also organisational implications of the new technology. For instance, when electricity was first popularised, plant managers left all the machines in the same places and just replaced the pipes used for steam engines with electric wires. It took more than 20 years for plant managers to recognise that the strength of electricity lay not only in the technical feature as a new power source but also in the organisational feature that an assembly line could be entirely redesigned so that plant managers could have workers work more efficiently (Duhigg, 2016).

problems in R&D. As a broker, they foster market transactions among clients. As a mediator, they foster non-market-based, mutually beneficial collaborations among clients. As a resource provider, they secure clients in collaborations with access to financial, technological, and physical resources to achieve a collaborative outcome (Howard Partners, 2007).

Typical examples of private innovation intermediaries are trade associations that disseminate information on business opportunities, management practices, and technological standards so that participating firms can introduce best practices in the industry and perform better. In many developed countries, various public innovation intermediaries have been developed as part of regional innovation policy. Examples include public research institutes, technology transfer organisations, and liaison offices and incubators in universities and science parks. They develop and deploy human resources that act as gatekeepers⁹ bridging different realms (Westhead and Batstone, 1999; Collins and Wakoh, 2000; Fritsch and Lukas, 2001; Santoro and Chakrabarti, 2002; Balconi et al., 2004; Fukugawa, 2006a; Woolgar, 2007; Cassi et al., 2008; Molina-Morales and Martinez-Fernandez, 2010). Another strand of research stresses the importance of the division of labour between public and private intermediaries (Intarakumnerd and Chaoroenporn, 2013). They argue that public intermediaries, such as national research institutes, should play an active role in producing public goods that are necessary for the general technological upgrading of firms in the sector, while private intermediaries, such as trade associations, should play active roles in creating public goods that can be used among private actors. Furthermore, public intermediaries tend to be important as consultants and resource providers, while private intermediaries tend to be important as brokers, creating competitive advantage according to the needs of users.

The significance of innovation intermediaries is closely associated with ‘cognitive distance’ in knowledge transfer. The provider and user of knowledge become more cognitively distant when they exhibit greater difference in knowledge bases, codes of behaviour, and cultural backgrounds. For instance, the issue of cognitive distance is salient in the case of university–industry collaborations where universities pursue open science, while industry prefers proprietary technology. Furthermore, innovation

⁹ Cohen and Levinthal (1990) describe a gatekeeper as a person who possesses the ‘knowledge of who knows what, who can help with what problem, or who can exploit new information’ (Cohen and Levinthal, 1990, p. 133). Previous sociological and business studies refer to such an interface using different terms. See Lewin (1949) and Allen and Cohen (1969) for knowledge gatekeepers, Burt (2003) for network entrepreneurs, Harada (2003) for knowledge transformers, and Aldrich and Herker (1977), Adams (1980), and Tushman and Scanlan (1981) for boundary spanners.

intermediaries are particularly important for small and medium-sized enterprises (SMEs), which tend to suffer from market failure and systemic failure. SMEs tend not to retain sufficient business records, tangible assets, or reputation in the business community, all of which are required to secure financial resources from the financial market. SMEs also are vulnerable to weak appropriation of innovative returns in the product market as they retain insufficient complementary assets (production facilities, distribution channels, and customer service networks), which negatively affect R&D investment, and thus hamper the long-term growth of firms.

Innovation intermediaries can also address the systemic failure that makes it difficult for SMEs with insufficient social capital to identify external sources of knowledge, develop ties to potential partners, and exploit links for innovative activities.¹⁰ With regard to the role intermediaries play in SME innovation, Fukugawa (forthcoming) examines the division of labour among innovation intermediaries for SMEs by comparing policy-led groups, such as cooperative associations, and voluntarily formed groups, such as cross-industry interaction groups (Fukugawa, 2006b), both of which are SME inter-firm organisations developed only in Japan. The estimation results of an endogenous switching regression model that enables counterfactual analysis show that cooperative associations improved participants' TFP through cost sharing, such as joint logistics, while voluntary groups improved participants' TFP through knowledge sharing, such as joint R&D. Furthermore, innovative SMEs exploited different intermediaries so that the benefit from each intermediary would be complementary to TFP growth. These results suggest that the division of labour between innovation intermediaries is critical for the innovative activities of SMEs, which tend to lack social capital and absorptive capacity and, thus, have the greatest need for intermediaries in their innovative activities.

¹⁰ Public institutes for testing and research, called *Kosetsushi*, constitute an important component of regional innovation policies in Japan. *Kosetsushi* were initially established in the late 19th century in agriculture, textiles, and brewing (e.g. sake and soy sauce), and then gradually developed in manufacturing. They play three key roles in regional innovation systems. First, they diffuse technological knowledge mainly for local SMEs through various routes, such as testing, use of analytical equipment, technical consultation, joint research, and seminars for the introduction of new technologies and standards. Second, they conduct their own research, patent inventions, and license patents mainly to local SMEs. Third, they act as a catalyst for local SMEs to develop innovative networks to external sources of knowledge (Fukugawa, 2016; Fukugawa and Goto, 2016). At least partially inspired by Japan's experiences, some developed countries have established technology diffusion programmes for SMEs as a part of their regional innovation policies. Examples include the Industrial Research Assistance Programs in Canada, the Steinbeis Foundation in Germany, the Regional Board for Economic Development in Italy, the Technology Innovation Centre in the United Kingdom, and the Netherlands Organisation for Applied Scientific Research (Shapira et al., 2011). Previous studies provide econometric evidence that such programmes have had a positive impact on their clients' labour productivity growth (Jarmin [1999] examined the impact of manufacturing extension) and innovations (Ponds et al. [2010] examined the Netherlands Organisation for Applied Scientific Research; Fukugawa [2017] examined *Kosetsushi*).

2.5.3 Entrepreneurship

As previously mentioned, this chapter emphasises diffusion as a critical element of innovation. This recognition leads to another important perspective in the design of innovation policy: entrepreneurship. Inventors are those who create something new by exploiting technological opportunities resulting often from scientific advancement, while entrepreneurs are those who are alert to business opportunities and able to turn inventions into innovation through successful commercialisation. Entrepreneurship is therefore central to the diffusion of innovation (Say, 1803;¹¹ Schumpeter, 1942). Figure 2.9 shows a typology of entrepreneurial activities. Entrepreneurship in the first place refers to the discovery of business opportunities (Kirzner, 1973;¹² Shane, 2003). Entrepreneurs find business opportunities not only from scientific advancement, but also from internal information, such as unexpected success or failure in the market and customers' feedback, and exogenous shocks, such as changes in demographic structure, the perception of people, regulations, and market structure. The exploitation of business opportunities often takes a form of new organisation creation (Gartner, 1988), which is closely associated with risk taking (Cantillon, 1755;¹³ Knight, 1921¹⁴) and new entry (Lumpkin and Dess, 1996).¹⁵

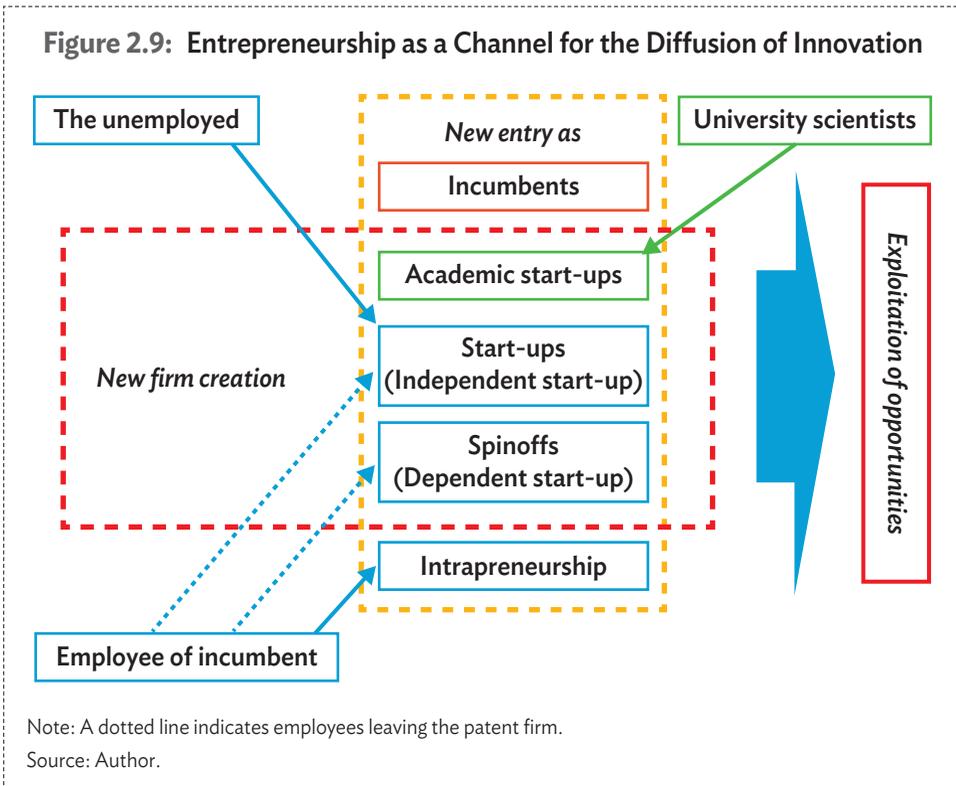
¹¹ 'The application of knowledge to the creation of a product for human consumption is the entrepreneur's occupation' (Say, 1803, p. 330).

¹² 'The entrepreneurial element in the economic behavior of market participants consists ... in their alertness to previously unnoticed changes in circumstances which may make it possible to get far more in exchange for whatever they have to offer than was hitherto possible' (Kirzner, 1973, pp. 15–16).

¹³ '[Inhabitants of a state] can be divided into two classes, undertakers and hired people; and that all the undertakers are as it were on unfixed wages and the others on wage fixed' (Cantillon, 1755, Higgs' translation, p. 55).

¹⁴ 'Entrepreneurs also guarantee to those who furnish productive services a fixed remuneration' (Knight, 1921, p. 271).

¹⁵ It is notable that entrepreneurial activities are not confined to new firm creation. Indeed, incumbents play an important role in the exploitation of business opportunities through 'intrapreneurship', which means an entrepreneurial attempt made by an employee without starting a new firm (Burgelman, 1983; MacMillan, 1986). There are ample examples of major innovations created through intrapreneurship, including SR-71 by Lockheed Martin, the Post-It by 3M, Elixir by Gore, the VHS by JVC, autofocus by Konica, the digital camera by Casio, the plasma display panel by Fujitsu, and the PlayStation by Sony. They are the R&D outcomes from skunk works or yami-ken (research in secret) where employees explore unconventional ideas (i.e. non-core tasks) before having their research sanctioned by senior management. According to Parker (2011), intrapreneurship accounted for a significant proportion (22%) of entrepreneurial activities by American adults from 2005 to 2006. Hellmann (2007) argues that intrapreneurship becomes important when a company is firmly committed to an internal development policy, a key intellectual property right is owned by the company, and the environment for external development is not favourable for employees (e.g. the incumbents are efficient in appropriation in the existing market, financing for external venturing is difficult, and intellectual property rights protection is ineffective).



The promotion of entrepreneurial activities is affected by a number of factors: demography and education as a source of potential entrepreneurs, the degree of competitiveness of the market as a port of entry for entrepreneurial firms, and the protection of intellectual property rights as a means for entrepreneurial firms to appropriate innovative returns. This means that incorporating entrepreneurship into innovation policy inevitably expands the boundaries of the policy as it encompasses diversified policy fields, which will be discussed later. More specifically, entrepreneurship has important implications for innovation policy in knowledge-based economies. Previous studies on the knowledge spillover theory of entrepreneurship (Acs et al., 2013; Ghio et al., 2015) argue that an increase in knowledge stock inevitably creates the need for high-tech entrepreneurship because, in knowledge-based economies, more inventions will be left undeveloped by large R&D-intensive firms and research universities. Increasing the knowledge stock requires entrepreneurship for the following reasons. Large high-tech firms with a greater stock of knowledge tend to have a larger portion of undeveloped ideas because of ‘asymmetries of valuation’ on inventions (companies tend to underestimate the economic value of employee inventions that are unrelated to their core task), which create a ‘knowledge filter’ (Acs et al. 2004) impeding the exploitation of potentially valuable ideas.

Asymmetries of valuation on inventions become greater when a company commits to a development policy that focuses exclusively on the core domain, which is most certain to make profits, and as a result, non-core inventions are never developed internally (Hellmann, 2007). Universities also tend to have a greater portion of undeveloped knowledge when regulations prevent academic inventions from being efficiently transferred to the private sector, such as through academic entrepreneurship.

The knowledge spillover theory of entrepreneurship regards entrepreneurship as an important conduit for such undeveloped inventions. This theory essentially argues that knowledge stock created endogenously results in knowledge spillovers, which allow entrepreneurs to identify, create, and exploit opportunities. In other words, this theory endogenises entrepreneurial opportunities by linking innovation (the accumulation of knowledge stock) to entrepreneurship (new firm creation), while previous studies tend to view entrepreneurship as an exogenous factor like a genetic trait.

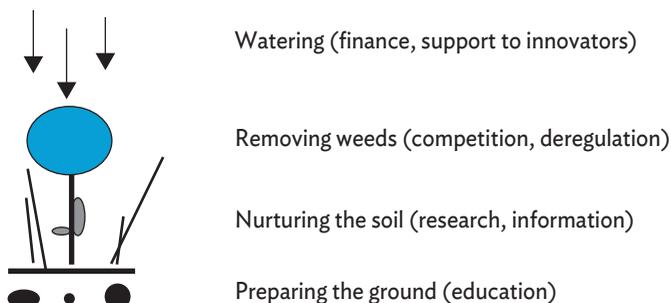
In addition to focusing on endogeneity of entrepreneurship, the knowledge spillover theory of entrepreneurship is distinctive from previous theories in its focus on clusters. The theory argues that in exploiting opportunities, entrepreneurs are faced with localised competition, and localised entrepreneurial activities have a self-reinforcing nature, leading to entrepreneurial clusters. Knowledge about new opportunities and resource requirements tends to be tacit (Rocha and Sternberg, 2005). As tacit knowledge tends to be disseminated through personal interactions, which benefit from geographical proximity, entrepreneurial activities tend to be localised. Geographic concentration expands the knowledge pool, such as entrepreneurs' previous successes and failures (Acs and Virgill, 2010), from which potential entrepreneurs can learn, thereby facilitating the demonstration effect (Audretsch et al., 2006). Furthermore, entrepreneurial clusters encourage the development of knowledge-intensive business services and professional services firms, such as legal services, accounting services, and venture capital, which in turn encourages new firms to locate nearby (Nystrom, 2007). These positive feedbacks lead to the persistence of entrepreneurial clusters. Entrepreneurship in a region is suppressed in cases where localised competition among entrepreneurs is fierce (e.g. because of excessive entry), incumbents appropriate innovative returns so efficiently that they make the rate of return to entrepreneurship very low, and government interventions and regulations hamper entrepreneurial activities (Acs et al., 2009). This highlights the importance of taking entrepreneurial clusters into account when designing innovation policy.

2.5.4 Whole-of-government approach

As previously emphasised, innovation is a social process that inevitably hinges on how receptive users are to new knowledge embodied in technologies and practices and how responsive providers of knowledge are to social needs. Furthermore, discussion on the promotion of entrepreneurial activities reveals that a wide range of policy fields are relevant to innovation policy. These features of innovation policy call for a whole-of-government approach. Such an approach is important, particularly in developing countries, because social structures incubating innovations tend to be immature and unfavourable in those countries.

The World Bank (2010) uses a gardening metaphor to explain the whole-of-government approach to innovation policy. Figure 2.10 illustrates four key ways in which gardeners help plants grow. First, ‘preparing the ground’ refers to policies concerning education, training, and migration to create a source of potential innovators. Second, ‘nurturing soil’ refers to policies for making the nation’s research base strong in terms of quality and making it responsive to social needs. Third, ‘removing weeds’ refers to eliminating unnecessary regulations on innovation, entrepreneurship, entry, and competition, thereby securing private companies the freedom to do business. Fourth, ‘watering plants’ refers to the provision of pecuniary or non-pecuniary incentives for potential innovators. This metaphor implies that although the fourth recommendation (finance and support to innovators, e.g. R&D subsidies and tax credits) is what is normally recognised as innovation policy, simply watering the plants would be inefficient unless it is complemented by efforts represented by the first, second, and third recommendations.

Figure 2.10: Explaining the Whole-of-government Approach Using a Gardening Metaphor



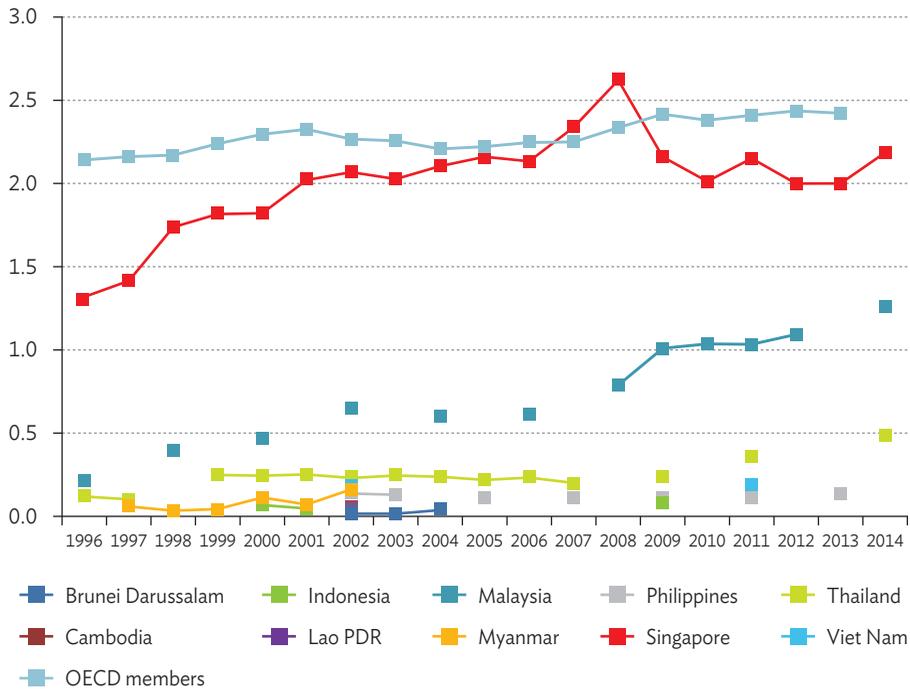
Source: World Bank (2010, p. 60).

The whole-of-government approach has wide implications for innovation policy in and for ASEAN. The most important implication is the significance of different types of education according to a country's development phase. A number of studies show that the social rate of return to investment in education (the macroeconomic growth effect of education) is greatest for primary education, which is most salient in developing countries, while the private rate of return (the wage effect of education) is greatest for tertiary education (Psacharopoulos, 1994; Psacharopoulos and Patrinos, 2004; Canton, 2007; Psacharopoulos, 2009). This suggests that developing country governments should support primary education in the first place as it helps eliminate illiteracy and reduce transaction costs, accruing huge social benefits. Although its social benefit is the lowest, supporting higher education helps reduce the cost of private R&D through enlarging the domestic labour supply of scientists and engineers.

Implementing the third recommendation is economically the most efficient step but politically the most difficult one. Although it requires little economic cost for the government to adopt 'removing the weeds' type policy measures, it is very difficult to do because the most serious obstacles to competition and innovation normally include bureaucracy and vested interests (e.g. unions, guilds, and lobbies). Bureaucracy is inevitable as the government grows in size, and it tends to create more regulations and interventions to increase authority, which hampers innovation. Incumbents with vested interests tend to put pressure on the government through donations so that they are better able to appropriate returns from the product market and exclude new entrants, which hampers entrepreneurship.

Another implication of this approach is that developing countries should make public research responsive to social needs in order to promote private R&D as the private sector tends to be technologically immature and is unlikely to have the accumulated, sufficient absorptive capacity to exploit external sources of knowledge. R&D intensity (R&D as a share of GDP) exceeds 3% in developed countries but is less than 1% in developing countries. As Figure 2.11 indicates, this tendency is true for AMS. Private R&D constitutes over 60% of the total in developed countries but less than 30% in developing countries (World Bank, 2010). The supply-side factors in less active private R&D in developing countries are the higher opportunity costs, such as of foreign direct investment; imported technology; having many small firms, fewer scientists and engineers, and fewer college students in science, technology, engineering, and mathematics; and the high cost or scarcity of capital. The demand-side factors are a less competitive, more segmented, and barrier-rich domestic market. The institutional factors are an unstable macroeconomic environment, complex bureaucracy,

Figure 2.11: Research and Development Intensity in ASEAN Member States (%)



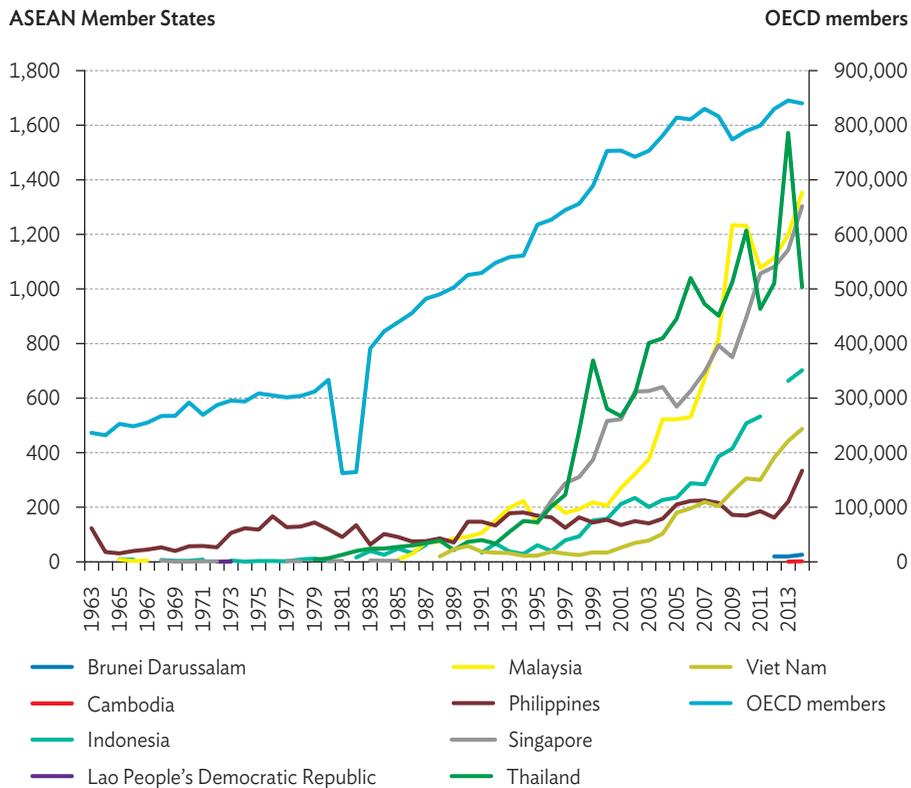
ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic, OECD = Organisation for Economic Co-operation and Development.

Source: World Bank, World Development Indicators.

weak intellectual property rights, high transaction costs, and political instability. Under such circumstances, it is important for developing country governments to make public research responsive to social needs, as such research is often conducted in an 'ivory tower', isolated from the local technological environment.

Another important fact is that foreign firms, especially multinational enterprises, are key private R&D performers in developing countries. A comparison between Figures 2.12 and 2.13 suggests that multinational enterprises making foreign direct investment perform a significant proportion of R&D in developing countries. This underlines the significance of coordinating trade policy (e.g. the creation of a pro-business environment for foreign firms) and innovation policy (e.g. the promotion of technology transfer from parent firms to local firms). Regarding advanced economies, this approach suggests that they should arrange policy measures to support basic research through the promotion of university technology transfer (e.g. the Bayh-Dole Act, or the Patent and

**Figure 2.12: Patent Applications by Residents in ASEAN Member States
(number of applications)**



ASEAN = Association of Southeast Asian Nations, OECD = Organisation for Economic Co-operation and Development.

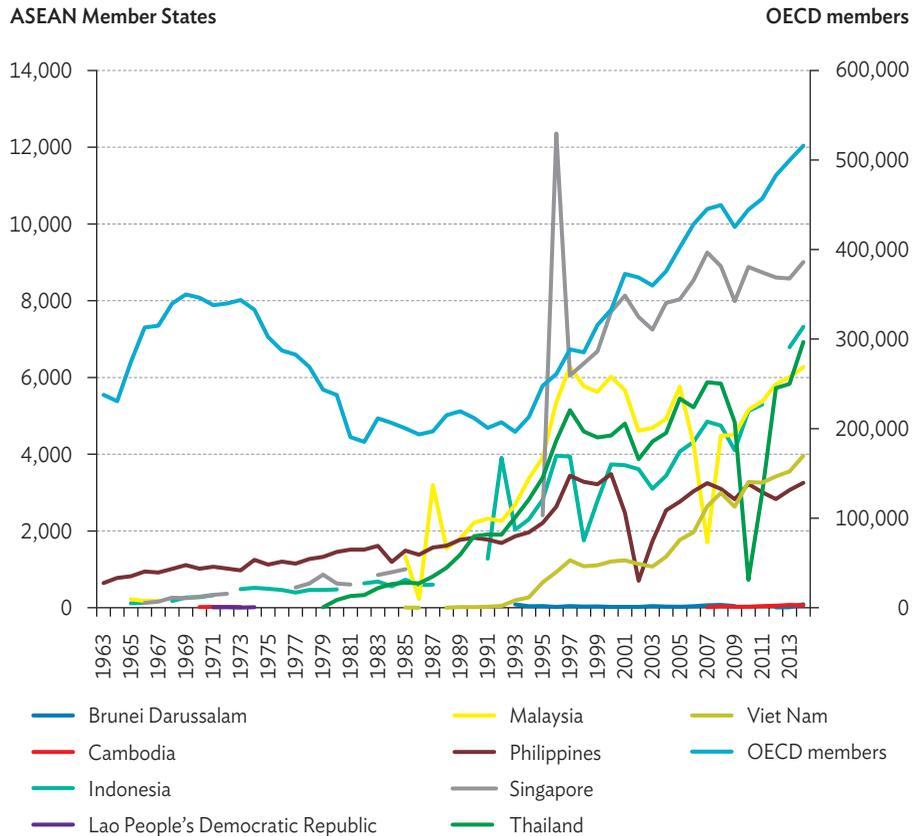
Source: World Bank, World Development Indicators.

Trademark Law Amendments Act), technology transfer organisations, science parks, and business incubators. In light of the discussion so far, Table 2.3 summarises the factors affecting innovation policy according to the industrial characteristics.

2.6 | Conclusion

This chapter defined innovation as the creation and dissemination or diffusion of knowledge. Throughout the chapter, we emphasised the latter element, taking account of the great diversity among AMS. The chapter demonstrated why innovation policy matters for any government under various development phases and economic

Figure 2.13: Patent Applications by Non-residents in ASEAN Member States (number of applications)



ASEAN = Association of Southeast Asian Nations, OECD = Organisation for Economic Co-operation and Development.

Source: World Bank, World Development Indicators.

environments. In short, innovation is a significant, though not unique, source of welfare improvement, and thus the promotion of innovation is a critical policy target for any government at any development phase. Innovation is determined through supply-side factors, such as technological opportunities, and demand-side factors, such as appropriation conditions. Governments can influence both factors by devising policy instruments that secure the private sector's ability to appropriate returns to innovative investments and by providing potential innovators with wider access to public knowledge. In the context of innovation policy in and for ASEAN, it is notable that the optimal design of the policy should vary according to the development phases and sectors. For less-developed AMS, the dissemination of knowledge

Table 2.3: Innovation Policy from the Perspective of Industrial Knowledge Bases

Industrial Knowledge Base	Analytical Knowledge	Synthetic Knowledge	Symbolic Knowledge
Sample industries	Pharmaceuticals, circuit design	Machine tools, automotive	Web design, architecture
Technological opportunities	Scientific advancement	Shop-floor heuristic problem solving	
Appropriability	Patents, UPOV	Know-how	Trademarks, design patents
Knowledge spillovers	Licensing, academic spin-offs	Technical consultation, learning by doing	Learning by observing
Geographical distance to spillover pool	Matters least	Matters more	Matters most
Cognitive distance to spillover pool	Large in university-industry collaborations	Large in university-industry collaborations	
Innovation intermediaries	Science parks, university liaison offices	Trade associations, local public technology transfer organisations	
Entrepreneurship	Academic spin-offs	Intrapreneurship, spin-offs	Spin-offs
Complementary policies	Education, IPR, competition	Education, trade, competition	Education

IPR = intellectual property rights, UPOV = International Union for the Protection of New Varieties of Plants.

Source: Author.

is more important than the creation of knowledge because tapping into existing technologies can have an immense impact on the living standards in such countries. For economically advanced AMS, policies aiming at demand-side factors are more important as they provide the private sector with stronger incentives to perform R&D. For sectors based on analytical knowledge, stronger protection of intellectual property rights would enhance licensing suitable for the transfer of analytical knowledge, while intermediaries, such as technology transfer organisations, would promote licensing and, thus, innovation. Furthermore, promoting university-industry collaborations, such as academic spin-offs, would foster innovations that can leverage the outcomes of academic research, especially in the life sciences.

Another theoretical implication of the fact that dissemination matters for innovation is that entrepreneurship needs to be incorporated in innovation policy. For more economically advanced AMS, the knowledge spillover theory of entrepreneurship provides an important insight for innovation policy. It highlights that knowledge

accumulation in developed countries inevitably creates a large number of undeveloped ideas that are held by large firms and research universities. Entrepreneurial activities by employees at incumbents and university scientists bolster innovation through the creation of new organisations to commercialise undeveloped ideas.

The incorporation of entrepreneurship into innovation policy calls for another important perspective: clusters. Like innovative activities, entrepreneurial activities tend to become geographically concentrated because knowledge about new business opportunities and resource requirements tends to be tacit. This feature of entrepreneurial activities points to the importance of policy instruments that support entrepreneurial clusters, such as business incubators and science parks. Furthermore, the promotion of entrepreneurial activities involves diverse policy issues, such as macroeconomic stability; education and training; competition in the markets for goods, labour, and capital; and international trade. This suggests that coordination among related policies is critical in designing and implementing innovation policy. Such features of innovation policy call for a whole-of-government approach, which is important for less-developed AMS due to the institutional obstacles to innovation that characterise such economies.

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Innovation Policy in China

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ECONOMIC RESEARCH FOR ASEAN AND EAST ASIA

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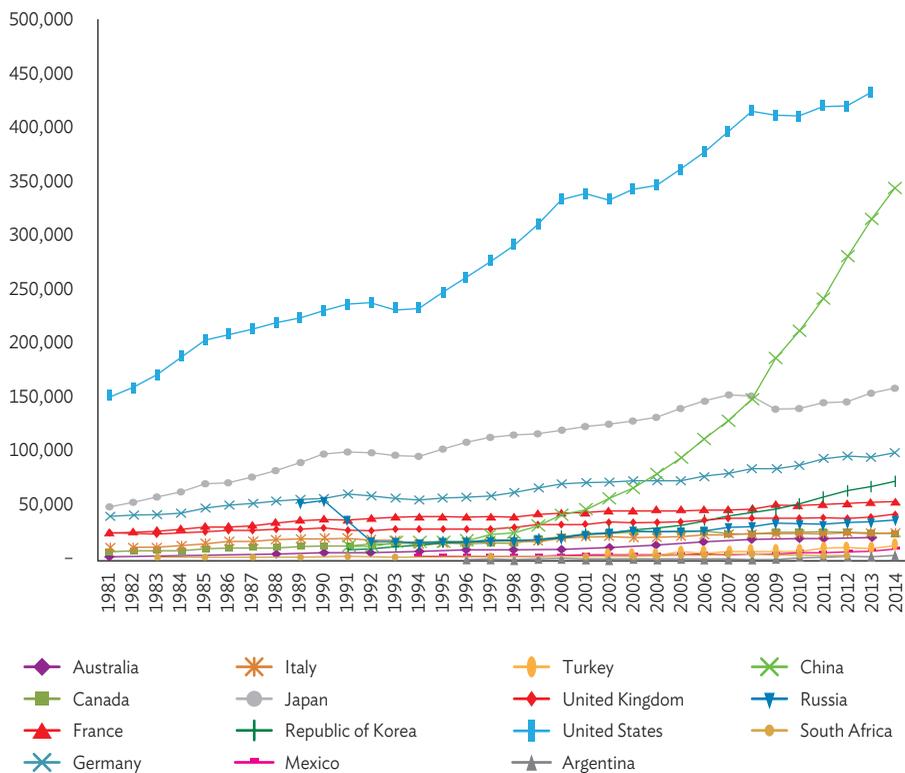
3.1 | Introduction

China has recently emerged as a key power driving research and development (R&D) and innovation in the world. According to the World Bank's World Development Index database, the country contributed more than 400,000 science and technology (S&T) journal articles in 2013, slightly fewer than the United States (US) and almost four times as many as Japan. The country also now has the largest number of full-time researchers in the world. Accordingly, China registered 1.1 million patent applications in 2015, 87% more than the US and about 2.5 times more than Japan (World Intellectual Property Organization [WIPO], 2016). These figures seem to be driven by the country's total annual spending on R&D, which was 2.05% of gross domestic product (GDP) during 2005–2015, compared to 2.73% of the US and 3.58% of Japan during the same period. Figure 3.1 shows the total domestic spending on R&D of 15 countries, including China.

The government plays a key role in R&D initiatives and funding in China. In 2014, about one-third of China's R&D expenditure was funded by the government (Krasodomsykte, 2015). The goals of the government's R&D policies include to (i) advance China's comprehensive innovation capability ranking from 18th to 15th by 2020; (ii) increase the rate of contribution from technological progress to economic growth to above 60%; (iii) extend the share of knowledge-intensive services in GDP to 20%; and (iv) reduce the import of technologies to 30% of the country's total needs by 2020, and have Chinese R&D achievements ranked among the top five in the world in terms of the number of patents and citations. To reach these goals, the government has announced the 13th Five-Year Plan for Economic and Social Development,

the National Strategic Program for Innovation-driven Development, and the 13th Five-year National Science and Technology Innovation Plan. These plans represent a continuation of the previously announced National Medium- and Long-term Program for Science and Technology Development (2006–2020) and the 12th Five-year Plan (2011–2015). Correspondingly, R&D expenditure will reach 2.8% of GDP by 2020 (Xinhua Net, 2016a, 2016b).

Figure 3.1: Gross Domestic Spending on Research and Development, 1981–2014 (US\$ million)



Source: Authors' compilation based on World Bank data.

The Wall Street Journal (2014) frames this development in terms of the critical mass argument, stating: 'China's technology sector is reaching a critical mass of expertise, talent and financial firepower that could realign the power structure of the global technology industry in the years ahead', and so that '[t]raditionally Chinese companies were fast followers, but we are starting to see true innovation'.

However, the evidence shows that China is still significantly lagging in technology and innovation. According to the World Bank's World Development Indicators, payments for intellectual property made by China in 2015 were 22 times higher than its receipts from the rest of the world. Meanwhile, what the rest of the world paid to China for intellectual property use was less than 1% of what the world paid to the US. These data are puzzling if indeed China has accomplished its transition from an imitative latecomer in technology to an innovation-driven knowledge economy. Moreover, the question is whether China has become or will soon become a technological innovation superpower.

It is hard to give a definite answer. This is partly because knowledge is limited regarding (i) how technological catching up works, especially the impact of various industry policies; (ii) how technology advances or how innovations happen at both the macroeconomic and microeconomic levels; (iii) what the key factors, components, and design of national and regional innovation systems should be to ensure effective catching up and innovation; and (iv) what business and industrial strategies and industry policies should be applied at different stages of technological development to ensure competitive advantage. Another issue is the difficulty in measuring technological progress and innovation performance, and thus the lack of data.

This chapter will contribute to the literature in three ways. First, it gives a detailed and in-depth review of the characteristics of several selected industrial sectors in China and examines what factors have been driving the successful cases and what factors may have worked to China's disadvantage. Second, a quantitative method is applied to test whether the influence of these factors is statistically significant and to what extent they determine success or failure. Third, two case studies shed some light on how these factors work at the firm level and identify additional findings at this level.

The rest of the chapter is organised as follows. Section 3.2 reviews China's policies for technological catching up and innovation. The first part of Section 3.3 discusses the theoretical basis of effective policies and presents quantitative evidence from the Chinese economy. The second part of Section 3.3 presents case study evidence, since it is well understood that many aspects and factors that relate or contribute to technological progress and innovation are not quantifiable. Section 3.4 derives the implications for the country's future innovation policies. Section 3.5 concludes.

3.2 | The Innovation Situation in China

For developing countries, catching up in technology is equivalent to innovation. This chapter adopts the broad definition of innovation by Zanello et al. (2016). It includes not only the adoption of new products or processes, or new organisational and marketing practices (where 'new' means new to the world, new to the country, or new to the firm) but, in line with the Schumpeter tradition, also new business models and new sources of supply. This means that innovation could either be ground-breakingly novel, incremental, or imitative. Creation, adoption, adaptation, assimilation, and the diversification of technologies are all part of the innovation process. It also means that innovation can take many forms, such as product innovations, process innovations, marketing innovations, and managerial and organisational innovations. In this sense we can account for the different innovation modes to isolate their diffusion patterns and their impact on firm performance.

In the catching-up stage, the following mechanisms could be applied to absorb imported or transferred technologies: (i) licensing, technical consulting, technical services, and co-production; (ii) movement of goods through international trade; (iii) movement of capital goods through foreign direct investment (FDI), purchase, or leasing; (iv) movement of people with specialised knowledge, expertise, and skills through migration, travel, and overseas education and training; (v) international research collaboration; (vi) diffusion through public media and the Internet, especially of codified and digitised knowledge; and (vii) transfer and spillover through participating in the global value chain (Fu et al., 2016).

While there are many means of catching up in technology, whether or not an economy succeeds in acquiring and then absorbing the technology depends on many factors (Zanello et al., 2016). The theory of innovation diffusion distinguishes two types of factor: external and internal. The four external factors are as follows. First, the nature of the technology, which strongly influences the speed of diffusion. Basic technologies or technologies that are standardised or modularised spread faster. Second, the adaptability of the technology. This refers to the skills, knowledge, tools, and complementary conditions required to perform the modification or customisation for local needs. Third, the communication channels, including both the transmission of information and the transportation infrastructure. Communication is not only between the entities of the advanced economy and those of the recipient economy (thus common culture, language, and social characteristics matter) but also between firms, intermediaries, public research institutes, and the government within the

recipient economy. Fourth, incomplete, outdated, or underdeveloped institutions may become barriers to diffusion. Internal factors are mainly related to the firms of the recipient economy, such as the availability of financial resources, skills, knowledge, capacities, entrepreneurship, and management; and the organisational structure, size, location, degree of competition, the role of clusters, regulations, and policies.

There appear to be different models in reality. Wong and Goh (2015) conducted case studies to examine the S&T policy models and trajectories of S&T development in mainland China, the Republic of Korea (henceforth, Korea), Malaysia, Singapore, and Taiwan. Korea and Taiwan implemented a 'new start-ups for product technology pioneering' model in which the governments set national goals and offered incentives and support to firms to build their capacities and competencies in conducting R&D to achieve technological progress in line with national goals. At the same time, the governments allocated resources to advance scientific activities that would later fuel technology development and co-evolve with it. Importantly, the governments focused on selected areas where certain firms are perceived as capable in achieving the goals. Interestingly, both economies applied the reverse product life cycle strategy, which builds up process capability using imported foreign technology in the initial stages and is followed by the mastering of sophisticated products through imitative R&D.

In Taiwan's case, this strategy was reflected in the transition from original equipment manufacturing (a kind of contract assembly operation) towards original design manufacturing (indigenous product development and process technologies). In the Korean case, the strategy was implemented mainly through *chaebols* (large domestic firms), which focused on both heavy industries and consumer electric and electronic products. Taiwan, on the other hand, chose to support small and medium-sized enterprises (SMEs) and focus on niche areas along the global value chain.

Malaysia and Singapore mainly followed the FDI leveraging model, which relies on the introduction by multinational companies (MNCs) of new and advanced technologies or the upgrading of their production processes and capabilities in the host country. The spillover of know-how from the MNCs is expected to spawn local supporting industries and eventually foster local enterprises in the main businesses to compete with the MNCs. This model focuses on the provision of basic infrastructure, including general education and training and non-specific incentives for in-firm training and technology diffusion, to provide complementary local human resources as well as maintain political stability and security to support export-intensive manufacturing activities.

In the case of mainland China, the economy appears to have implemented both models with its own modifications and characteristics. It implemented the FDI leveraging model through joint ventures with local firms. This model has dominated China's high value-added and high-tech exports so far. However, since 2009, the modified product technology pioneering model, which has been implemented through large state-owned firms in selected industries, has emerged as a strong force in driving technological catching up in strategic industries, such as high-speed rail, space and aviation, electronic chips, infrastructure engineering and construction, energy,¹ and advanced computing.

Since the reform and opening-up in 1978, China has established a comprehensive and modern national innovation system (NIS) complemented by regional innovation systems. The current stage of China's NIS is firm-centred or business-driven, with the government, universities, and public labs playing supportive roles (OECD, 2008). Table 3.1 lists the main policies and institutional set-up from the 1950s to 2016.

Figure 3.2 sets out the implementation of the NIS in China. In summary, the State Council Steering Committee of Science and Technology and Education is the top policymaker in China's NIS. Various ministries and ministry-level agencies carry out different functions under the direction of the steering committee. The Ministry of Science and Technology is the key ministry for implementation. Its main tasks include (i) formulating strategies, priority areas, policies, laws, and regulations for S&T; (ii) promoting the building of the NIS; (iii) guiding reform of the NIS; (iv) designing and implementing programmes to fund basic and applied research; (v) creating science parks and incubators and inducing firms to innovate; (vi) developing measures to promote investment in S&T and allocating and encouraging the development of human resources and specialised talents; and (vii) promoting international cooperation and exchanges in S&T. It provides innovation funds for small high-tech firms in collaboration with the Ministry of Finance; supports university-related R&D, science parks, and human resources development in collaboration with the Ministry of Education; and works with other ministries to define and implement sector R&D policies and programmes.

¹ This especially includes unconventional and offshore oil and gas, renewable, (smart) power grid, and nuclear energy.

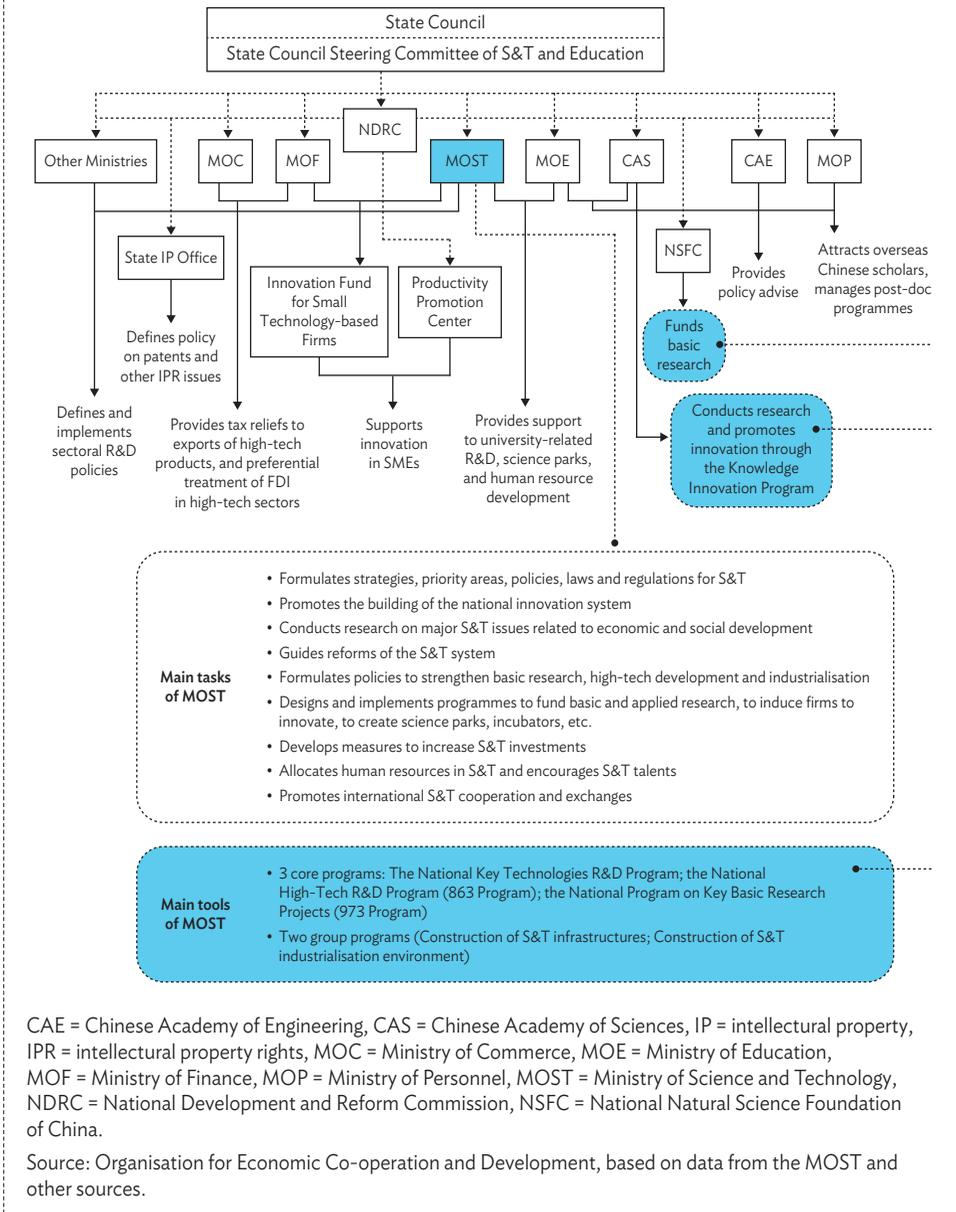
Table 3.1: Brief History of Policies and Institutions for Scientific and Technological Development and Innovation in China, 1950–2016

Period	Policy or Institution
1950–1977	Formation phase of the national innovation system
1978–1994	National plans for science and technology (S&T): <ul style="list-style-type: none"> – High-tech Research and Development Program (“863 Program”) – Torch Program – Spark Program The National Program for Key Basic Research Projects <ul style="list-style-type: none"> – National Natural Science Foundation – Climbing Program – Other policies: reform of the funding system, development of the technology market, and commercialisation of S&T achievements
1995–1997	<ul style="list-style-type: none"> • Enterprise-centric reform: innovation by enterprises and property rights reforms • Strategy of Invigorating the Country through Science and Technology and Education • Establishment of national engineering centres and productivity promotion centres • Technology Innovation Project (for enhancing the innovation capacity of enterprises) • Other policies to accelerate the commercialisation of S&T achievements
1998–2005	Chinese Academy of Sciences approved to implement the knowledge innovation project and the construction of the national innovation system
2006–2015	National Medium- and Long-term Plan for Science and Technology Development (2006–2020): <ul style="list-style-type: none"> – To enhance indigenous and self-dominant innovation – To leapfrog in priority fields – To enable development and lead the future
2016	The 13th Five-year National Science and Technology Innovation Plan

Source: Authors’ summary based on Song (2013).

The Ministry of Commerce and the Ministry of Finance also work together to provide tax relief to exporters of high-tech products and preferential treatment to FDI in the high-tech sectors. The Chinese Academy of Sciences not only conducts research directly and through programmes such as the Knowledge Innovation Program but also works with the Ministry of Education and the Ministry of Personnel to attract overseas Chinese scholars and manage postdoctoral programmes. The Chinese Academy of Engineering is another academic body that provides advice on S&T-related policies. Importantly, the National Development and Reform Commission – the powerful national economic policymaker – is also involved in the NIS as it sets up productivity promotion centres and works with the National Natural Science Foundation of China in funding basic research.

Figure 3.2: Institutional Profile of Public Governance of Science, Technology, and Innovation in China



3.3 | Analysis of Innovation Policies Undertaken in China

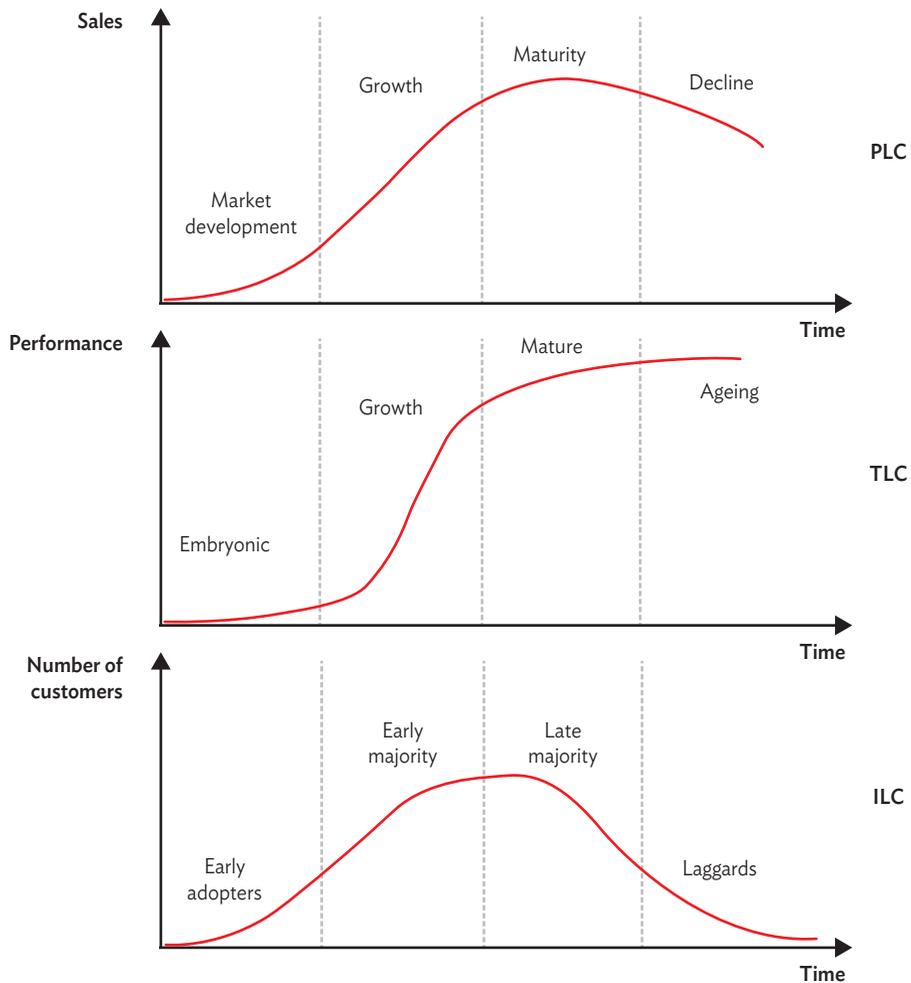
3.3.1 Theory and quantitative analysis

Theories in the literature

Since the characteristics of technology appear to be important factors in determining the strategy for catching up, it is necessary to look into theories that explain the evolution of technology as well as the role of firms, industry, and clusters in this process. The product life cycle theory, proposed by Levitt (1965) and Vernon (1966), divides the evolution of a technology into four subsequent stages: introduction, growth, maturity, and decline. At the maturity stage, an extension strategy may be applicable through measures such as rebranding, price discounting, seeking new markets, and creating new uses of the product. The theory was initially developed to explain the marketing of new products and subsequently was used to explain international trade, industrial organisation (e.g. entry, exit, market power, and market structure), firm theory (e.g. firm size, investment decisions, and competition strategy), and, eventually, innovation and the evolution of technology (Segerstrom et al., 1990; Klepper, 1996). The product life cycle is further elaborated as the technology life cycle (Taylor and Taylor, 2012) and the industry life cycle (McAuliffe, 2015). The technology life cycle focuses on the pattern of changes in performance over time. The focus of the industry life cycle is the pattern of the number and types of customers over time along the product life cycle. In principle, all three can be divided into four stages (Figure 3.3).

However, these theories do not explain why some countries have managed to catch up in certain technologies while others have not. In other words, the dynamics about learning are not reflected in these models. The product life cycle theory can easily be extended to the international product life cycle model (Ayal, 1981). As Figure 3.4 shows, the innovating economy starts and dominates exports from the beginning until the product reaches maturity. Other advanced economies are initially importers but subsequently start production themselves so as to also become exporters. Eventually, as the product becomes mature and affordable, low-income economies start to import it. Subsequently, with standardised design and production processes, low-income economies take over production and eventually become exporters of the product. Empirical evidence from electronics and electrical product manufacturing seems to follow such a pattern. Nonetheless, this theory does not explain technological catching up and spillover in all industries. Some technologies, such as precision instruments, machinery tools, core computer chips, and aviation

Figure 3.3: Product, Technology, and Industry Life Cycle Theories

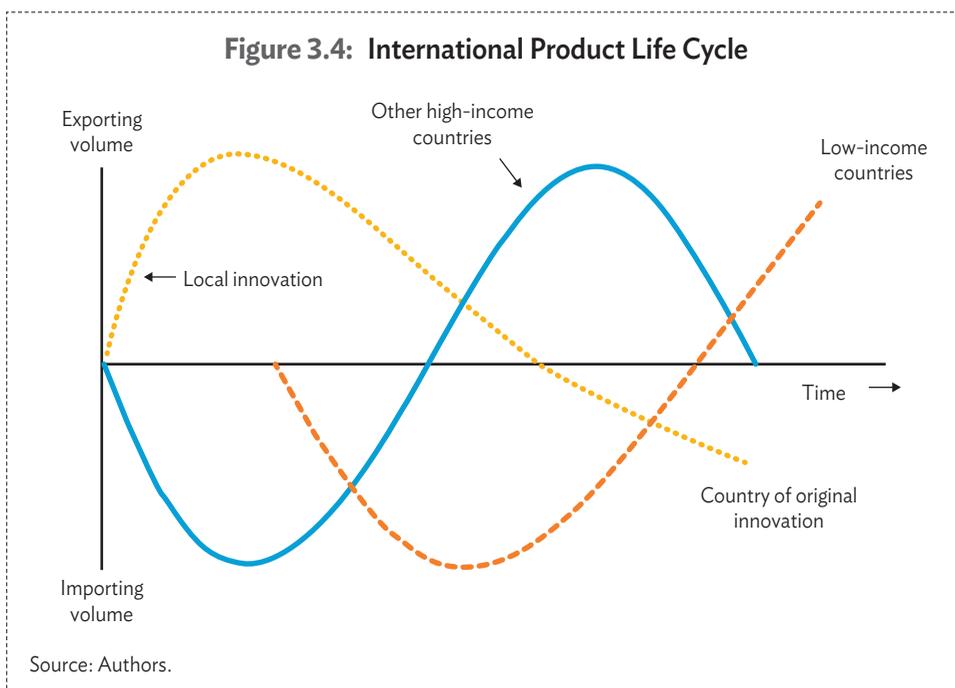


ILC = industry life cycle, PLC = product life cycle, TLC = technology life cycle.

Source: Authors.

and space technology, have several successful cases of catching up. These exceptions should motivate further innovations in economic theories to explain the dynamics of catching up and the barriers in this process.

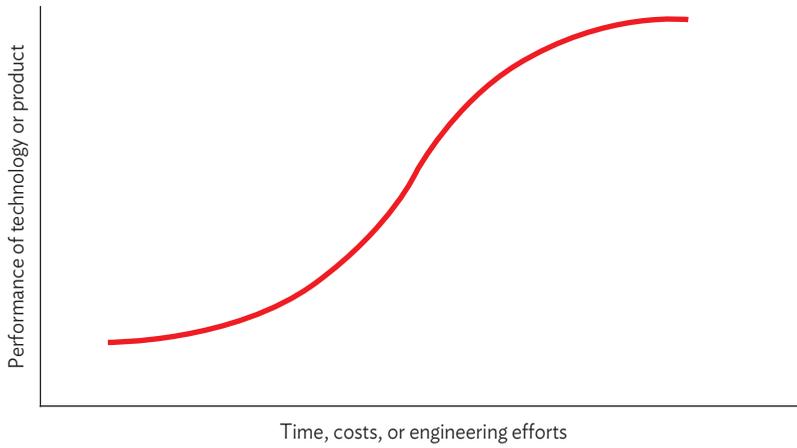
As will be further explored and developed in the next section, the S-curve theory, in other words, the S-curve of the evolution of a single piece of technology, provides some insights into the standing theoretical issue mentioned above.



This theory considers the relation between the performance of a technology and the cost (in terms of time or engineering efforts) of reaching the level of performance. This typically appears as an S-shape curve (Figure 3.5). As Christensen (1992a, 1992b) states: '[In] a technology's early stages, the rate of progress in performance is relatively slow. As the technology becomes better understood, controlled, and diffused, the rate of technological improvement increases. But the theory posits that in its mature stages, the technology will asymptotically approach a natural or physical limit, which requires that ever greater periods of time or inputs of engineering effort be expended to achieve increments of performance improvement.'

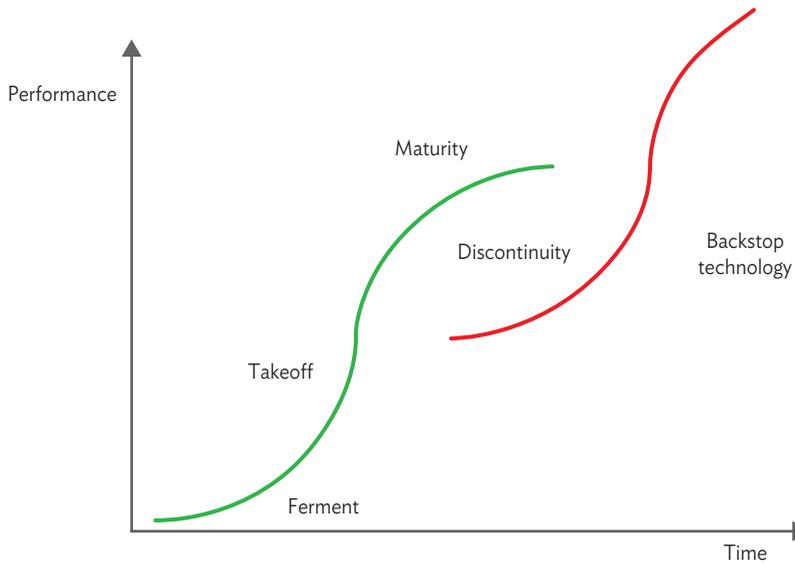
Moreover, as new phenomena, materials, and/or methods are discovered, breakthrough technologies will subsequently appear and present their own patterns of evolution – a necessary condition for the new technology to substitute for the old one. As Figure 3.6 illustrates, another S-curve then starts, beginning with a high level of performance. The new technology is sometimes referred to as a 'backstop technology'. This process is divided into four stages: ferment, takeoff, maturity, and substitution or discontinuity.

Figure 3.5: S-Curve Theory of Technological Advances and Innovation



Source: Authors.

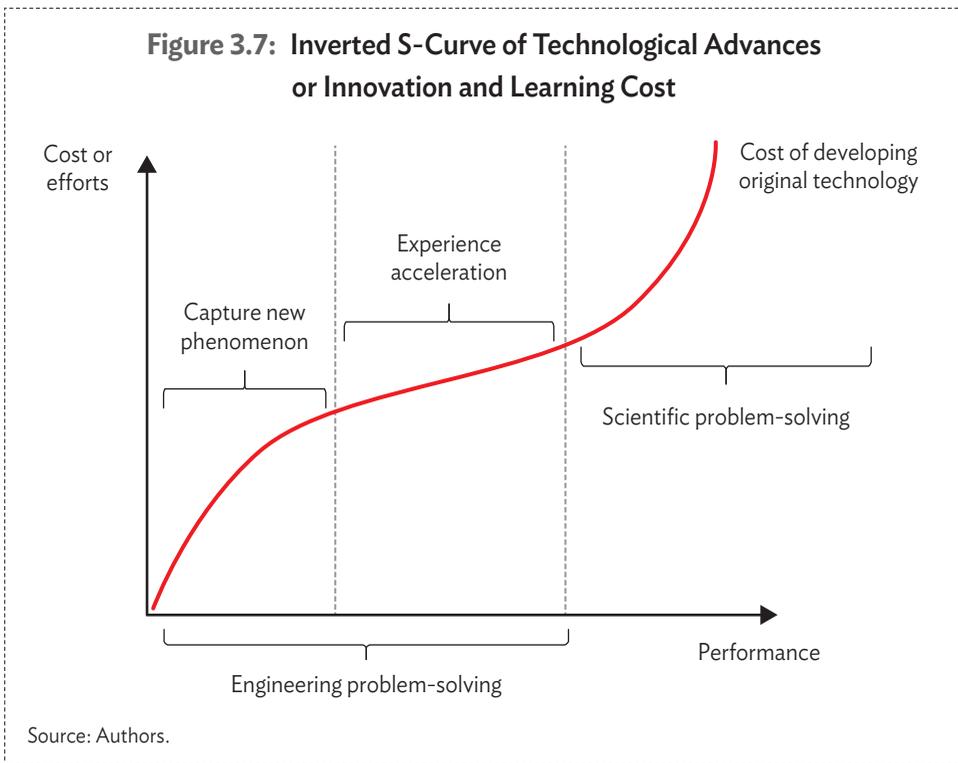
Figure 3.6: S-Curve Theory of Technological Advances and Innovation: Backstop Technology



Source: Authors.

The inverted S-curve theory

This chapter proposes a new theory of technological catching up, by focusing on the cost of technological advances or innovation and the cost of learning. The theory is built on the existing S-curve theory. However, we invert the coordinate system by making the vertical axis represent the cost or efforts paid, while the horizontal axis represents the performance or sophistication of the technology. As Figure 3.7 shows, each point on the inverted S-curve represents the cost paid to arrive at a certain level of performance.

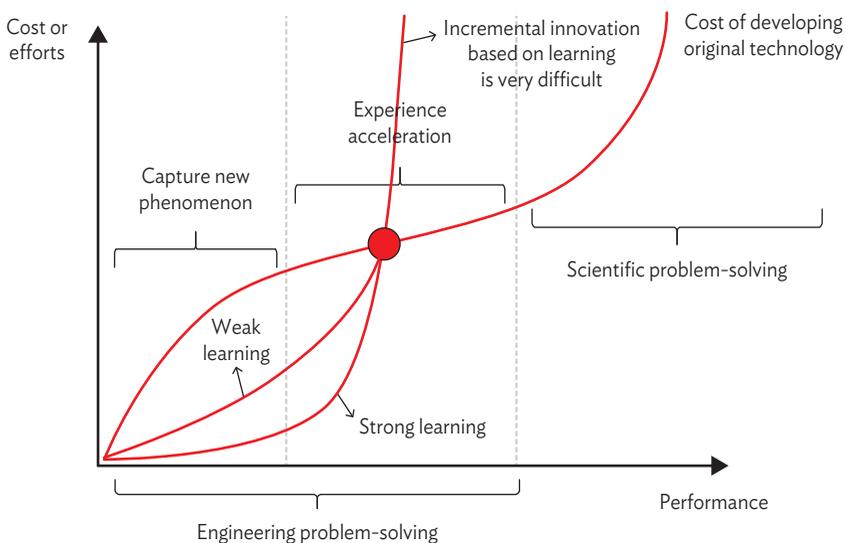


According to the type of driving force behind technological progress as well as the speed of evolution, we also divide the pattern into three phases. First, as is always the case with a new technology, a new phenomenon must be captured by some simple method, tools, equipment, machinery, or system. This can be referred to as the ‘engineering problem-solving phase’. Subsequently, as experience and knowledge are built up, based on growing amounts of understanding, observation, and data about the phenomena and the performance of the initial technological solutions, incremental improvements are made that typically enable significant

progress towards better performance. This can be referred to as the ‘experience acceleration phase’. As the improving technology approaches the theoretical limits of the phenomena, more sophisticated knowledge based on scientific research is necessary, as science enables the discovery of in-depth mechanisms driving the phenomena, which is usually beyond the capability of observation and manipulation by intuition or experience. Arthur (2009) gives a detailed and systematic illustration of the same idea. For example, crude oil exploration used to be based on experience, such as surface indications of oil and gas seepage. Gradually, industry practice began to be based on increasingly sophisticated geological theories. Today, the oil and gas giants use supercomputers and theory-based algorithms to crunch massive amounts of geological data in searching for new reserves.

We can now model the process of learning by a latecomer (Figure 3.8). Let us consider the case that the advanced economy has already pushed the frontier of technology into the scientific problem-solving phase. With the inverted S-curve of a certain technology given, the early stage of learning should be much cheaper than conducting R&D and developing the technology, in the same way as reading a book is much easier than writing one. The shape of the learning curve depends on the learning capability of the latecomer and the availability of codified knowledge, as well as the extent to which knowledge is embedded in the products and equipment that contain the technology.

Figure 3.8: Inverted S-Curve of Technological Advances or Innovation and Learning Cost: Latecomer



Source: Authors.

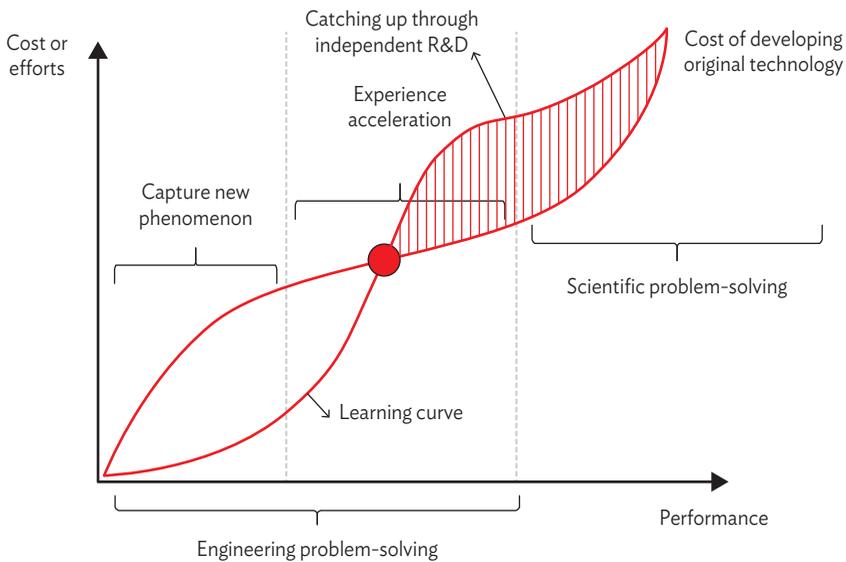
Therefore, on the one hand, the learner whose costs rise fast with slow progress in performance is considered a weak learner, while the one who makes good progress in performance with slower increases in costs is considered a strong learner. The cost of learning should be interpreted broadly to include time, staffing, money, and other resources. On the other hand, the availability of codified and embedded technology determines how far learning can go – how soon the learning curve becomes steeper than the inverted S-curve (and thus crosses the inverted S-curve). Beyond this point, technology and knowledge might be either tacit or kept as strictly protected patents and business secrets, and, thus, learning becomes almost impossible by regular means. Also, beyond this point, based on what the latecomer has already learned, incremental innovation will prove difficult and of limited potential, as indicated by the very steep extension of the learning curve. This is also intuitive: you might have read and understand Albert Einstein's books and papers, but that does not mean you can immediately become Albert Einstein and innovate as well as he could.

Intuitively, innovation is a problem-solving process. Therefore, when the latecomer has finished reading the available 'book' closest to the frontier, if they determine to catch up further in technology, they can start trying to use what they have already learned to solve new problems and, thus, acquire experience. In Figure 3.9, the learning curve stops due to the availability of codified and embedded technology, and the bold curve starts above the original inverted S-curve, rising much faster in cost, as the early stage of building up experience is intuitively much more costly. One can also consider the case of the latecomer that starts its own inverted S-curve to conduct innovation from this point. Along this 'catching-up curve', the latecomer typically has to pay more to innovate and improve the performance of the technology than the original developer did to develop it. However, intuitively, this gap narrows, especially as the evolution of the technology comes to the scientific problem-solving phase. We expect the catching-up curve to eventually converge to the original inverted S-curve and the latecomer to become a technology leader shoulder-to-shoulder with the original developers.

The tricky part is the size of the shaded area in Figure 3.9. This area implies the cost of catching up, the additional cost that the latecomer has to pay to follow the pace of the most advanced technological progresses. The size of the area, however, depends on both the nature of the technology and the structure of the market. For some technologies, the area could be thin, as it might be easy to acquire and accumulate the necessary experience, or the tacit knowledge may be easily available and codified. For other technologies, it may be difficult to accumulate the necessary

experience, or the tacit knowledge may not be available or codified, and, therefore, this area could be thick. For example, it is difficult for latecomers to innovate incrementally on an integral single piece of product based on what they have learned without a long history of accumulated experiences. Motor engines and aviation engines are examples. Technologies such as supercomputers and high-speed railway belong to the ‘system integration’ type of technology. As long as the component technologies used to build the system are available on the market, new system designs using new component technologies can be tested, and, thus, the experience of developing the system is easier to acquire. However, if the supply chain is incomplete or incapable of supplying advanced component technologies, bottlenecks can be expected in catching up in system integration technologies.

Figure 3.9: Learning Curve and Catching Up through Independent Research and Development



Source: Authors.

The structure of the market thus also matters because the more competitive the market is (i.e. the lower the concentration of the industry), the more likely codified and embedded technology will be available from the global technology market. This could take the form of a product (component technology, or intermediate inputs or equipment); transfer; licensing (patents); education and training; acquisition and

merger; partnership; original equipment manufacturing; joint venture; FDI; or imports of equipment and machinery. Therefore, in this case, the learning curve could extend further to the right, reducing the area to be covered under the catching-up curve.

For a certain technology, if the three curves – the inverted S-curve, the learning curve, and the catching-up curve – are given, the cost of learning and catching up can be determined accordingly. The latecomer must therefore conduct its own cost-benefit analysis. The benefit of learning and catching up depends on the market demand the latecomer can expect, including both the domestic market and the potential for export. If the expected demand is high, and thus revenue could more than compensate for the exceptional cost of technological catching up, then there is an economic rationale for the decision to embark on catching up. However, market demand is not modelled in the current technological catching-up theory as it is only related to the supply side. The theory focuses on explaining the dynamic nature of technological catching up for latecomer economies.

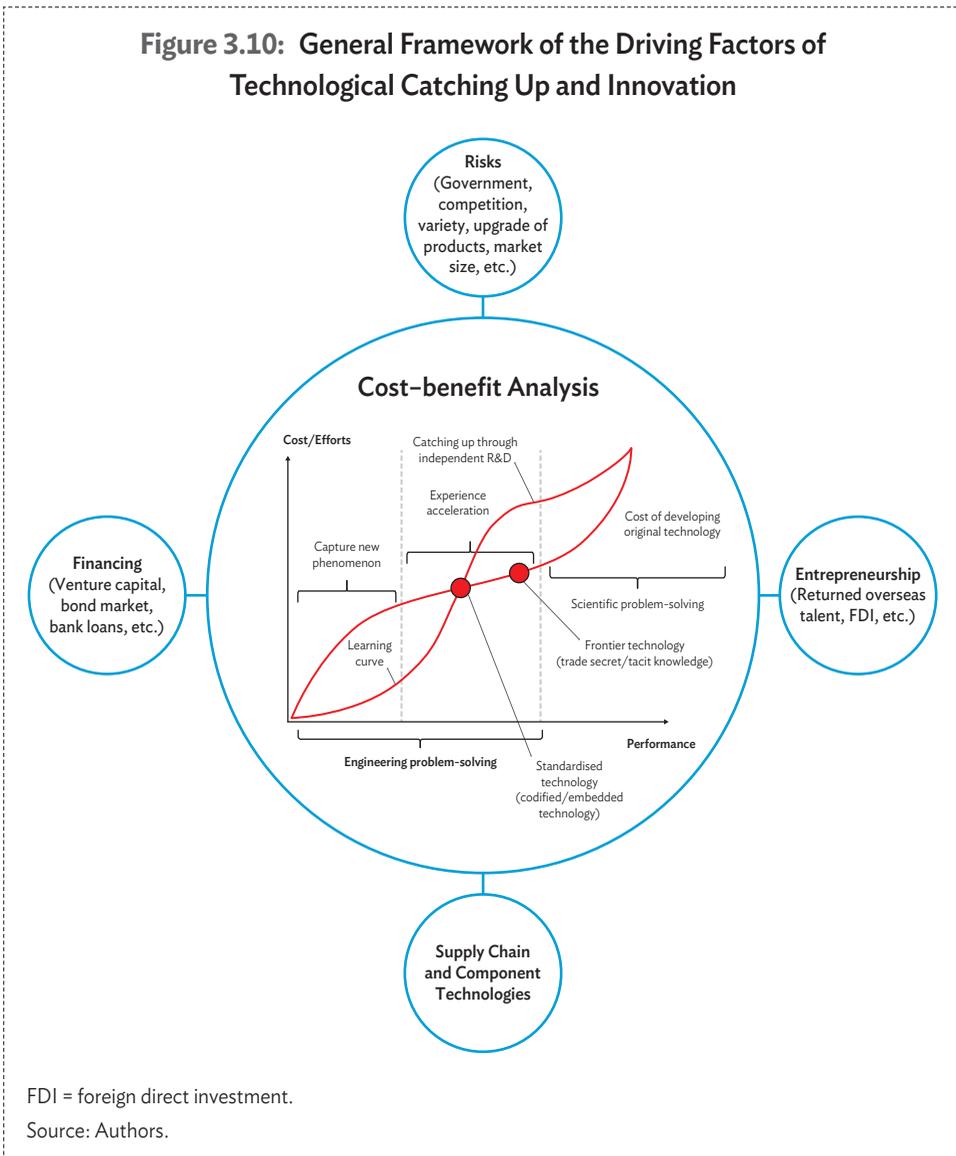
General framework of the driving factors of technological catching up and innovation

The inverted S-curve theory explains the cost-benefit analysis of the motivation for catching up in technology in a well-defined sector or section of the sector's supply chain. However, a mature decision for investing in technological catching up and subsequent innovation is also contingent on several key external factors.

Four categories of external factors are summarised in Figure 3.10. In the first category are the risks involved in technological catching up and innovation. In this regard, government policy, regulations, and various forms of support play important roles. The market of each industry then determines the level of competition, how much variety there will be in the products and services, how soon products and services will be upgraded, and how much demand there is in each niche market. The second category concerns the source of the entrepreneurship to drive catching up and innovation. In developing countries, returned overseas talents and FDI by international MNCs are the most important sources. The third category concerns the structure of the supply chain. A country with a more comprehensive and well-developed supply chain will find it easier to upgrade technologies, as the component technologies are more readily available. If the control of supplies of core technologies, such as engines for vehicles and aircraft, is missing, this could become a bottleneck to the development of more technologically advanced cars and aircrafts. For example, if the US government does not wish to see supercomputers developed too fast in China,

it could issue administrative orders to ban the export of high-end chipsets to China. The fourth category is about the financing solutions available in an economy to support technological catching up and innovation. In this regard, conventional banks and innovative financing, such as venture capital and the bond market, are important. Typically, the latter is important for creating a vibrant environment for catching up and innovation.

Figure 3.10: General Framework of the Driving Factors of Technological Catching Up and Innovation



Quantitative analysis

Methodology. We follow Diebold and Yilmaz (2009, 2012, 2014) by using the vector autoregressive (VAR) model approach to investigate which factors contribute to innovation and to what extent. The model starts with a K variable VAR(p) model in the form of

$$y_t = c + \sum_{i=1}^p A_i y_{t-i} + u_t \tag{1}$$

where y is a $(K \times 1)$ vector of the time series variables in the system, c is a $(K \times 1)$ vector of constants, and u is a $(K \times 1)$ vector of the error terms; A represents $(K \times K)$ dimensional matrices of coefficients. After estimating the model, we use forecasting error variance decomposition (FEVD) to interpret how the variables are dynamically related.

The FEVD approach starts with constructing the mean squared error of the H -step forecast of variable y_i and examining the contribution of each variable to other variables in the system. Defining θ_{ij}^H as the contribution of variable j to i , and H as the forecasting horizon, the basic idea of Diebold and Yilmaz (2009) can be shown in a connectedness table, as in Table 3.2.

Table 3.2: Connectedness Table Based on Variance Decomposition

	y_1	y_2	...	y_K	From others
y_1	θ_{11}^H	θ_{12}^H	...	θ_{1K}^H	$\sum_{j=1}^K \theta_{1j}^H, j \neq 1$
y_2	θ_{21}^H	θ_{22}^H	...	θ_{2K}^H	$\sum_{j=1}^K \theta_{2j}^H, j \neq 2$
\vdots	\vdots	\vdots	\ddots	\vdots	\vdots
y_K	θ_{K1}^H	θ_{K2}^H	...	θ_{KK}^H	$\sum_{j=1}^K \theta_{Kj}^H, j \neq K$
To others	$\sum_{i=1}^K \theta_{i1}^H, i \neq 1$	$\sum_{i=1}^K \theta_{i2}^H, i \neq 2$	...	$\sum_{i=1}^K \theta_{iK}^H, i \neq K$	$\frac{1}{K} \sum_{ij=1}^K \theta_{ij}^H, i \neq j$

As the diagonal elements represent the contributions by/to the variable itself, the remaining elements reflect how much the variables are interconnected. Diebold and Yilmaz (2012) also introduce three additional measures: from others (FC), to others (OC), and net directional connectedness (NDC):

$$FC_i = C_{i \leftarrow}^H = \sum_{j=1}^K \theta_{ij}^H, j \neq i \tag{2}$$

$$OC_i = C_{\leftarrow i}^H = \sum_{j=1}^K \theta_{ij}^H, i \neq j \quad (3)$$

$$NDC_i = C_i^H = C_{\leftarrow i}^H - C_{i\leftarrow}^H. \quad (4)$$

FC calculates how much one variable gains from the system (excluding itself) and thus takes a value between 0 and 1. OC is not bounded by 1 as it shows how much one variable contributes to the variation of the whole system (excluding itself). NDC is negative if one variable gains more information from the system than it contributes to the system. It is possible to construct NDC in a pairwise way in that $NDC_{ij} = C_{ij}^H = C_{j\leftarrow i}^H - C_{i\leftarrow j}^H$, which shows the relative importance of all pairs in the system. The VAR model is sensitive to the order of the variables in the system, so the generalised variance decomposition approach of Koop et al. (1996) and Pesaran and Shinb (1998) is needed in practice.

Data. We set up a seven-variable VAR model including the growth rates of patents, loans, per capita GDP, FDI, fiscal expenditure, wages, and the high-tech market size. Patents are used as a measure of innovation in terms of output; loans as a percentage of GDP are used to represent financial market development; per capita GDP measures the level of income; FDI is used for international impacts; fiscal expenditure is a proxy of public investment; wages capture labour income, which is supposed to affect innovation; and the high-tech market size captures the general market environment for innovation. All data are in annual frequency from 1989 to 2015 and collected from the National Bureau of Statistics. The variables are explained in Table 3.3. The data are converted into growth rates before being added to the VAR model for further analysis.

Empirical results. We estimate a seven-variable VAR model with two lags.² The results are reported in Table 3.4. GDP growth is the most important contributor to the system with a total of 166.45%, and financial development is the second most important factor with a 141.57% total contribution. These two variables are the only two net contributors. All five other variables are net receivers (negative NDC). The fiscal expenditure growth rate gains the most from the system. The total connectedness of the system is 78.39%, which suggests that only 21.61% of the variation is due to self-contribution.

² Bayesian information criteria are used to choose the optimal lag order.

Table 3.3: Summary of Variable Definitions

Abbreviation	Variable Definition
Pat	Number of patent applications granted (growth rate)
FIN	Total outstanding loans in financial institutions (growth rate)
Growth	Real gross domestic product growth
FDI	Foreign direct investment growth
Fiscal	Annual growth rate of public fiscal expenditure
Wage	Urban average wage growth
HTM	Total trading volume of the technical market (growth rate)

Source: Authors.

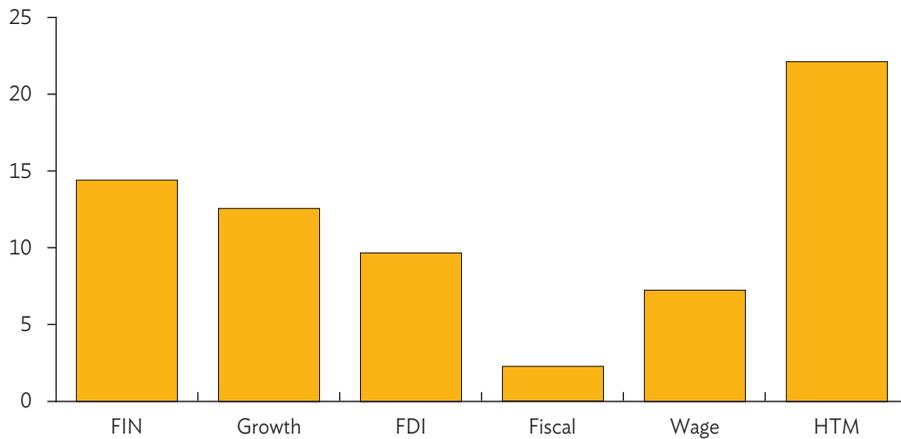
Table 3.4: Connectedness Table of the Estimated Vector Autoregressive Model (%)

Variable	Pat	FIN	Growth	FDI	Fiscal	Wage	HTM	From others
Pat	31.92	14.38	12.53	9.63	2.28	7.25	22.00	68.08
FIN	8.69	25.64	31.83	9.73	5.82	11.83	6.46	74.36
Growth	8.41	26.62	38.41	5.52	2.91	11.42	6.72	61.59
FDI	8.16	27.60	22.05	20.97	4.91	6.99	9.32	79.03
Fiscal	7.09	24.15	39.72	4.11	7.36	12.80	4.77	92.64
Wage	9.58	25.51	32.57	8.46	4.11	11.86	7.92	88.14
HTM	13.10	23.31	27.75	8.87	3.63	8.21	15.12	84.88
To others	55.03	141.57	166.45	46.32	23.66	58.50	57.19	78.39

Note: The number in bold represents the total connectedness measured in this system. Please refer to Table 3.2 for the definition of 'from others' and 'to others'.

Source: Authors.

Figure 3.11 plots the contribution to patents granted (growth rate) in China from other factors. The highest contribution to patent growth rate comes from the high-tech market growth, and it explains 22% of the variation in patent growth. It shows that a healthy market-oriented system is very important for innovation. Although there are still gaps between China and the developed economies, it is clear that the efforts made by the Government of China to improve the high-tech market conditions have paid off.

Figure 3.11: Contribution to Patents Granted from Other Factors (%)

FDI = foreign direct investment growth, FIN = total outstanding loans in financial institutions (growth rate), fiscal = annual growth rate of public fiscal expenditure, growth = real gross domestic product growth, HTM = total trading volume of the technical market (growth rate), wage = urban average wage growth.

Source: Authors.

Income growth and financial development contribute to more than 10% of the variation in innovation. Growth contributes 31.83% to financial development, whereas financial development explains 26.62% of the growth variation. These two are intrinsically linked, although growth is the net contributor to financial development. The logic is that when an economy is getting richer and its financial system is becoming more developed, innovation is more likely to be funded. A caveat is that we cannot include the equity market due to the availability of data.³ The development of the equity market should also promote innovation. In other words, the role of financial development should have stronger role in the innovation system of China.

FDI does not have a very strong role in affecting China's innovation. One may expect that international investment would bring technological progress to the host country, but it appears that the logic does not apply to China. China is indeed a very big recipient of international investment, however, being the world's biggest factory, it does not benefit much in terms of technical progress. Fiscal expenditure and wage growth have little impact on innovation. One explanation is that both variables gain significantly from 'FIN' and 'growth', the two variables that dominate here.

³ The stock market in China started only in 1991.

3.3.2 Industry cases

Driving factors of technological catching up and successful innovations in Chinese industries

Based on the above theory, the following paragraphs and tables list four key dimensions of the characteristics of the market and technologies of a broadly defined industry in the context of China. The dimensions are (i) the market concentration of technology vendors, (ii) the type of technology (system integration or single piece of technology), (iii) the completeness of the supply chain within the economy, and (iv) the variety and frequency of upgrading of the products (or services). We focus on the characteristics of the industry or technology per se. Common factors, such as entrepreneurship, financing, public R&D, and government support for education and labour skills, are not discussed. Table 3.5 presents these dimensions and summarises the characteristics of several key industries of strategic interest to the Chinese economy. The profiling of each industry according to the four dimensions is based on trade statistics and anecdotal evidence or experience. The last row of each section of the table concludes on the effectiveness of technological catching up or innovation of the industries as a result of these characteristics. In this study, effective catching up is indicated by a significant share of exports of products with autonomous technologies, patents, or design by the Chinese industry in the global market.⁴

⁴ Refer to the following for further details:
<http://www.worldstopexports.com/> for statistics on broadly defined industries, such as electronics, vehicles, and aeroplanes;
http://news.xinhuanet.com/tech/2016-09/19/c_1119580852.htm for automobiles, vehicle engines, and electronic chips;
http://www.sohu.com/a/135343162_676567 for the aviation engine industry;
<http://www.cccme.org.cn/news/content-274184.aspx> for the telecom equipment industry;
http://www.iberglobal.com/Archivos/china_aerospace_rand.pdf for the space industry;
https://www.rand.org/pubs/research_reports/RR245.readonline.html for the aviation industry;
<http://www.roboticschina.com/news/article/201706121612> for robotics;
http://www.guancha.cn/economy/2016_03_24_354912.shtml for digital machinery tools;
http://news.xinhuanet.com/globe/2017-08/15/c_136500569.htm for advanced computing;
http://paper.people.com.cn/rmrb/html/2017-04/05/nw.D110000renrb_20170405_8-01.htm for the nuclear energy industry;
http://news.xinhuanet.com/science/2015-12/24/c_134946932.htm for high-speed rail;
<http://www.biotech.org.cn/information/134424> for the medicine and biotechnology industry;
<https://hbr.org/2017/07/60-countries-digital-competitiveness-indexed-for-e-commerce>;
<http://www.chinareform.net/index.php?m=content&c=index&a=show&catid=30&id=19887> for infrastructure engineering and construction; and
<http://www.cailiaoniu.com/89839.html> for advanced material technologies.

Table 3.5: Anecdotal Evidence of the Driving Factors in Chinese Industries’ Technological Catching Up and Innovation

Industry	Space	Aviation	Automobile	Telecom System	Nuclear Energy	Electronic Chips
Market concentration	High	High	Low	High	High	High
Type of technology	SI	SI	SI	SI	SI	INT
Completeness of supply chain	Y	Y	N	N	Y	N
Variety and regeneration of products	Low	Low	High	Low	Low	High
Effective catching up or innovation	Y	Y	N	Y	Y	N

Industry	High-speed Rail	Aviation Engine	Vehicle Engine	Digital Machinery Tools	Robotics	Advanced Computing (AI, cloud computing, big data)
Market concentration	High	High	Low	Low	Low	Low
Type of technology	SI	INT	INT	SI	SI	INT
Completeness of supply chain	Y	N	N	N	N	Y
Variety and regeneration of products	Low	Low	High	High	High	High
Effective catching up or innovation	Y	N	N	N	N	Y

Industry	Medicine and Bio-technology	E-commerce Application	Infrastructure Engineering and Construction	Supercomputers and Data Centres	Advanced Materials (chemical and metallic)
Market concentration	Low	Low	High	Low	High
Type of technology	INT	SI	SI	SI	INT
Completeness of supply chain	N	Y	Y	N	N
Variety and regeneration of products	High	High	Low	Low	High
Effective catching up or innovation	N	Y	Y	Y	N

AI = artificial intelligence, INT = integral piece of technology, N = no, SI = system integration, Y = yes.

Source: Authors, based on the Thirteenth Five-year Planning for National Scientific and Technological Innovation and various media and industry consultancy reports.

A general pattern can be summarised as follows. China has performed well in the catching up of the system integration type of technologies. Where the market concentration of technology vendors is high, the supply chain is complete within the Chinese economy, and the variety and frequency of upgrading of products and services is low, successful technological catching up is almost guaranteed. Examples include space, aviation, telecoms, nuclear energy, and high-speed rail. The telecom industry deviates a little from this pattern as its supply chain of component technologies is not as complete within the Chinese economy; various components need to be imported or patents for the components need to be licensed. However, it is common practice in this industry for international giants to exchange the patents and licences they hold for free, or to provide low-cost access to each other's component technologies. Thus, Chinese telecom equipment manufacturers only need to own a certain portion of original component technologies among all patented component technologies along the supply chain to be able to exchange them for access to advanced component technologies held by other international players.

For a few other system integration technologies, even if some of these factors are different, such as e-commerce application and supercomputers and data centres, successful catching up can still occur. Thus, it seems that China has intrinsic strength in catching up in system integration technologies. Importantly, as long as high-quality component technologies are available from the international market, system integration technology by nature allows latecomers to assemble such components and turn them into products and services of acceptable quality, stay marginally competitive in the market (especially if there are cheap labour, natural resources, and land available within the latecomer economy) and, thus, survive at the early stage. Having a sufficiently big domestic market may also be crucial to the survival of these latecomers at this stage. The longer they survive, the more likely they will complete the catching-up curve by learning from their own incremental innovation efforts. This may explain the catching up of Chinese companies in e-commerce application and supercomputers and data centres, for which the domestic market is not only big but also heavily protected.

Nonetheless, the cases of the automobile, digital machinery, and robotics industries show that if all or most of the other factors deviate from the observed pattern, even if it is a system integration technology, Chinese industries could still fail to catch up. So far, China has not become a main exporter of vehicles, high-end machinery tools, or robots. Nor does it have any world-renowned vehicle, machinery tool, or robot brands.

These three industries are notably competitive, having many international technology vendors (many choices of technological paths and standards), an incomplete domestic supply chain of component technologies, and a large variety of products and services and a high frequency of upgrade.

For ‘single-piece’⁵ technologies, China has only managed to catch up in advanced computing. This could imply that other factors not listed here are at work, such as the high availability of codified knowledge in this industry, such as advanced algorithms, and the relatively low cost of accumulating experience through trial and error, such as computer simulation. For other industries applying single-piece technologies, such as aviation engines, vehicle engines, medicine and biotechnology, and advanced materials, catching up appears to be difficult for Chinese industries because (i) there are many international technology vendors and, therefore, many choices of technological paths and standards, (ii) the domestic supply chain of component technologies is incomplete, and (iii) there is a large variety of products and services and a high frequency of upgrade.

These characteristics of the market and technologies of these industries may determine whether China’s indigenous resources, such as its large market size and its cheap land and labour – especially labour for research, development, and demonstration – can render the necessary competitive advantages to catch up in technologies and conduct subsequent innovations.

The theory that has been proposed and illustrated has ample policy implications. Three important policy-related observations are highlighted. First, protective measures against competition from advanced foreign technology developers could help ensure that the latecomer in the host country is able to generate sufficient revenue from the domestic market and thus compensate for the high cost of catching up. The theory thus also explains why some developing countries must provide subsidies or tax incentives for exporting certain industrial products and services, especially in their catching-up stage. However, this may be more applicable to system integration technologies and in cases where the international market is highly concentrated and has a low intensity of competition. Second, our theory suggests using public finance or public sector research to reduce the exceptional cost of catching up for the

⁵ This is usually a single product with a complicated design and high-precision assembly, such as vehicle engines and advanced computer chips.

latecomer country. Third, establishing a complete and capable domestic supply chain could accelerate catching up in system integration technologies. In a small economy, which is unlikely to be capable of hosting a complete supply chain, the government should ensure sound partnership and cooperation with the global supply chain to enable effective and affordable cross-licensing of patented component technologies.

Firm-level strategies leveraging on state-level policies

The China General Nuclear case of catching up in nuclear energy technologies.

China General Nuclear (CGN) is a young, state-owned energy company founded in 1994. Its main business is nuclear energy, although it has diversified into hydro, solar, and wind power. As of January 2017, CGN had 19 nuclear reactors with a total capacity of 20.38 gigawatts in operation and another 9 reactors under construction, making it China's largest nuclear energy producer. Being a latecomer in nuclear energy technology, this company is now already exporting its own version of second- and third-generation nuclear energy technologies as its recently announced projects with Romania and the United Kingdom show.⁶

Nuclear energy reactors are the system integration type of technology. The industry is highly concentrated, both globally and domestically. The technology also progresses slowly, usually taking two or three decades for a new generation to appear. Thus, the industry almost fits our 'pattern of success' observed in the previous subsection. Indeed, billion dollar nuclear power plant projects introduced in China in the 1980s and 1990s always came with requirements for technology transfer and licensing from international technology, vendors such as Westinghouse, Areva, and Candu. The introduction of high-speed rail technologies later on followed a similar pattern. Such a strategy is also pursued as much as possible in the acquisition of core parts of nuclear power plants. This is reflected as a higher localisation rate or import substitution rate of the parts and components. In the case of nuclear energy technology, such as large forgings of core equipment, reactor pressurised vessels, steam generators, water pumps, critical valves, main transformers, and emergency diesel generators, CGN collaborates with domestic suppliers in localising the supply chain. Therefore, a supply chain capable of supplying 80%–90% of all parts and components has been set up in China. In return, localisation of the supply of key parts and components has become a major factor in helping keep the cost of new nuclear power plants within the budget plan. Today, the 'overnight' cost

⁶ See <http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/romania.aspx> and <https://www.theguardian.com/business/2016/sep/15/hinkley-point-chinese-firm-to-submit-essex-nuclear-plant-plans> (accessed 21 March 2017).

(i.e. with no interest incurred) of a new nuclear power plant in China is one-third less than that in the European Union, while costs in the US are 30% higher than in China (World Nuclear, 2017).

The government's policy of steadily promoting the share of nuclear energy in the national energy mix has lowered the risks and guaranteed the returns to the investment made by domestic companies along the supply chain. The relevance of technologies in the parts and components supply in conventional power generation equipment, as well as a strong domestic human resources reservoir consisting of scientists, engineers, technicians, and manufacturing specialists from the nuclear-related national defence system, all helped in the fast catching up. The government is still pouring public resources into the R&D of advanced nuclear energy technologies, such as fourth-generation nuclear fission technologies, small-module and high-temperature reactors, and even fusion technologies. With all these factors at work, this industry is becoming one of the major exporters in the global nuclear energy markets.

The Huawei case of catching up in telecommunication technologies. Huawei is a purely private enterprise originating in China. It started as a downstream assembler of existing, standardised, and marketable information and communication technology (ICT). Its programme control telephone exchanger was a symbolic product in the 1980s and 1990s. As the era of mobile and wireless communication arrived, followed by the digital communication era, Huawei gradually emerged as a telecommunication equipment supplier, especially serving the telecom service carriers. Its competitive advantage was to customise the design and functions of equipment built using standardised technologies and components. It was a system integrator and an assembler, and it also innovated on the peripheral technologies to provide customers with a better user experience. However, it was its patents for design and peripheral technologies that helped Huawei establish itself as one of the global players in the industry. From there, the company gradually moved its R&D closer to the central core of ICT technologies, especially by becoming one of the makers of the global telecom standards, such as the 3G, 4G, and 5G wireless communication technologies. Its R&D expenditure was kept at as high as 30% of its revenue. It was this intensity of R&D, combined with its practical strategy of customer-driven innovations, that allowed the company to keep increasing its sales while also going deeper into advanced ICT.

A salient feature of the ICT industry is how fast the technologies change, which provides more opportunities for a company to build up its patent pool not only by creating breakthrough innovations but also by making incremental innovations as part

of the continuous improvements in performance of new technologies. The merging of information technologies and computing technologies, especially the arrival of the smartphone, also make the number of component technologies needed to make an ICT system function huge. Eventually, the patents end up in the hands of a few international giants, such as Ericsson, CISCO, Siemens, Alcatel, Nokia, Samsung, and even Google and Apple. They exchange, trade, or sue for the use of patents and designs held by each other.

Huawei gradually squeezed itself in, first by trading its peripheral technologies for the use of core technologies then subsequently by participating in global R&D efforts to establish new standards, thus introducing a new generation of technologies. Under this arrangement, Huawei need not own all the core technologies to stay in the first squadron of technology players; it only needs to contribute a fair share of the total number of patents of a new technological system. A larger share is always better, as it means it can trade its patents for the use of others' patents for free or even charge extra royalties if it is believed that Huawei's patents are more critical. This is why Huawei has started charging global giants, such as Apple, royalty fees.

Huawei continues to move up to the top tier of the industry. Today, it manufactures its own communication chips for its telecommunication equipment and central processing unit chips for its smartphones. The company has made use of any leverage it has to rapidly break into new technological areas, especially in moving from downstream to upstream technologies. It partners with international giants; establishes overseas labs and R&D centres; and identifies the mature, standardised, and available modules in a new technological field in order to focus on making incremental innovations to quickly conquer markets. In other words, contrary to the case of CGN in the nuclear energy industry, in this industry, Huawei to a very large extent makes use of the global supply chain to acquire the most advanced component technologies and then incrementally innovates on top of them. This difference may be due to the more competitive market of the telecom world in terms of how fast the technologies are being changed and upgraded.

Observations from the case studies. Both nuclear energy technologies and ICT are extremely complicated technologies. They also took more than half a century to evolve to today's levels of complexity and performance. Today, the two technologies are becoming increasingly standardised, embedded in equipment and products, or codified and, thus, available in various forms from various markets, such as licensing, consultancy, the acquisition of equipment and products, and even reading

and lecturing. However, both the cost of learning and the cost of accumulating experience, as indicated in Figure 3.9, appear prohibitive to most potential market entrants. Of course, China has the second-biggest economy today and one of the largest markets in the world to absorb the costs of learning and catching up. Both CGN and Huawei started out by focusing on the domestic market and used the revenue to invest in further learning and catching up, especially conducting incremental innovation and improvement on the technologies learned at each stage. However, strong and sustained overseas demand could have the same effect if trading partners do not pursue protective trade policies.

In any case, an industry from a developing economy cannot immediately jump into the core and most advanced technologies as the target of catching up. It is more practical to import core parts or pay for the use of core technologies and at the same time focus on catching up or innovating in complementary or peripheral component technologies that are typically easier or entail lower costs of learning and catching up. Depending on how much revenue can be recouped from the market seized by these innovated products or services and how soon this can be achieved, the industry can invest more to pursue further technological development closer to the core technologies. Such is the strategy played by CGN and Huawei.

The timing of catching up is essential. If it is too slow, in a industry with frequent technological progress and upgrade, catching up may end up being futile. To do the most catching up within the shortest time, it is critical to have a catching-up strategy in areas that the company or the industry of a developing economy has comparative advantages. Neither CGN nor Huawei own a majority of the patents in the most advanced technologies in their industries. However, owning even a small fraction is sufficient as a stake on the table for negotiation and exchange to use other key players' core technologies. This is how partnerships or alliances have been formed between CGN and Areva, and between Huawei, Samsung, and Google.

Last but not least, the availability of the latest component technologies is as important as the core technologies owned by a downstream company or industry. In the case of a highly competitive and dynamic industry, such as ICT, Huawei can rely on the international supply chain. In the less competitive and less dynamic nuclear energy industry, CGN chose to foster a supply chain that mainly relied on domestic suppliers to reduce the costs of supplying key components and shorten the response time of the supply chain. In the nuclear energy industry, the lead time of a power plant project is directly translated into the cost of the project.

3.4 | Future Innovation Policies in China

In view of the global new wave of technological progress in robotics, artificial intelligence (AI), big data, cloud computing, and the digitisation of conventional industries, China has issued its future-oriented industrial technology development plan, called 'Made in China 2025'.⁷ This is a comprehensive plan aimed at developing more innovative, more productive, more digitised, and, thus, more competitive Chinese manufacturing industries. It emphasises the development of localised manufacturing of core components (usually high-tech and high-value-added components) for integrated circuit chips, telecommunication equipment, operation system and industrial software, sophisticated digital machinery tools, advanced robotics, space and aviation systems and equipment, maritime engineering equipment and advanced vessels, advanced railway equipment, energy-efficient and alternative energy vehicles, advanced power-generation technologies, advanced agricultural equipment, new materials development, biomedicines, and advanced medical equipment. These are deemed to be fundamental industries that will enable other industries to innovate more rapidly and become more productive.

Two key nexuses will be developed in the future NIS. The first is the joint efforts in research, development, and demonstration by government, industry, academia, and public research institutes. The purpose of this collaboration is to better translate the engineering, technological, and scientific innovations or breakthroughs into marketable products and services and, thus, competitive advantages for the industries. The second nexus is the concept of 'smart manufacturing', which means the digitisation of conventional manufacturing industries and their integration with robotics, AI, big data, and cloud computing.

The implementation of this plan involves two salient features. The first is an emphasis on forming several innovation centres, reflecting a recognition of the importance of the proper clustering of industries, talents, expertise, and knowledge. The second is to connect to other economies' plans for advanced manufacturing, such as Germany's 'Industry 4.0'. This will occur through the development of common standards in the future smart manufacturing systems of industries in China and Germany.

⁷ See <http://english.gov.cn/2016special/madeinchina2025/> and <http://qys.miit.gov.cn/n11293472/n11293877/n16553775/n16553792/16594486.html>.

3.5 | Conclusion and Implications for ASEAN Economies

China's rise in sectors such as nuclear energy, space, aviation, high-speed rail, and supercomputers seems impossible to replicate in the Association of Southeast Asian Nations (ASEAN) Member States, as China's industries benefited not only from a large domestic market but also from the ability of state-owned companies and state-owned financial institutions to substantially and continuously invest in catching up in targeted areas. However, some common lessons can be summarised.

Scientific knowledge has no administrative borders to restrain its spillover. Technologies, unless specially embedded or physically codified and thus with spillover effects that can be administered, have no border either. Thus, with very few exceptions, all advanced technologies eventually become available to anyone, no matter which country the customer comes from. What really matters about the availability of technologies is their price. That is the most important reason why technological catching up is an important part of economic growth, especially for developing countries.

For component technologies, which are usually embedded in the intermediate inputs along the supply chain, their prices determine the profitability of the downstream industries. For example, high profits in the high-tech parts and components of smartphones make the profit for smartphone manufacturers and assemblers quite marginal. Therefore, pursuing higher technologies and moving into the upper stream of the supply chain becomes critical for developing economies that have already accomplished the early stage of industrialisation to avoid the middle-income trap. In this regard, bringing up SMEs capable of supplying high-tech components in various industries seems to be a good indicator for policymakers to pursue as the outcome of their industrial technology policies.

The presence of vibrant SMEs in each industrial sector reduces the risks faced by each stream of efforts in technological catching up and innovations, as the risk of failure is relatively small in each case. Strong and well-specialised SMEs are also compatible with the age of robotics, AI, and perhaps Industry 4.0. These technologies will to a large extent minimise the need for manpower in future production and services in almost all industries. Economies of scale may assume a smaller importance compared to small-batch and customised supply in various industries. This is because there is still the possibility that specialisation will complement the automation of jobs brought

by robotics and AI along the value chain of certain industries. In these industries, SMEs can thus take advantage of robotics and AI to build competitiveness in highly specialised niche markets. Such a future landscape of industrialisation in ASEAN looks very likely if one believes that China may be able to quickly commoditise robotics and AI, as it did for solar photovoltaics and wind turbines. Therefore, identifying such niche markets and fostering the competitiveness of SMEs in the future scenario in ASEAN economies could be critical for industrial policies to be successful.

Many ASEAN economies have implemented either import substitution or export-led industrial policies. Some of them, such as Thailand, have successfully integrated themselves into the global value chain or production networks in certain industries, such as for automobiles, electronics, and electrical appliances. Local SMEs supplying parts and components to manufacturing conducted using the FDI of MNCs have developed well in Thailand and have managed to slowly catch up in terms of technologies and capabilities (Asian Development Bank, 2015). Such development represents a successful conventional path of technological catching up. While public policies should continuously pay attention and give support to this stream, emphasis should also be given to prepare for the coming revolution brought by robotics, AI, and perhaps Industry 4.0. This is because in applying these new technologies, besides importing the high-tech equipment and parts, local efforts will be needed to integrate the technologies into local business and energy systems, and innovative transformation and restructuring may be needed. Such complimentary engineering and innovation should be the kind of capability and capacity that ASEAN countries, which are typically adopters of new technologies, should focus on developing. The necessity of such developments is a critical lesson we learned from the first wave of ICT revolution in the 1990s to early 2000s. This will not only accelerate the penetration of new technologies but also significantly reduce the costs of adopting the technology and ensure high performance of these technologies in ASEAN economies.

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Innovation Policy in Indonesia

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4.1 | Introduction

Schumpeter (1947) defined innovation as simply the doing of new things or the doing of things that are already being done in a new way. To put it more concretely, innovation can take the form of improvements or upgrades in products, processes, technology, methods of production, management, organisational arrangements, or the extent of markets being served. The important role of innovation in achieving better economic performance is well-documented in the economic literature. Among other things, innovation is critical for developing countries, such as Indonesia, to avoid the middle-income trap and achieve much-needed industrial, productivity, and technological upgrading. Attaining sustainable, competitive, and solid economic growth requires accumulating not only more labour and capital but also new technology and innovation – the ‘inspiration’ as opposed to ‘perspiration’ approach to development. Hence, the important role of innovation cannot be overstated.

To better understand the Indonesian context for innovation, we first need to provide a brief historical account. Since the 1960s, Indonesia’s economy has undergone a significant transition from being dominated by agriculture (before 1970), to relying on oil revenues and import-substitution industries (from 1970 to the mid-1980s), to being led by labour-intensive and export-oriented industries (from the late 1980s), before moving gradually towards a services-led and knowledge-based economy. Foreign direct investment (FDI) was open at the end of 1960s, and then relatively closed during 1970s, before being opened up again during the massive trade and investment reforms of the 1980s. The reforms triggered a significant amount of technology diffusion from foreign firms that started to enter the country.

Evidence has shown that FDI played an important role in increasing productivity in Indonesia, and hence, economic performance, particularly during the boom from the mid-1980s to the early 1990s.

However, Indonesia's economic growth has been driven primarily by natural resources and trade rather than by science and innovation. In other words, Indonesia's growth owes more to the accumulation of labour and capital than to increases in productivity. This is demonstrated by the declining rate of total factor productivity growth since the 1990s to a level far below that of its regional peers. At the same time, constantly rising labour costs have further eroded competitiveness.

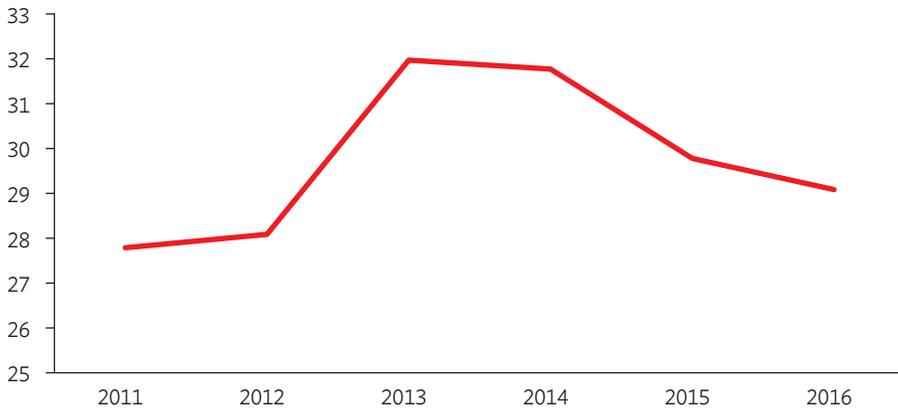
Innovation contributes inadequately to Indonesia's economic growth, and the country's innovation performance lags that of its regional peers. Only since the mid-2000s has the government started to give greater emphasis to innovation in the formulation of economic policies, and this is expected to continue in the future. Various development planning documents explicitly and indirectly mention efforts to improve innovation and the target of becoming a more competitive, technology-driven, and knowledge-based economy.¹

Section 4.2 discusses the indicators of innovation in Indonesia. Section 4.3 describes the institutional governance of innovation, innovation policies implemented in the past and lessons from them, and lessons from cases of innovation policies in past or ongoing projects. Section 4.4 explores considerations for the future national innovation system. Finally, Section 4.5 concludes and provides a summary of suggestions for future innovation policymaking.

4.2 | Current Situation and Indicators of Innovation in Indonesia

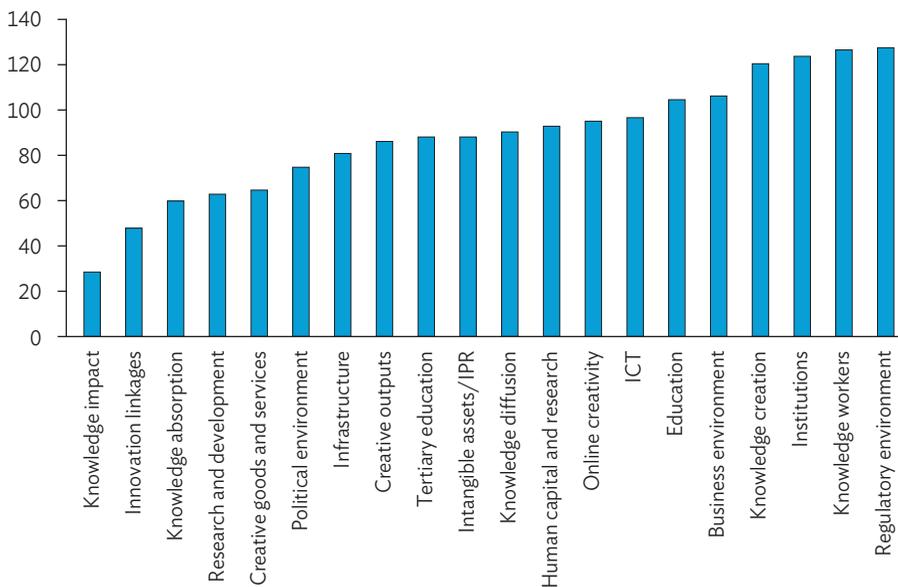
Several indicators testify to the poor performance and limited availability of innovation in the Indonesian economy relative to most of its regional peers. For example, Indonesia was ranked 88th out of 128 countries in the Global Innovation Index 2016, and sixth out of 10 countries in Southeast Asia. Its score (100 represents the maximum score) declined consistently from 32 in 2013 to 29 in 2016 (Figure 4.1).

¹ These include the National Long-Term Development Plan, the National Medium-Term Development Plan, the Masterplan for Acceleration and Expansion of Indonesia's Economic Development, and the Masterplan for National Industrial Development.

Figure 4.1: Total Global Innovation Index Score for Indonesia, 2011–2016

Source: Global Innovation Index by Cornell University, INSEAD, and WIPO.

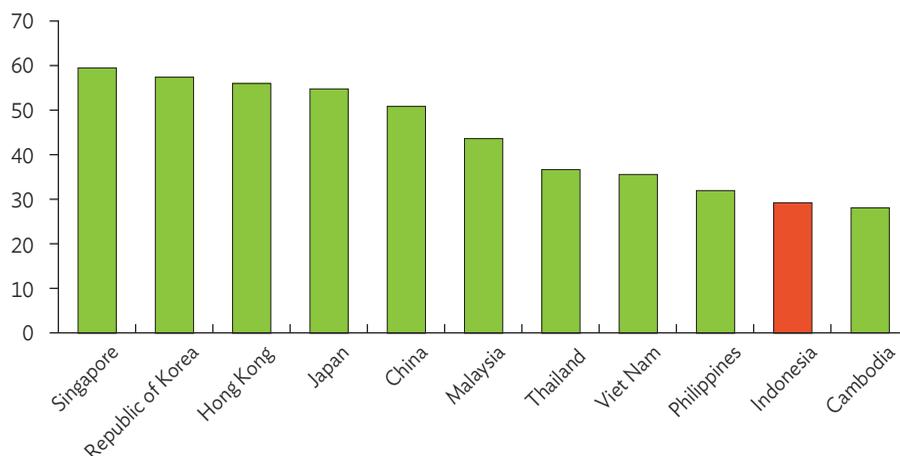
Further breakdown shows that institutional and regulatory bottlenecks and a lack of knowledge workers are major factors restricting innovation in Indonesia (Figure 4.2).

Figure 4.2: Global Innovation Index for Indonesia: Ranking of Selected Innovation Enablers (lower is better)

ICT = information and communication technology, IPR = intellectual property rights.

Source: Global Innovation Index by Cornell University, INSEAD, and WIPO.

Figure 4.3: Global Innovation Index 2016 Score for Selected Asian Countries (higher is better)

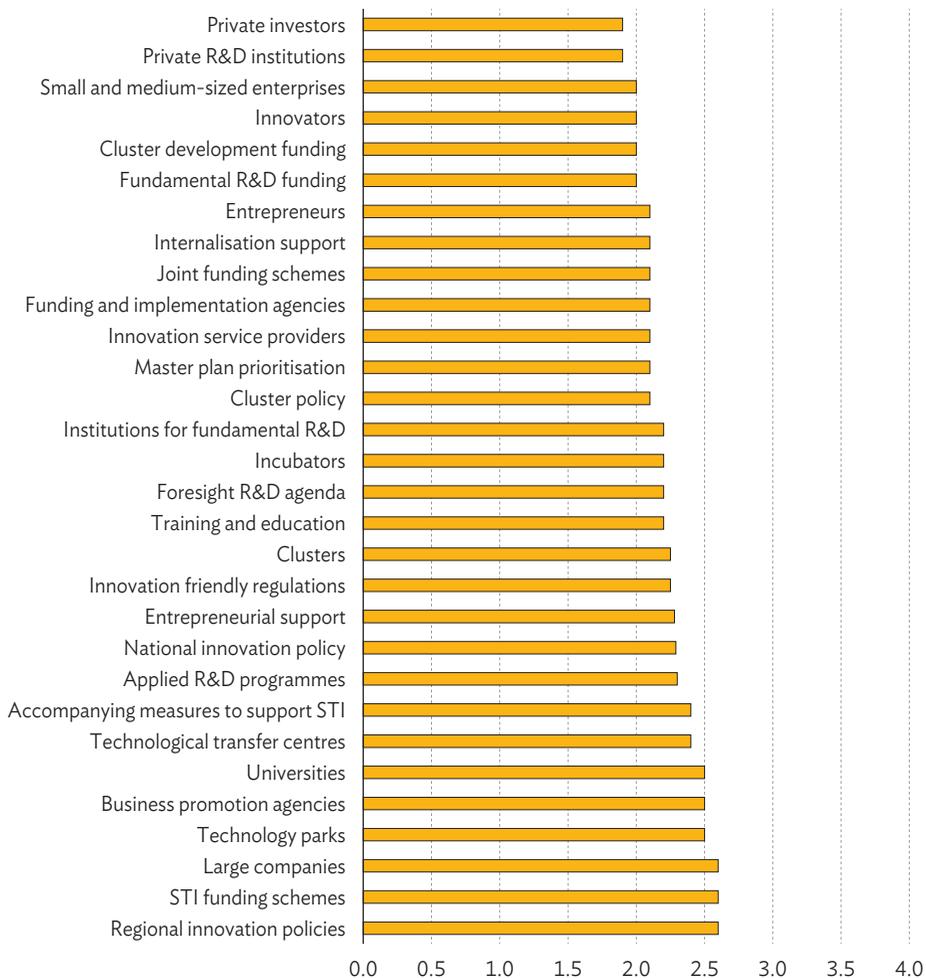


Source: Global Innovation Index by Cornell University, INSEAD, and WIPO.

A collaborative study by the Institute for Innovation and Technology and the Federal Ministry of Education and Research (2012) provides another interesting and detailed analysis, which is summarised in the Innovation Maturity Index (Figure 4.4). In general, Indonesia scored on par with the average of the lower middle-income, transition economies in various innovation indicators at the macro, meso, and micro levels. The subcategories of the index reveal that Indonesia was particularly weak in the area of private sector involvement in research and development (R&D) activities.

At the firm level, the lack of a significant shift toward high-tech industries involved in both exports and imports is shown in Figures 4.5 and 4.6. There has even been a shift away from high-tech exports in recent years. This might indicate, among other things, a lack of noticeable improvement in Indonesian firms' technological capability since 2000.

Indonesia's weak innovation performance corresponds with its extremely limited spending on R&D activities at both the macro and micro levels. Government spending on R&D barely reached 0.1% of gross domestic product in 2013 – far below the middle-income country average of 1.0% (Figure 4.7).

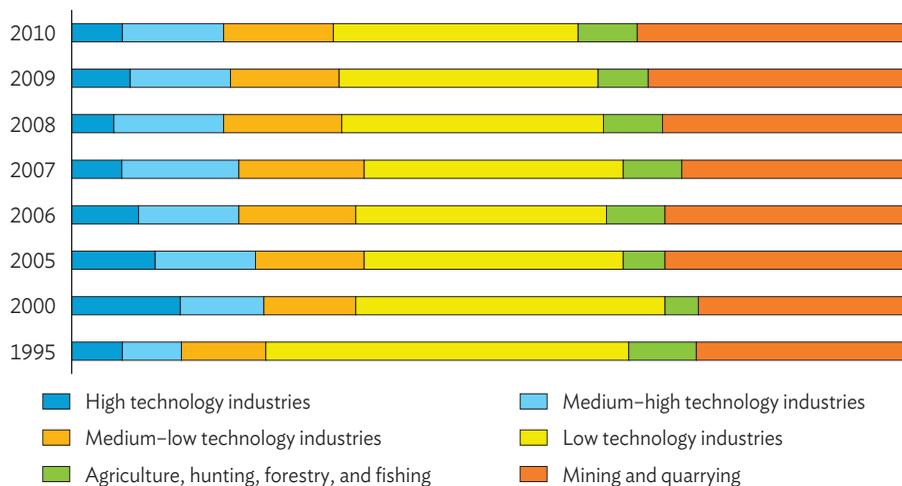
Figure 4.4: Innovation Maturity Index for Indonesia (higher is better)

R&D = research and development; STI = science, technology, and innovation.

Source: Institute for Innovation and Technology and the Federal Ministry of Education and Research (2012).

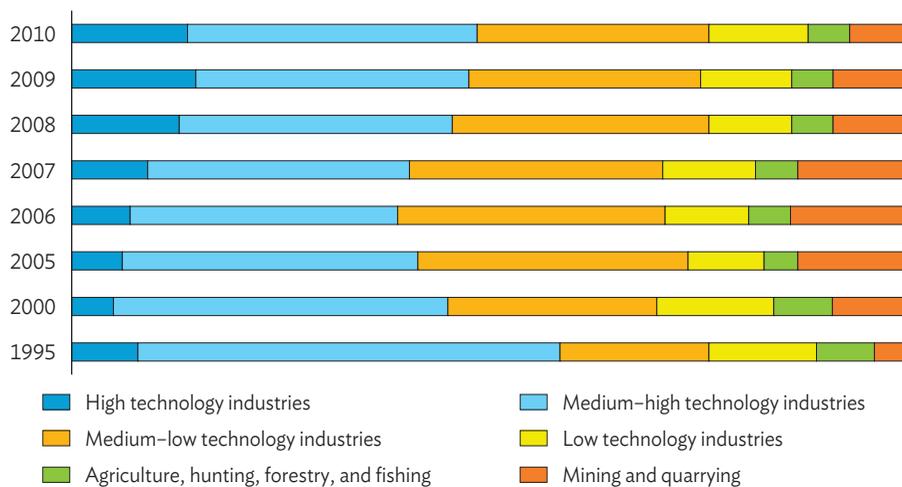
As shown by Aminullah (2015), R&D expenditure in Indonesia has predominantly been government-centric, with government agencies and public universities accounting for 80%. On the other hand, very little private R&D activity has been undertaken in the manufacturing sector, except in large companies, as most firms have a low level of innovation conscientiousness (Hill and Tandon, 2010). Besides, almost no prominent multinational enterprises (MNEs) are willing to set up R&D facilities in Indonesia; instead they favour more developed countries in the region, such as Singapore, Malaysia, Thailand, and Viet Nam.

Figure 4.5: Indonesia's Manufacturing Exports by Technology Intensity, 1995-2010



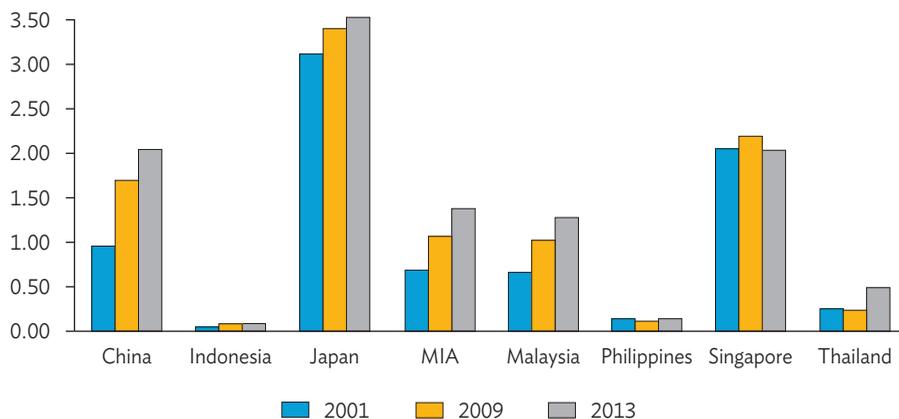
Source: OECD (2013, p. 155).

Figure 4.6: Indonesia's Manufacturing Imports by Technology Intensity, 1995-2010



Source: OECD (2013, p. 156).

Figure 4.7: Research and Development Expenditure for Selected Countries, 2001–2013 (% of gross domestic product)



MIA = middle-income average.

Source: World Bank, World Development Indicators.

Furthermore, Indonesia has also suffered from the poor performance in one of the most critical enablers of innovation in general, and diffusion in particular: intellectual property rights (IPR) protection. Table 4.1 shows that Indonesia's score generally lagged those of some of the more developed countries in the Asia-Pacific region and did not improve significantly during 2010–2015. Breaking this down further, patent protection and copyright protection remain the weakest factors in IPR protection (Table 4.1). Another problem is also displayed by the low score in the enforcement subsection. The lack of proper enforcement or sanctions for IPR violations is evident, particularly in piracy cases, which further discourages innovation and diffusion activities. IPR utilisation has increased in recent years (Table 4.2), although it is still dominated by non-residents (Figure 4.8).

The final story here is Indonesia's weak absorptive capacity for innovation, as evident by the poor performances in education and academic outputs and the lack of availability of knowledge and skilled workers. Figures 4.9 and 4.10 show that despite increases in recent years, Indonesia's academic outputs are still worryingly low compared with its peers, indicating limited innovation. Consistently, poor performance in the Programme for International Student Assessment (PISA), as indicated by the mean science scores, in which Indonesia ranked 62nd out of 72 countries in 2015, shows the limited base of human capital to produce and absorb knowledge. Tertiary education, an important driver of innovation and research, is financially limited (Figure 4.11).

Table 4.1: Intellectual Property Index for Selected Countries, 2010–2015

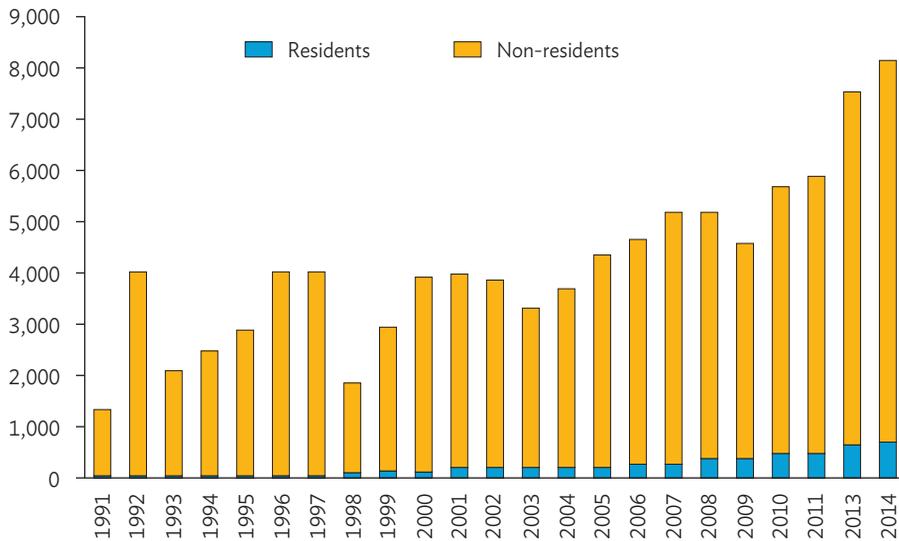
Country	2010	2011	2012	2013	2014	2015
New Zealand	8.3	8.2	8.2	8.4	8.3	8.2
Singapore	8.2	8.3	8.1	8.1	8.2	8.1
Japan	7.6	7.6	7.7	7.7	7.8	8.0
Canada	8.0	8.0	8.0	8.0	8.0	7.9
Australia	8.2	8.0	7.8	7.9	7.8	7.7
United States	7.9	7.5	7.5	7.6	7.7	7.6
Chile	6.4	6.7	6.7	6.8	6.8	6.6
Malaysia	6.1	6.1	6.5	6.5	6.5	6.6
Indonesia	4.1	5.0	4.8	4.9	5.0	4.9
Mexico	4.7	5.0	5.1	5.2	5.2	4.7
Peru	4.3	4.9	5.0	5.0	5.0	4.6
Viet Nam	4.5	4.9	4.7	4.7	4.8	4.5
Item	Indonesia	Malaysia	Singapore	Thailand	Viet Nam	
Rank	28	12	5	31	30	
Total score	8.61	14.62	25.38	7.10	7.84	
Patent-related rights and limitations	1.50	2.75	6.50	1.50	1.75	
Copyright-related rights and limitations	1.77	3.78	5.24	1.53	1.03	
Trademark-related rights and limitations	2.75	3.25	4.00	2.75	3.25	
Enforcement	1.34	2.43	4.64	1.07	1.31	
Membership and ratification of international treaties	1	1	3	0	0	

Source: 2015 Global Intellectual Property Center Index.

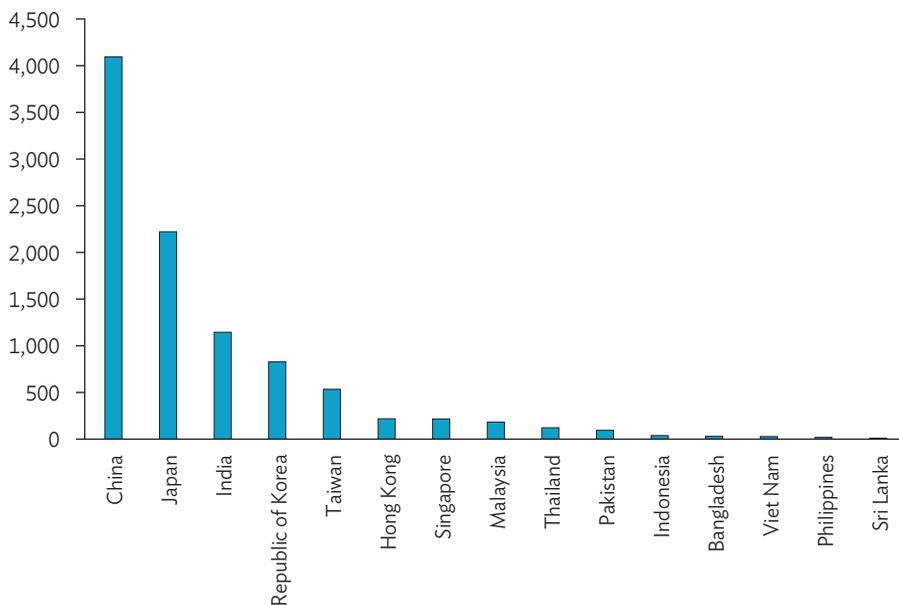
Table 4.2: Number of Intellectual Property Rights Registrations in Indonesia, 2010–2015

Year	Patent	Copyright	Trademark	Industrial Design	Total
2010	5,821	4,882	47,794	4,047	62,544
2011	6,123	5,541	53,196	4,196	69,056
2012	7,027	6,382	62,445	4,612	80,466
2013	7,800	6,190	62,813	4,258	81,061
2014	8,348	5,142	60,894	3,376	77,760
2015	8,874	5,467	61,787	2,770	78,898

Source: Directorate General of IPR, Ministry of Law and Human Rights.

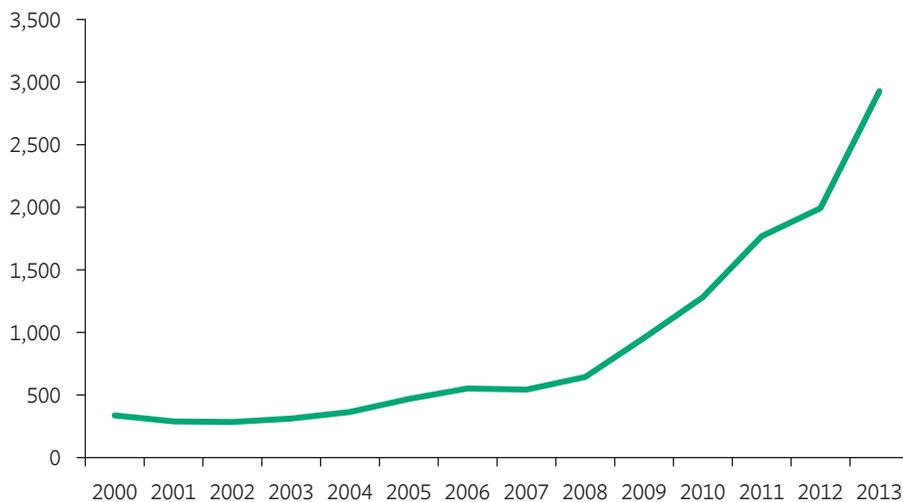
Figure 4.8: Number of Patent Applicants in Indonesia, 1991–2014

Source: World Bank.

Figure 4.9: Number of Scientific Publications in Selected Countries, 1996–2015 ('000)

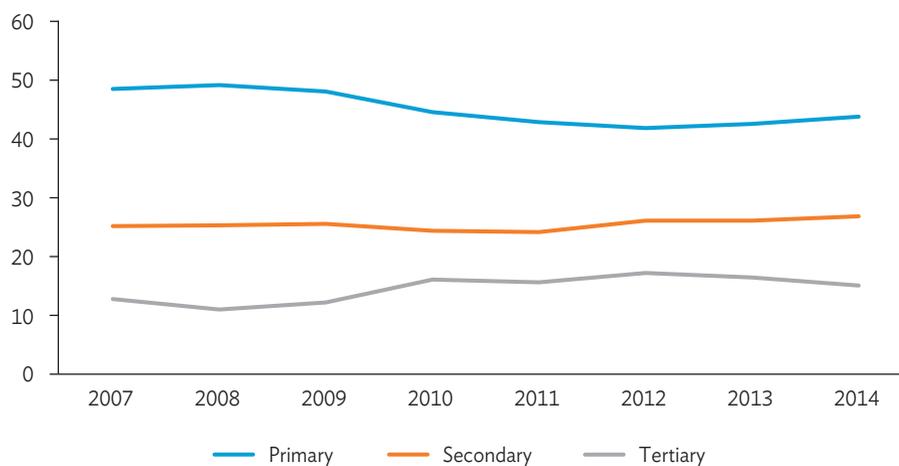
Source: SCImago Journal Rank.

Figure 4.10: Number of Scientific and Technical Journal Articles from Indonesia, 2000–2013



Source: World Bank.

Figure 4.11: Government Spending on Education by Category (% of total education spending)



Source: World Bank.

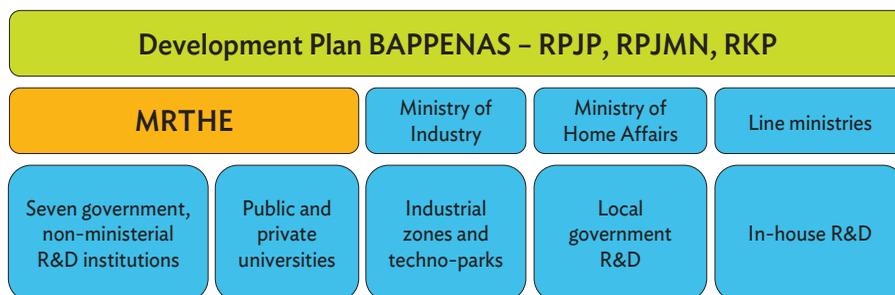
4.3 | Lessons from Past Innovation Policies in Indonesia

Indonesia is still in the relatively early stages of adopting a formal and fully integrated national innovation system. It also lacks a single-referenced, integrated, grand strategy underpinning all the innovation-related policies in the country, as policy action plans to promote more innovation in the economy are scattered across the different documents of various government agencies. Currently, there is no single high-level body with the responsibility to oversee and coordinate the various innovation policies and undertakings happening across the ministries. In 2010, the National Innovation Committee was set up to assume this function. Not long after its establishment, the committee submitted a proposal providing suggestions for the future national innovation system in Indonesia. However, the committee was dissolved amid efforts by the newly elected president to streamline bureaucracy, setting back efforts to harmonise innovation policies at the national level. The closest thing that Indonesia has to a coordinating institution for innovation is the Directorate General for Innovation Strengthening, under the supervision of the Ministry of Research, Technology and Higher Education. However, given the committee's position in the state hierarchical system, it lacks the necessary political authority to conduct inter-ministerial coordination.

There are plans to introduce a more formal and comprehensive innovation system. The development of the Sistem Inovasi Nasional (SINAS) (National Innovation System), based on the mandate from the Medium-term Development Plan, 2015–2019, is seen as the primary means for improving Indonesia's innovation capacity and science and technology (S&T) performance. In early 2017, SINAS was still in the development phase through various ministerial meetings. In the current absence of a formal innovation system, innovation governance in Indonesia can be understood by mapping the existing 'triple-helix' innovation actors – government, university, and industry – and the interactions among them.

In Indonesia, one of the primary roles of government related to innovation is formulating S&T development policy. This function has been assumed by the Ministry of Research and Technology and Higher Education (MRTHE). The government not only facilitates and creates a supportive environment for innovation but also actively drives, conducts, and, in some cases, even leads R&D activities. The government also decides on the priority sectors for R&D.

Figure 4.12: Institutional Setting for Research and Development in Indonesia



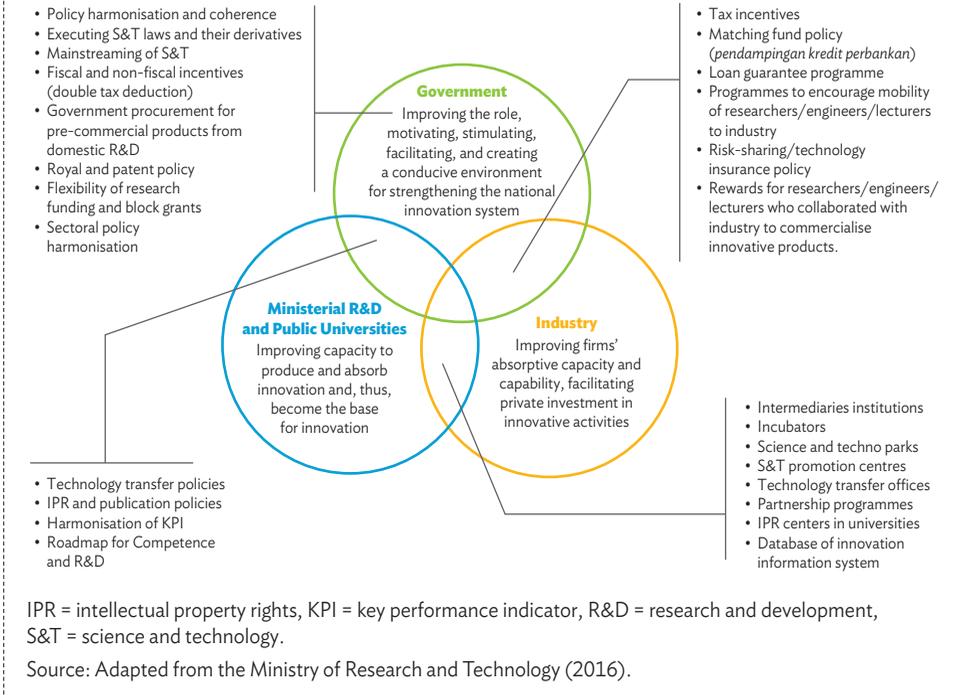
BAPPENAS = Ministry of National Development Planning, MRTHE = Ministry of Research, Technology, and Higher Education, R&D = research and development, RKP = Government Work Plan (1-year period), RPJMN = National Medium Term Development Plan (5-year period), RPJP = National Long Term Development Plan (25-year period).

Source: Authors' compilation.

Several public institutions conduct R&D activities with different scopes and intensities (Figure 4.12). The MRTHE is responsible for spearheading public R&D enterprises and has the authority to oversee seven non-ministerial government R&D institutions, including the Indonesian Institute of Sciences, a government think tank focusing on science development and basic research; the Agency for the Assessment and Application of Technology, which focuses on technology application and diffusion; and more than 30 applied research institutions. Public universities' R&D activities, which take up a significant portion of public R&D spending, are coordinated by the Directorate General of Higher Education, which was recently merged to the MRTHE. Every year, the central government allocates and distributes funds for R&D to ministries, non-ministerial government institutions, and public universities by direct and usually non-competitive funding, such as research grants. Other R&D capacities, albeit relatively limited, exist in local governments and technical ministries.

In the past, innovation policies related to the diffusion of knowledge were almost non-existent in Indonesia, except indirectly through FDI-facilitating reforms in the mid-1980s, which brought in knowledge diffusion from FDI firms. It was only in the mid-1990s that the government began to launch formal innovation policies that were specifically intended to facilitate technological diffusion. Through these policies, the government attempted to create and strengthen collaboration with universities and firms, as shown in Figure 4.13.

Figure 4.13: Basic Framework for the Design of Indonesia's National Innovation System



The initiatives to stimulate R&D and technological diffusion usually fall into the following three categories:

- i. **Funding and incentives for research and development.** This is the earliest type of innovation policy in Indonesia. It consists of various measures to facilitate more R&D in both universities and firms, and includes direct, non-competitive R&D funding to public universities; competitive research grants; tax credits; tax deductions for R&D; a technology insurance scheme; the establishment of government R&D institutions (*balitbang*); R&D subsidies for firms; and R&D partnerships between the government, universities, and industry.
- ii. **Platforms to trigger, facilitate, and diffuse innovation.** Some platforms were established long ago, but most have been set up in the last 5–10 years. Undertakings such as the Business Innovation Center, technology transfer offices, the Techno Park, science parks, industrial clusters (*kawasan industri*), special economic zones, entrepreneurship centres and incubators, testing and certification centres, and various ad hoc collaborations with foreign companies to set up innovation or training centres fall into this classification.

- iii. **Building capacity and improving absorptive capacity.** This includes most of the government's in-house training programmes, exchange programmes for local engineers under government-to-government arrangements, (e.g. with the Government of Germany), research training in and by public universities, scholarship programmes for Indonesian students to study abroad, and general education and S&T development policies.

The innovation initiatives or programmes undertaken by the government vary in their degree of effectiveness in promoting knowledge diffusion. Nevertheless, there are three general patterns from which lessons can be drawn.

First, most of the initiatives are top-down, yet lack coordination. Most have been too reliant on the initiatives and resources of the public sector, particularly central government. This corresponds with the fact that most of the R&D budget and activities have been allocated to and performed by public institutions, such as universities or technical ministries. The development of innovation and S&T infrastructure has been carried out almost exclusively with public funding.

Despite being highly government-centric, many such initiatives are poorly coordinated. This is not surprising, given the absence of a formal and integrated national innovation system and grand strategy until very recently. Most of the innovation platforms offered by the government in the past were sporadic, short-lived, and likely to be discontinued in the event of a crisis or change of administration. Training programmes, the awarding of grants, exchanges, and partnership programmes took place infrequently and were detached from the government's broader policy framework. A lack of coherence between innovation policies and policies on innovation enablers (e.g. trade protection, investment restrictions, performance requirements, and rigid labour regulation) also restrained diffusion activities. Poor policy coordination reflects the dispersed nature of institutional governance of innovation in Indonesia. The execution of innovation policies is scattered across various ministries and agencies, and there is no single national innovation coordination agency to harmonise all such initiatives. In the absence of a national innovation agency, the continuous monitoring and evaluation of innovation initiatives has been almost non-existent, further undermining the effectiveness of such policies.

The lack of policy and institutional coordination results in limited links among the triple-helix actors of innovation. Interactions among government, industry, and university are generally weak. Although some innovation policies have aimed to bridge

the gap and create links between actors (e.g. collaborative programmes in the form of competitive grants), most have not had significant success. Given this predicament and the uncertainty it creates, it is not surprising that most initiatives have not been very successful in attracting prospective suitors. Private participation in R&D activities generated as a direct result of government innovation programmes has been limited and, thus, often considered not very effective in promoting sufficient knowledge diffusion.

Second, funding and incentives for R&D are the most prominent methods used by the government to promote innovation. Most innovation policies in Indonesia originated from the Ministry of Research and Technology and the Ministry of Higher Education, which are now merged. The vast majority of innovation policies are aimed at S&T development, especially by facilitating R&D activities in universities and firms. However, the R&D facilitation offered by the government is primarily in the form of monetary incentives, such as grants, R&D funding, tax relief, or subsidies. R&D funding is often problematic because the amounts are too small, and most incentives are for a single year rather than multiple years. This creates uncertainty because R&D projects pose a greater risk of being commercially unsuccessful. The Insurance for Technology Development (ASTEKNO) programme was meant to answer this problem, but it did not receive enough interest from firms. Funding was primarily non-competitive.

Implementation problems are also common. Some firms and universities found that administrative procedures to obtain some of the incentives were burdensome with difficult requirements and lengthy processes. Those that received funds sometimes experienced disbursement delays. Furthermore, simply offering funds has not been effective in helping local firms perform R&D activities. For example, Hidayat et al. (2013) suggest that in addition to funds, industry expects assistance in providing information technology and guidance for technology users, joint R&D activities, training for technical personnel, and managerial training, among other things. Although some programmes have addressed such concerns to a degree, there have not been enough of them, and still some are lacking in implementation or socialisation. As a result, most firms have been reluctant to join these programmes as they prefer to import the technology directly rather than trust local R&D capability or develop the technology themselves. For economic and practical reasons, they have not responded well to the incentives offered. Most of the R&D collaboration projects between government, universities, and firms are not fruitful due to difficulty in achieving a common R&D objective, and sometimes even vulnerability to rent-seeking behaviour.

Third, for various reasons, the programmes are not effective. For all their good intentions, many government projects or policies, which in theory should be useful instruments to facilitate innovation, are not effective in promoting diffusion activities and even struggle to remain in operation. Some of these projects are very young (five years old or less), so it may be too early to judge their success or failure. However, although in theory such platforms should have brought innovation, many programmes have stagnated. Among the primary reasons for their ineffectiveness in stimulating innovation and diffusion so far is the severe lack of one or more of the following factors: (i) most importantly, a clear strategy for moving forward; (ii) enough technical human resources for operation, management, and maintenance; (iii) a sustainable financial plan; and (iv) sufficient participation from the segment of the enterprises initially targeted, especially the private sector.

In some cases, the government lacks ideas on how to bring the innovation actors and activities into the established platforms or infrastructure. The lack of progress in special economic zone projects – a recent industrial clustering policy in Indonesia – is a prominent example. The government has had enormous difficulty in even attracting firms to locate in such clusters, let alone induce agglomeration or diffusion. Other public projects, such as technology or science parks or technology transfer offices, have also suffered from similar problems.

4.3.1 Examples of past innovation initiatives or interventions

Especially since the massive economic reforms carried out in the mid-1980s, Indonesia has embarked on some specific policies and interventions to infuse the economy with more innovation. Some have been successful, and others have not. This section briefly describes examples of such initiatives and analyses the reasons behind their success or failure.

The automotive and component industry. Indonesia's manufacturing sector has plenty of experience of receiving knowledge diffusion through FDI arrangements or joint ventures with MNEs closer to the technological frontier. Two such cases can be found in the automotive industry. From the 1980s, Indonesia developed its automotive assembly industry with the aid of FDI from Japanese auto manufacturers acting as principals.

Pane (2005), as quoted in Aminullah and Adnan (2011), describes the example of innovation by Suzuki. In 1976, PT Indomobil, the Indonesian subsidiary of Suzuki Motors, proposed a product innovation to its principal in Japan: to assemble

a new pickup car (later known as the Suzuki ST20) by installing a Japanese motorcycle engine into the assembled body. With its unique characteristics, this car was designed to provide the local Sulawesi market with affordable transportation for clove farmers in mountainous terrain. The innovation became a marketing success. In the years that followed, Suzuki carried out more product innovation using a similar sequence (propose-approve-diffuse-produce) involving the Japanese principal. They went on to upgrade the technological capabilities of the subsidiary to be able to produce the engine for the ST100 (improving upon the ST80 that previously existed in Japan), the chassis, and other components. Innovation in Suzuki happened in the form of product design and engineering by putting Japanese engines in different types of bodies modified to suit the Indonesian market.

Interaction with FDI firms not only stimulates product, process, and managerial innovation (as is well-documented in the literature) but also marketing to create products able to serve a new market segment that previously either did not exist or was unexploited. This was the practice of automotive components producers, such as ASPIRA, a local brand of PT Astra International, an MNE conglomerate whose business line is auto components and spare parts for cars and motorcycles. ASPIRA provides a wide range of spare parts. With the Asian financial crisis in 1997 and the subsequent exchange rate devaluation, importing genuine, original equipment manufacturer automotive spare parts became far more expensive. Around the same time, the far cheaper imports of low-quality Chinese components flooded the Indonesian market. However, innovation by ASPIRA provided the Indonesian market with a third alternative. Using the existing pool of knowledge in terms of technology, management, and production methods diffused and accumulated from a long period of engagement with Japanese automotive firms, ASPIRA managed to produce high-quality, multi-platform (installable across various vehicle brands) spare parts at more affordable prices. This innovation has served the domestic market very well.

Such examples show how frequent and profound interactions with advanced foreign firms possessing sufficient innovation capital, enabled by FDI and joint venture arrangements, have proved an excellent way for technologically underdeveloped Indonesian firms to absorb innovation and gradually upgrade their technological capabilities.

Aircraft industry promotion. Since the late 1970s, the Government of Indonesia, led by BJ Habibie, then the State Minister for Research and Technology, put forward plans to develop industries, including the high-tech aircraft industry. The plans covered design, manufacture, and assembly. This endeavour was primarily led by Industri Pesawat

Terbang Nusantara, a heavily subsidised and protected state-owned enterprise. Among its major products was the CN-235 aircraft. The essential objective of the programme was to prop up Indonesia to enable it to be more reliant on technologically sophisticated industries requiring substantial innovation and, thus, to compete and catch up with firms from more developed countries. Unfortunately, the programme was not successful as the aircraft were costly to produce and, ultimately, could not be marketed successfully. Given its massive financial cost, which greatly exceeded its benefits, the endeavour collapsed after the crisis, triggering massive layoffs.

McKendrick (1992) offers an insightful explanation of the main reason behind the project's failure. Despite possessing a sufficient pool of S&T resources and generally able engineers to enable the project to survive, the company lacked managerial skills. This subtle, yet impactful, managerial inability to manage information exchange and the efficient assimilation and adaptation of the transferred technology, as well as insufficient marketing know-how to commercialise the sophisticated product, proved to be highly detrimental.

Two important lessons can be drawn from this undertaking. First, the diffusion of knowledge should not focus merely on technology transfer but should also consider equally important managerial know-how, which is probably harder to attain independently. Upgrading the innovation capabilities of firms requires managerial skills as much as properly incentivised scientific and technical ones. FDI could play a role in achieving this balance. Second, although seemingly more a lesson for industrial policy, this experience also demonstrates that making the leap into overly complex and technologically demanding innovation projects, enterprises, or policies will not necessarily bring about the desired innovation and diffusion. Rather, in the Indonesian case, innovation should be gradual, starting with minor or incremental processes or product adaptation in labour-intensive industries, and should consist of importing and learning technologies that may even be considered outdated or lower-tier in developed countries, while slowly building up local firms' major change capabilities.

4.3.2 Tax incentives for research and development activities

In the past, the government has often attempted to trigger and facilitate innovation and the diffusion of knowledge through R&D activities. Incentive schemes have been offered to firms and universities to conduct R&D activities. Unfortunately, most of these programmes received scant attention and have generally been considered unsuccessful at promoting innovative activities in firms.

One such case is the launch of tax deduction incentives. In 2010, for example, as stipulated in Government Regulation 93/2010, the government offered a 5% tax deduction for firms making R&D expenditures or undertaking other projects considered to generate positive externalities, such as developing sports and education facilities. However, a 2013 study by the World Bank explained that some firms found it very difficult to receive the tax deduction due to the complicated and lengthy administrative tax procedures. No significant improvements took place, even though a clarifying Minister of Finance decree (PMK 76/2011) on this matter was issued a year later. Some firms chose to get the same amount of tax deductions by spending more on straightforward sports facilities rather than riskier R&D undertakings.

Two lessons can be learned from this programme. First, implementation is as important as launching an initiative. Thus, reducing unnecessary administrative burden is the key to any successful innovation programme, along with continual monitoring and evaluation. This is an area where most innovation programmes could have done better. Second, and perhaps more importantly, the experience shows that to gain meaningful reception from firms, any innovation programme must offer substantially larger incentives and benefits, not just small monetary ones, to overcome firms' perennially adverse attitudes toward R&D activities. However, past initiatives show that stand-alone R&D incentives have generally not been enough to spur innovation and diffusion. Rather, the Indonesian case suggests that exposure to competition in the market – especially the global market – is arguably a greater incentive for innovation and diffusion. Facilitation and competition should always go together.

4.3.3 Local innovation initiatives in Bandung

Innovation needs to be facilitated at both the national and local levels. There are several Indonesian cities in which the local governments have established a conducive ecosystem for stimulating innovation and initiated effective programmes to facilitate extensive knowledge flows among innovation actors.² One of the few successful examples of such local-level innovation enterprises is Bandung, the capital city of West Java Province. Bandung possesses the most mature quadruple-helix collaboration (government–industry–university–community), and it is commonly referred to as one of the smartest, most creative, and innovation-led cities in Indonesia.

² Jakarta, Pekalongan, and Surakarta are three other interesting cases of successful local-level innovation initiatives in Indonesia.

Innovation initiatives in Bandung include the Bandung Creative Hub, start-up incubators, Bandung Creative City Forum, the Creative Tourism Village, Bandung Digital Valley, the Little Bandung Initiative, the Bandung Creative Center, Bandung Technopark, the New Entrepreneurs Program, Bandung Technopolis, and many more. Such initiatives, most of which are led by young, educated people, have been successful in producing innovation and developing entrepreneurship projects with the local community.

At least four factors explain the success of the local innovation ecosystem in Bandung. First, the critical role of strong and tangible political support and commitment by a local leader with high innovation literacy and awareness cannot be overstressed. These innovation initiatives are not stand-alone but are embedded within the urban planning. Innovation is at the forefront of the development vision of the city. Second, Bandung has sufficient innovation resources available nearby, especially universities, such as Bandung Institute of Technology, Telkom Institute of Technology, and Padjadjaran University. However, the local government has gone beyond mere funding and has expertly crafted and properly maintained the implementation of platforms that link innovation actors and resources. Third, many of these platforms have strong private participation. For example, the Bandung city government regularly invited MNEs (e.g. Intel for the incubator programmes) with advanced technology to collaborate with local universities or communities, creating important channels for knowledge diffusion at the local level. Fourth, local community and characteristics are not ignored. As a result, citizens are empowered to produce innovation, and real diffusion takes place. For example, innovation gave rise to the development of the Sundanese handicraft industry through the addition of technology developed by engineering students from a Bandung university. This resulted in a unique and innovative product with embedded local culture.

Many other Indonesian cities can emulate Bandung's innovation governance, although emulation may not be possible in every region due to their differing characteristics and endowments. Nevertheless, the success story of Bandung can be seen as a microcosm of what a successful triple- or quadruple-helix collaboration should look like at the national level. Furthermore, this case also demonstrates that local and micro-level innovation platforms are generally more manageable and, thus, a reliable way of producing substantial knowledge diffusion.

4.4 | Toward a More Conducive Environment for Innovation

Given the importance of innovation for achieving a competitive and sustainable economy, Indonesia needs to immediately address some of the problems and bottlenecks preventing sufficient innovation and knowledge diffusion from taking place. However, the solution is far more comprehensive than simply allocating more budget for R&D activities. The following four factors must be considered and calibrated to constitute an effective national innovation system in the future.

4.4.1 The role of foreign direct investment and global value chain participation for inducing greater innovation

Considering Indonesia's shallow innovation and technological base, it is not surprising that at this stage of development, FDI and joint venture arrangements with MNEs have been the most important channel for innovation, particularly knowledge or technological diffusion, to Indonesian firms. This is true at both the aggregate and micro levels.

Several studies have shown that FDI firms in general achieve higher productivity, export performance, and value added per worker, which likely stem from process innovation, higher technological attainment, and more complex production methods. Plenty of firm-level cases, like the Suzuki example depicted earlier, have demonstrated how frequent interaction with MNEs under such arrangements can successfully produce innovation (in terms of either product, process, organisational, management, or marketing innovation) and, to some extent, technological upgrading among domestic firms. Various forms of technical assistance and technology transfer from foreign principals have resulted in at least minor improvements in the change capabilities of local firms in several sectors (Thee and Pangestu, 1998). Therefore, the government should consider attracting more private FDI inflows, along with the innovation they bring, rather than placing all the responsibility for innovation on public institutions.

Indonesia still requires more FDI to spur innovation because FDI firms possess the necessary innovation capital (primarily in technology and management processes) that is closer to the frontier. By engaging in FDI or joint ventures, local firms can access not only the principals' innovation capital but also their other capital indirectly, leading to an urge for more innovation. This capital includes, among other things, marketing links, global market access, and global competition.

For now, technological progress should involve the adoption or mere adaptation of technologies (even outdated ones) and not the creation of new technology. FDI provides an excellent channel for this purpose. FDI can promote diffusion through direct technology transfer, technical licensing, R&D facilities, and even the movement of workers from MNEs to other local firms. It creates imitation and demonstration effects and, when used properly, can be an important basis for building up domestic technological capabilities.

Knowledge diffusion occurs not just in the form of technology adoption but also equally importantly, yet more difficult to achieve, in the form of organisational and managerial capabilities, as was demonstrated by the failure of the aircraft industry. At this point, FDI can provide the most powerful and effective impetus and know-how for innovation. This is an important point to consider since most of the current innovation programmes tend to not have any real engagement with foreign firms or markets. Therefore, in the short run, the most effective policy to generate diffusion of knowledge to the economy should primarily involve facilitating the entry of more FDI into Indonesia by having a generally open and friendly regime towards it.

The government can achieve this objective by addressing problems related to the general investment climate, such as ensuring regulatory certainty and coherence and pro-competition policies, and enhancing the quality of hard (logistics and physical connectivity) and soft (information and communication technology and bureaucracy) infrastructure. Any investment policy that discourages FDI will indirectly restrain potential innovation diffusion, so it must be seriously and carefully reconsidered. Various local content regulations, performance requirements, and forms of investment restriction or stipulations in the negative investment list fall into this category. Even trade policy on intermediate goods imports matters. In addition, firms that both possess significant diffusion potential and are willing to transfer their technology should be further facilitated.

FDI is simply not enough to guarantee that a satisfactory amount of innovation and knowledge diffusion will happen, however, and two important caveats have been raised. First, for the Indonesian case, a study by Qoyum (2017) showed that export orientation is a more significant factor for inducing product innovation than mere foreign ownership. Although innovation can and has existed in FDI catering to the domestic market (as in the automotive industry case described), more export-oriented FDI – particularly FDI that participates in global value chains (GVCs) – can provide greater impetus and the necessary context for even more innovation and diffusion to take place.

There are two main reasons why export- or GVC-oriented FDI tends to produce more innovation than domestic-oriented FDI. First, developed countries' higher and more demanding technical standards and requirements usually call for more complex technology and production methods. Therefore, foreign principals or lead firms have more incentive to ensure their subsidiaries can produce in an efficient and competitive manner. Diffusion of knowledge in the form of either technology, technical assistance, or managerial know-how usually follows. Second, exposure to the global market creates more intense competition from similarly positioned firms in other countries, which in turn makes innovation indispensable for firms. This also gives foreign principals more incentive to transfer the necessary technology to their facilities in Indonesia, for fear of losing their competitive edge over rivals in nearby countries.

In the last two decades, the nature of production has been shifting closer to the concept of GVCs, which are modular, happen across numerous countries, and rely on transferable codified knowledge. Indonesia no longer needs to have the resources and technological diversity to produce an entire product domestically to improve its export performance. On the contrary, the country can focus on some parts of the goods or stages of production within a few industries in which it has comparative advantage and gradually learn through interaction with FDI firms to upgrade its technological and innovation capabilities. GVC production essentially relieves developing countries of the need to master too many industries or to jump directly into high-tech industries, as Indonesia has in the past, in order to produce meaningful innovation that is well-rewarded by the market. Improving GVC participation caters more effectively to the global market and, thus, improves competitiveness and innovation. Indonesia's automotive industry is a perfect case of this. In the medium term, the challenge will be how to upgrade styles of GVC governance from primarily captive and hierarchical styles, which allow for limited innovation, to styles that allow for more innovation. Examples include market and modular arrangements, which require a higher degree of codification and supplier competence. Other labour-intensive industries, such as textiles, garments, and electronics, which are naturally GVC-oriented, need to be facilitated to stimulate more innovation and technological upgrading.

The second caveat is that Indonesia should not necessarily remain forever reliant on FDI to conduct innovation. In the long run, Indonesia also needs to improve its technological attainment and capabilities to perform major product change. Therefore, alongside measures to attract FDI, the government must also consider preparing attractive incentives to ensure sufficient technology transfer takes place. Currently, no regulatory framework on, or explicit incentives for, technology transfer activities exists.

The government should re-evaluate and revitalise the strategies of the existing Technology Transfer Office. But any future regulation concerning technology transfer should strike the right balance so as not to deter firms from entering in the first place. As important as these measures are, it should be acknowledged that the most powerful incentive government can offer to attract FDI firms to enter and perform diffusion activities is to address innovation supply-side issues, as will be elaborated in the following subsection.

4.4.2 The role of improved key innovation enablers and infrastructure

To effectively promote knowledge diffusion, the government should (i) avoid micromanaging innovation policies, (ii) abandon an interventionist and winner-picking approach to industrial promotion, and (iii) cease to be the main agent of innovation undertaking the bulk of innovation or R&D activities. Rather, the government should restrict its role to that of a facilitator of innovation and create a necessary environment for the private sector to thrive. One of the main ways of doing this is by significantly enhancing the quantity and quality of the following four types of innovation enablers: absorptive capacity, S&T infrastructure, IPR, and the regulatory climate. Attracting reputable MNEs to invest in R&D facilities in Indonesia, which is a huge channel for diffusion, will be almost impossible without first addressing these problems.

Absorptive capacity. The diffusion of foreign knowledge can only effectively occur if there is sufficient domestic absorptive capacity. Among other things, this refers to the basic skills and knowledge needed by the domestic labour force to understand and improve upon imported knowledge. Given the current lack of absorptive capacity, improving it should rank high on the government's list of priorities.

To this end, substantial investment in human capital is needed, particularly in higher education and in the engineering sector. Universities' basic research capabilities must be enhanced. Given the more rapid pace of technological change, especially with the development of Industry 4.0,³ academic training in universities must be agile and flexible enough to quickly adapt to the new technological trends.

³ Industry 4.0, also known as the fourth industrial revolution, is a recent development in the industrialisation process, which will increasingly involve smart factories with more advanced technology. Among other things, this trend is categorised by the more ubiquitous use of automation, big data, artificial intelligence, and Internet of Things (IoT) in the industrial process.

Providers of basic technical labour, such as vocational schools (which ironically record the highest share of unemployment), need to be significantly improved. The government must ensure that basic scientific, language, and computer skill attainment is achieved, and the vocational school curriculum should be aligned with modern industrial needs. Finally, a national certification system must be created for specific sets of industrial occupations or technical skills to provide a ready pool of skilled workers for foreign firms when they set up their operations in Indonesia. This eventually allows for easier skills-matching and smoother knowledge diffusion to take place.

Science and technology infrastructure. Enhancing the availability and performance of S&T infrastructure is also crucial to facilitate innovation. The government needs to build more public laboratories that are open for use by private entities, as well as technology support services, including metrology, standards, testing, and quality assurance (MSTQ) facilities and various technology information services. According to Pietrobelli and Rabellotti (2010), MSTQ facilities, in particular, play an essential role in upgrading a country's ability to participate in the market and modular types of GVC, which require higher supplier competence and, thus, require more innovation and promote knowledge diffusion. Unfortunately, in Indonesia, MSTQ facilities are severely lacking in quantity and quality. This has created inefficiencies in the national standardisation process, for example.

The government, however, cannot and should not develop all S&T infrastructure using its own resources. Inviting the private sector to participate in building public innovation facilities, which eventually will be used by private sector as well, is key. To facilitate this, an attractive and effective public-private partnership mechanism is needed.

Existing S&T parks also need greater support and facilitation, chiefly in the form of a clearer and more effective long-term strategy, which is largely missing, and to a lesser extent, financial and operational support for the management and maintenance of the parks.

Intellectual property rights. Stronger IPRs in developing economies will bring about long-term growth and efficiency benefits as they attract additional FDI and induce further innovation and technology spillovers (Maskus, 1997). Consequently, improving IPR protection and enforcement is probably the most crucial factor for ensuring sufficient technical licensing, technology transfer, and other diffusion activities take place. In Indonesia, few FDI firms are willing to transfer their technology for fear that

it might be used inappropriately or spill over to competitors, given the currently weak IPR regime. Solving IPR protection issues, therefore, remains the key to stimulating more knowledge diffusion into the economy. Although regulatory framework on IPR in Indonesia exists and is frequently updated, the government needs to focus on the implementation side of the IPR regime, ensuring that punishments for IPR violations are strictly enforced according to the law.

Favourable regulatory climate for innovation and diffusion. As a regulation-producing agency, the government should remove any regulatory bottlenecks that impede innovation and diffusion activities, including regulations that do not seem to be directly related to innovation policy. One prominent example is the regulation on the movement of labour and experts. As a developing country with a limited technological base, successful technology diffusion happens not just by importing capital goods but also – and perhaps more importantly – through the transfer of skills from technical experts by foreign firms or suppliers who come to train domestic workers or engineers in the operation of newly installed technology or machinery. Some manufacturing firms complain about regulatory burdens, including lengthy procedures and the time needed to bring in foreign technical experts. Sometimes, a two-day visit by foreign experts requires weeks or months of administrative processes. Therefore, ensuring quicker and easier procedures in the labour regulations, and, hence, freer movement of labour and technical experts, is crucial for Indonesia to facilitate the diffusion of knowledge.

4.4.3 The role of a formal, integrated, well-functioning innovation system

In the medium to long run, sustainable innovation, and particularly diffusion activities, will happen effectively only if the country has a formal, integrated, and well-functioning national innovation system. Therefore, the development of SINAS is a step in the right direction and should be continued. SINAS needs to follow best practices from the innovation systems of countries at a similar development stage and with comparable characteristics. However, at this point, the aim should not be to build a full-fledged innovation system of the type found in advanced countries but to gradually advance the development process of the currently embryonic national innovation system.

The government should consider assigning a specific institution or task force with a strong political mandate to oversee the national innovation system, coordinate the various innovation policies and activities across ministries, and align them with the National Medium-term Development Plan. It is advisable to establish a new national

innovation body along the lines of the now dissolved National Innovation Committee. The system's effectiveness, however, depends to a large extent on the coherence of the innovation policy with investment, trade, S&T, and labour policies.

There are several issues to be considered, for which a good balance must be calibrated. The first is the triple-helix collaboration, especially the university–industry link. Solving the two following perennial problems should remain the highest priority. First is the skill mismatch involving the incompatibility of the labour force provided by local universities with industry's needs. Second is the research mismatch, which currently is more supply driven and based on university expertise rather than being demand driven and based on industry needs. Bridging these gaps requires frequent and sustained communication between the representatives of firms and academics, in which business associations can play an important role.

Second, policies to enhance the availability of and access to innovation finance must be formulated. A system should be devised to overcome the natural risk aversion of the banking sector towards innovation activities that involve plenty of risk. The government needs to creatively facilitate and mobilise, or artificially manipulate, the banking sector's incentive structures to encourage it to participate in funding firms' R&D activities. Venture capitalists need to be facilitated.

Third, industrial clustering is an important medium for horizontal and vertical diffusion and, therefore, needs to be facilitated. A more effective strategy, implementation, and incentives to attract firms – and, of course, physical infrastructure – are essential if industrial clusters are to avoid the fate of the various special economic zones, which have not attracted the interest of firms and have generally been deemed unsuccessful at stimulating innovation.

Finally, only when such a system exists will a larger R&D budget be more effective in producing innovation. The government should aim to gradually increase the budget for R&D activities, and it should complement this with a well-planned strategy and well-conceived incentives for firms.

The system should not stand alone, however, and thus cannot be relied on as the sole instrument to produce innovation. In the Indonesian context, attracting more incoming FDI is still the policy that is most likely to bring about the necessary innovation, technology, and knowledge diffusion into the country in the short run.

4.4.4 The role of local innovation initiatives

Local governments must stimulate and facilitate more city-level initiatives, similar to the ongoing efforts in Bandung, Jakarta, and Solo. A powerful national innovation system should consist of ‘innovation pockets’ in several regions with various programmes and initiatives by local government that take full advantage of the availability of innovation sources within and around the city. Local initiatives are likely to be a more sustainable and reliable way of providing quick wins and the necessary momentum for producing more tangible and widespread innovation. Conversely, conducting nationwide innovation initiatives is likely to be more difficult because of the massive resources required for monitoring and coordinating such endeavours, and the differences in regions’ characteristics and endowments.

To promote local innovation, increasing the innovation literacy and awareness of local leaders about the benefits and practical know-how of innovation is essential. Given Indonesia’s decentralised political structure, the development of innovation-related initiatives, programmes, and infrastructure in cities is greatly influenced by tangible political support (or lack thereof) from their mayors. Effective triple-helix collaboration should exist not only at the national level but also at the city level. Programmes to connect universities’ technical skills with local entrepreneur projects under public initiatives and support need to be encouraged. Furthermore, given the limited innovation capital in the public sector, local governments should instead deploy strategies to attract and invite the private sector within or outside cities to participate in local innovation projects that bring about diffusion, such as training and collaboration provided by firms. Both factors are behind the success of the most innovative regions in Indonesia. Some local industries, especially the food, tourism, and creative industries, have shown excellent potential to be promoted and to benefit from the diffusion of knowledge at the local level.

A critical aspect of local innovation initiatives is entrepreneurship development. In large cities, start-ups should be encouraged and facilitated by the provision of co-working spaces, creative hubs for the exchange of ideas through training and workshops, and start-up incubator programmes. For the less-developed regions or parts of cities, however, providing access to entrepreneurship skills and finance for residents through entrepreneurship training and mentoring should be embedded in local development plans. Connecting them to the technical expertise of nearby universities will yield more diffusion. Given that diffusion requires frequent and extensive interactions with sources of knowledge, simply allocating more budget for entrepreneurship programmes is not enough.

4.5 | Conclusion and Summary of Recommendations

Innovation is an important issue that needs to be addressed immediately. Indonesia still lags behind in innovation indicators due to its generally lacking innovation culture. The limited amount of R&D undertaken corresponds to the absence of a formal, integrated, and well-functioning national innovation system. The limited innovation that has taken place has mostly involved only minor changes in capabilities. Few channels for diffusion exist, except for FDI or joint venture arrangements, or technical assistance from foreign buyers.

Unlike in advanced countries, which possess highly developed innovation policies within full-fledged innovation systems, the basic innovation prerequisites have been severely lacking in Indonesia. The explicit and sophisticated innovation policies applicable to developed countries would fail in Indonesia due to the severe lack of even a basic S&T and innovation base and resources. The government should, therefore, focus first on removing the obstacles for innovation and ensuring that a basic enabling environment for innovation is established before delving into more complex and technical innovation policies. Only then will more advanced innovation policies yield the desired results.

The government needs to reprioritise four different aspects to foster more innovative activities and the diffusion they usually bring. First, considering FDI's important role for innovation and diffusion in the past, the government needs to improve the current investment climate to attract more FDI to the country, especially in GVC-oriented sectors. Logistics infrastructure and regulatory coherence need to be improved. This open investment policy needs to be accompanied by incentives for technology transfer or diffusion by firms. So far, the country has not developed an explicit regulatory framework on technology transfer.

Second, beyond merely spending more on R&D activities, the government must invest heavily in improving other innovation enablers. Sufficient efforts should be made to strengthen local human resources, improve IPR protection, and prepare a financing mechanism for innovation activities. Infrastructure, such as public laboratories and MSTQ services, is very important to facilitate and upgrade innovation. Private participation in building and operating such infrastructure is essential given the government's limited financial and human resources.

Third, a formal innovation system must be prepared. The development of SINAS should be continued and encouraged. Establishing an institution along the lines of the National Innovation Committee to coordinate innovation governance across the ministries is advisable for better policy coordination across the triple-helix actors of innovation. University–industry collaboration should have a special focus within such a system.

Finally, local-level initiatives must be further encouraged and helped to flourish to create more momentum and quick wins, and to demonstrate good practices for other regions to follow. Top-down policies at the national level applied universally across regions have proved not to be an effective way of fostering national innovation.

This chapter is not exhaustive and does not have enough space to touch on many important innovation policies to promote more diffusion of knowledge. Perfect calibration of these diverse policy prescriptions needs a degree of trial and error. Many other aspects related to innovation are beyond the scope of this chapter. However, the chapter should provide the big picture of the current innovation condition and a general sense of what needs to be done to promote innovation and knowledge diffusion in Indonesia.

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Innovation Policy in Malaysia

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5.1 | Introduction

Malaysia, with a population of 30.3 million, gross domestic product (GDP) of US\$292.2 billion and GDP per capita of US\$26,314 (in purchasing power parity terms) in 2016, is considered an upper middle-income country. The country has recorded impressive economic growth rates since the 1980s (Table 5.1), and, aided by foreign direct investment (FDI), has successfully transformed itself from being an exporter of primary products into a major supplier of manufactured products.

Table 5.1: Contribution to Gross Domestic Product by Sector, 1980–2016 (%)

Period	Agriculture	Mining	Manufacturing	Construction	Services	GDP Growth
1980–1984	22.31	9.96	19.98	5.17	42.58	7.32
1985–1989	19.66	11.35	20.88	3.75	44.35	5.35
1990–1994	13.94	8.31	25.44	3.75	48.56	9.32
1995–1999	9.28	7.54	27.78	4.18	51.23	6.03
2000–2004	8.15	6.72	28.90	3.02	53.21	5.68
2005–2009	8.13	11.98	26.90	2.93	50.05	4.49
2010–2016	7.94	8.56	24.10	4.22	55.18	5.39

GDP = gross domestic product.

Source: Ministry of Finance.

The share of manufacturing in GDP increased from 19.9% in the early 1980s to a high of 28.9% during 2000–2004. With the rise of services, the share of manufacturing has since fallen. Despite the early emergence of manufacturing, the emphasis on

innovation has been relatively recent. The first important incentive for firm-level research and development (R&D) came only in 1986 in the form of a tax deduction for qualifying research expenditure (Narayanan and Lai, 2000).

Innovation is critical for initiating and sustaining progress (Phelps, 2006). Developed economies have nurtured innovation, although similar efforts have been less evident among developing countries. Innovation has traditionally been viewed as heralding something new (OECD, 1996) that requires substantial investment in talent and funds. Furthermore, neoclassical theories of growth have conceptualised new technologies as diffusing from developed to developing countries, and the latter accepted this recipient role. All this changed when innovation was broadened to embrace incremental initiatives that improved productivity and generated products, processes, or ideas that were not necessarily new to the world but brought new solutions to existing problems (Chapter 2). In addition, the success of East Asian economies, such as Japan, the Republic of Korea (henceforth Korea), Singapore, and Taiwan, in enhancing their technological capabilities has inspired other developing economies.

Innovation in the Malaysian economy gained new momentum with the launch of the New Economic Model (NEM) in 2010. The NEM maintained that Malaysia's strategy of relying on cheap immigrant labour to keep exports competitive was no longer tenable. Instead, a robust manufacturing sector, grounded on independent innovative capabilities, was needed to drive the economy up the value chain in a sustained fashion (NEM, 2010).

5.2 | Current State of Innovation

With no specific policies to foster innovation, what little research there was in the early periods was done by multinational corporation (MNC) affiliates (UNDP and World Bank, 1995). The scale and extent was determined by their self-interest. The current state of innovation is pieced together from some micro- and macro-level indicators.

5.2.1 Micro indicators

The micro indicators are based on firm-level data, drawn from various national surveys undertaken by different agencies.

Extent of innovation

Data from the Second Malaysia Productivity and Investment Climate (PICS-2) Survey carried out by the World Bank in 2006,¹ for example, indicated that 64% of the firms in manufacturing were engaged in some form of innovation. This was a higher figure than that reported by the national innovation surveys carried out by the Malaysian Science and Technology Information Centre (MASTIC). Differences in definitions, sample size, and other details preclude a strict comparison, but it is safe to conclude that firm-level innovation has grown (Table 5.2).

Table 5.2: Extent of Innovation

Period	Sample Size	Non-innovating Firms		Innovating Firms	
		Number	Percentage	Number	Percentage
1990–1994 (NSI-1)	412 ^a	144	35	268	65
1997–1999 (NSI-2)	1,044	825	79	219	21
2000–2001 (NSI-3)	749	487	65	263	35
2002–2004 (NSI-4)	485 ^a	223	46	262	54
2005–2008 (NSI-5)	1,212 ^a	588	49	624	51
2009–2011 (NSI-6)	1,682 ^a	504	30	1,178	70
2006 (PICS-2)	1,115	400	36	715	64

NSI = National Innovation Survey, PICS = Productivity and Investment Climate Survey.

^a Includes firms in the manufacturing and services sectors.

Sources: Malaysian Science and Technology Information Centre, various years; PICS-2 survey, 2007.

Types of innovation

Manufacturing companies conduct product, process, marketing, and organisational innovation. Product and process innovations are more important and relate directly to the diffusion of research knowledge in production. Product innovation includes new products in the market and products that are new to the firm. In 2012, under product innovation, 64% of manufacturing firms introduced new products, while 44% introduced products that were new to the firm (MOSTI, 2014a). Process innovation includes ‘new’ or ‘significantly improved’ supporting activities, improved logistics and distribution, and improved manufacturing methods. In 2012, 53% of firms were

¹ The PICS-2 survey is a nationwide collaborative survey undertaken by the World Bank and the Malaysian Department of Statistics in 2007.

engaged in supporting activities, 36% in improved logistics and distribution, and 66% in improved manufacturing methods. During 2009–2011, more ‘new’ products than ‘significantly improved’ products were introduced (Table 5.3). About 80% were developed internally by firms (closed innovation system), and more ‘new’ products were produced (82%) based on a closed innovation system compared to ‘significantly improved’ products (78%).

Table 5.3: Development of ‘New’ Products and ‘Significantly Improved’ Products in Manufacturing, 2009–2011

Innovation	Manufacturing				Total	%
	NP	%	SIP	%		
Closed	7,632	82	4,331	78	11,963	80
Joint	1,584	17	1,113	20	2,697	18
Open	114	1	120	2	234	2
Total	9,330	100	5,564	100	14,894	100

NP = new product, SIP = significantly improved product.

Note: Closed innovations are innovations developed internally by the company itself or the company’s group; joint innovations are innovations developed jointly by the company together with other companies and institutions; and open innovations are innovations developed mainly by other companies or institutions (externally).

Source: Ministry of Science, Technology and Innovation (2014a).

Data from the PICS-2 survey categorise innovation differently; firms are divided into three groups based on the innovation activity they were primarily engaged in (Table 5.4).

Table 5.4: Types of Innovation in Manufacturing, 2005–2006

Type of Innovation	Description	Number	%
Adoption	Upgraded machinery and equipment and/or introduced new technology over the last two years	100	14
Adaptation	Entered new markets due to improvements in quality or cost of products or processes and/or upgraded product line over the last two years	450	63
Creation	Firm filed patents, utility models, or copyright protected materials over the last two years	165	23
Total		715	100

Source: Adapted from Hosseini (2015, p. 92).

Of 715 firms that reported innovation over the two-year period (2005–2006), only 23% filed for patents or other protected materials. Most (63%) did adaptive work (improving products or processes), while the rest (14%) engaged in adoption (upgrading or renewing technologies). These findings are broadly consistent with the Ministry of Science, Technology and Innovation (MOSTI) data in Table 5.3.

Access to technology

Data from the PICS-2 survey indicate that 58% of innovating firms accessed technology through collaboration,² and nearly 53% gained technology from parent establishments. Only 24% secured technology as suppliers to MNCs (Table 5.5). About 17% had received research or technological support from publicly created institutions, such as SIRIM,³ the Malaysian Agriculture Research and Development Institute,⁴ and the Rubber Research Institute of Malaysia. Formal in-house R&D was less common (17%), and just 9% had outsourced innovative activities or engaged in ‘open innovation’. This sidesteps the need for in-house innovation and leverages outside expertise (Chesbrough, 2003).

Table 5.5: Modes of Access to Technology

Mode	Innovating Firms (%)
Sought collaboration in R&D from different sources	58.04
Staff exclusively for design/R&D	16.78
Technology transferred from parent establishment	52.45
Subcontracted out R&D	8.81
Received research and/or technology support from institutions	16.50
Supplier to a multinational company	23.64
N = 1,115	

R&D = research and development.

Note: A firm can rely on several modes of access.

Source: Hosseini (2015, p. 81).

² They collaborated with other firms, universities, multilateral agencies, or research institutions. Links with universities remain weak.

³ SIRIM is a solution-provider in quality and technology.

⁴ The Malaysian Agriculture Research and Development Institute conducts research in agriculture, food, and agro-based activities.

Factors motivating firm-level innovation

Hosseini (2015) estimated a simple Probit model using the firm-level data in the PICS-2 survey to determine the factors that predict firm-level innovation. The independent variables and their marginal effects are shown in Table 5.6. Royalty payments and chief executive officers with tertiary education qualifications were strong and significant predictors of innovation in large firms and small and medium-sized enterprises (SMEs), with the effects being stronger for SMEs than large firms.

Table 5.6: Marginal Effects of the Predictors of Innovation

Predictors	SMEs	Large Firms
	dy/dx	dy/dx
Market concentration (four-firm concentration ratio)	-19.58**	-1.15
Age of establishment	-0.19	0.52**
Equity ownership (% foreign)	0.03	0.01
University degree or higher degree completed by CEO or owner	14.28***	12.33***
CEO or owner makes all its investment decisions independently	-7.49	-1.71
Share of professionals and managerial workers (%)	-0.23	0.20
Share of sales exported directly (%)	0.17***	0.05
Made royalty payments	22.78***	15.62**
Share of foreign permanent workers (%)	0.10	-0.07
Penang	8.50**	5.47

CEO = chief executive officer; dy/dx = marginal effects; four-firm concentration ratio = sales of the four largest firms in a subsector divided by total sales in the subsector; large firms = >150 workers; SME = small and medium-sized enterprise, 50–150 workers.

Note: Coefficients are expressed in percentages; ** significant at 5%; *** significant at 1%.

Source: Hosseini (2015).

Exposure to the export market and a competitive environment were strong drivers of innovation among SMEs but not large firms. A 1% increase in the concentration ratio lowered the probability of innovation among SMEs by 19.6%. Thus, SME innovation was lowest in highly concentrated subsectors, such as textiles, machinery and equipment, electronics, and electrical machinery and apparatus, and highest in the food processing, rubber, and plastics subsectors.⁵ While age predicted innovation only

⁵ Based on the four-firm concentration ratios, the most concentrated subsectors were textiles (0.797), machinery and equipment (0.670), electronics (0.619), and electrical machinery and apparatus (0.617). The least concentrated were food processing (0.375) and rubber and plastics (0.211).

among large firms, cluster-specific advantages of being in Penang, the ‘Silicon Valley’ of Malaysia, predicted innovation among SMEs only. Penang-based SMEs had an 8.5% higher probability of innovation relative to SMEs located elsewhere. Finally, firm ownership, firm size, the share of foreign unskilled workers, and the share of professional and managerial workers did not predict innovation. Independent and sole owners appeared more risk averse and shied away from innovation, as evident from the negative coefficients, although they were not significant.

Linkages and technological spillovers

Spillover effects can occur either through horizontal linkages between firms in the same sector or industry or through vertical forward and backward linkages between firms in related sectors. Malaysian studies provide mixed evidence on this issue (Khalifah and Radziah, 2009; Choo, 2012; Kam, 2016).⁶

We compared the findings of two later studies. Choo (2012) used data from the PICS-2 survey and the Malaysian input–output tables for 2000 over a three-year period (2004–2006) and covering 938 firms. Kam (2016) relied on unpublished annual data for a longer period (2000–2008), drawn from the Annual Survey of Manufacturing Industries of the Department of Statistics, Malaysia. Firms with more than 50% of their equity owned by foreigners were classified as foreign firms by Kam and a similar cut-off was used to define domestic firms. Both studies found significant horizontal spillovers, but Choo noted that only non-export-oriented foreign affiliates and those with partial foreign ownership generated them. Kam, on the other hand, found that skill-oriented foreign affiliates, affiliates with high domestic sales, and affiliates with high imported input content generated horizontal spillovers, with skill-oriented foreign affiliates having the largest impact on the productivity growth of local firms.

Choo (2012) reported that domestic firms that gained the most from horizontal spillovers were either firms with high absorptive capacity or low export intensity, or small firms.⁷ Kam (2016) found that only domestic firms with lower skill requirements

⁶ Studies based on macro data cannot identify the channels of the spillovers. Spillovers are assumed to exist when there are significant associations between the presence of FDI affiliates and the productivity of domestic firms in a sector or across vertically related sectors. The studies also often give contradictory results based on the type of data used, the measures used to proxy foreign presence and the way spillovers are estimated. While panel data is superior to cross-section data, there are no preferred ways to proxy the other two variables (Görg and Strobl, 2001).

⁷ Firms with a high absorptive capacity were defined as those with a ratio of skilled to unskilled workers of 0.3 or above. Firms with a low export intensity were those that exported less than 30% of their sales. Small firms were defined as firms employing fewer than 50 workers. These are all arbitrary thresholds leaving open the possibility that the outcomes may change if the thresholds are changed.

benefitted. Skill-intensive domestic firms, on the other hand, showed productivity improvements, even without establishing links with foreign affiliates. Similarly, domestic firms with high imported input content experienced increased productivity even without such links, suggesting greater gains were secured from the global production network than from linkages in the domestic economy. However, firms linked with foreign affiliates registered greater productivity gains.

Vertical spillovers might be expected to occur primarily through backward linkages forged through purchases of intermediate inputs from domestic firms by MNC affiliates. Yet, Choo (2012) found no significant evidence of vertical backward spillovers in most cases. Where they occurred, they came from non-export-oriented firms and firms that were not fully foreign-owned. In contrast, Kam (2016) found evidence of significant vertical backward spillovers generated by export-oriented foreign affiliates, skill-intensive affiliates, and foreign affiliates with high domestic sales who utilise local inputs to lower costs. Affiliates with a high import content naturally showed no significant backward linkages. Although skill-oriented foreign establishments generated significant horizontal and backward spillovers to domestic firms, the foreign establishments had larger effects.

Both studies found no evidence of vertical forward spillovers, regardless of the characteristics of the foreign affiliate, possibly because the specialised inputs from foreign firms could not be used by domestic firms. Furthermore, there are restrictions on sales from foreign affiliates located in free trade zones to local firms.

5.2.2 Macro indicators

While there is micro-level evidence of growing innovation, macro indicators are used to evaluate the key inputs and outputs of innovation and to allow comparisons between countries.

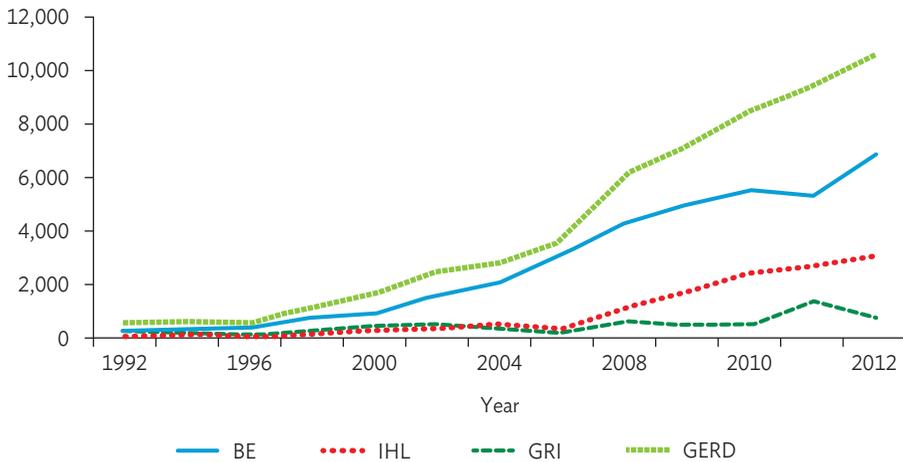
Research and development expenditure by sector

A key input is expenditure on R&D. During 1992–2012, Malaysia's gross expenditure on R&D increased from RM550.6 million to RM10.6 billion, achieving an annual compound growth rate of nearly 15.9%.

In 1992, government research institutes were the main drivers of R&D activity, contributing RM2.5 billion or 46% of total R&D expenditure. However, by 1994, business sector spending overtook that of public research institutions. By 2008,

R&D expenditure by institutions of higher learning surpassed that of government research institutes but remained behind the business sector. The bulk of business expenditures on research in Malaysia were undertaken by government-linked companies, such as Proton, Petronas, and Khazanah, rather than MNCs or domestic companies (Figure 5.1). By 2012, business sector expenditure stood at RM6.8 billion and accounted for 64.5% of total R&D expenditure; expenditure by institutions of higher learning stood at RM3.0 billion or 28.7% of the total; and government agencies and public research institutes spent RM7.3 million or 6.9%.

Figure 5.1: Research and Development Expenditure in Malaysia by Sector, 1992–2012 (RM million)



BE = business expenditure, GERD = gross expenditure on research and development (the sum of GRI, IHL, and BE), GRI = public research institutes, IHL = institutions of higher learning.

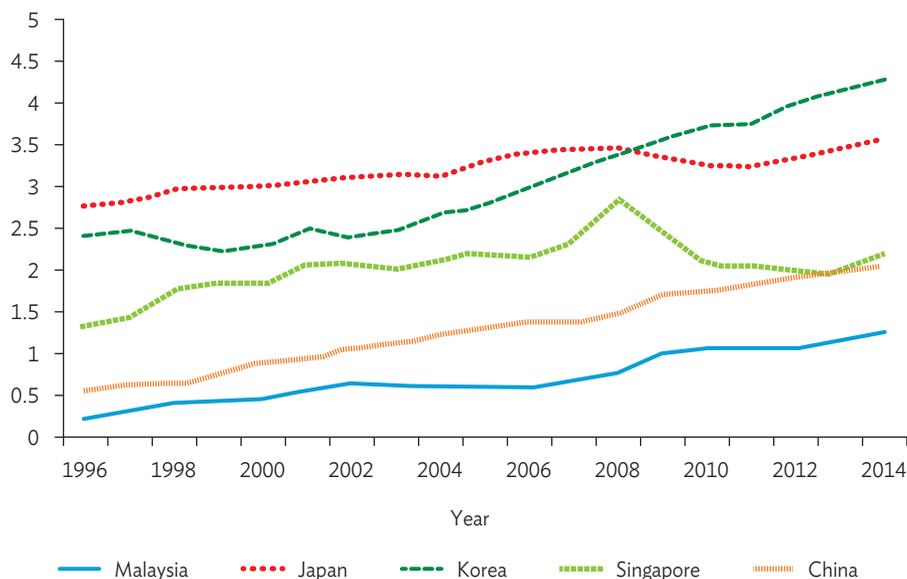
Sources: Compiled from Malaysian Science and Technology Information Centre, *National Survey of Research and Development*, various years.

Research and development expenditure as a proportion of gross domestic product

To allow meaningful comparisons across countries, research spending is expressed as a proportion of GDP. Despite allocating more funds to R&D, Malaysia's expenditure as a percentage of GDP (1.26% in 2014) remains low compared to Korea (4.29%), Japan (3.58%), Singapore (2.19%), and China (2.05%) (Figure 5.2).⁸ It is particularly notable that it lagged China, a relative latecomer to export manufacturing.

⁸ World Bank. Databank. Research and development expenditure (% of GDP). <http://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?page=1>

Figure 5.2: Research and Development Expenditure as a Proportion of Gross Domestic Product (%)



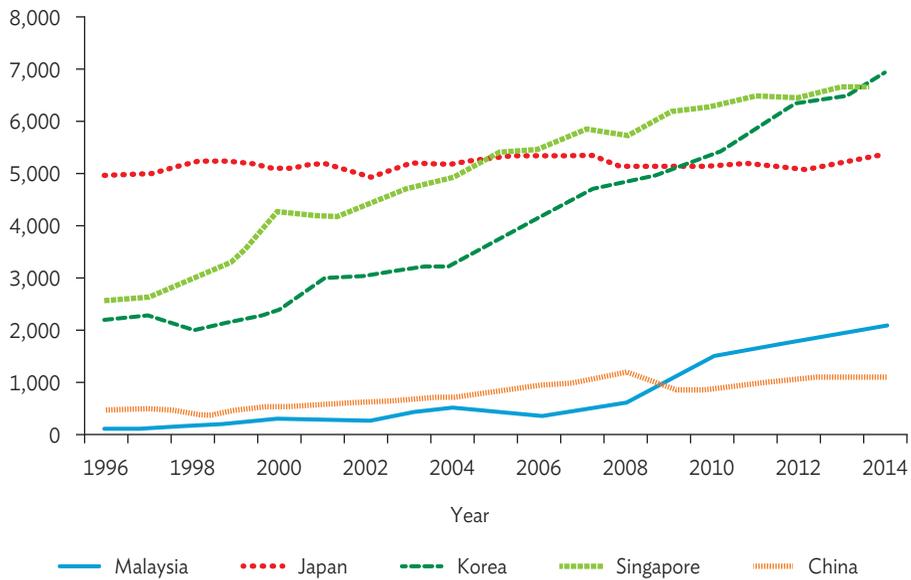
Source: Graphed using World Bank World Development Indicators. <http://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?page=1>

Research and development personnel per million population

Malaysia was also behind with respect to R&D personnel per million population in 2014 (Figure 5.3). Its figure of 2,051 compared unfavourably with those of Korea (6,899), Singapore (6,658), and Japan (5,386) but was ahead of China (1,113).⁹ However, given its small base, Malaysia experienced a high compound annual growth rate (23.9%) in R&D personnel per million population during 2006–2014. This compares favourably with the figure for Korea (6.5%), Singapore (2.6%), China (2.2%), and Japan (which recorded no growth).

In 1994, Malaysian public research institutes employed 60.1% of all R&D personnel (Table 5.7). The proportion has since dropped to 8.0% in 2012. Correspondingly, the proportion of R&D personnel employed in institutions of higher learning increased from 12.3% in 1994 to 80.7% in 2012. Although the business sector still leads in R&D expenditure, its share of R&D personnel has declined from 27.6% in 1994 to 11.3% in 2012, reflecting the applied nature of the research.

⁹ World Bank. Databank. <http://data.worldbank.org/country>

Figure 5.3: Research and Development Personnel per Million Population

Source: Graphed using World Bank World Development Indicators. <http://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?page=1>

Table 5.7: Number of Research and Development Personnel by Sector

Year	GRI		IHL		BE		Total No.
	No.	%	No.	%	No.	%	
1994	6,891	60.07	1,417	12.35	3,164	27.58	11,472
1996	4,231	45.82	1,757	19.03	3,245	35.15	9,233
1998	5,234	43.16	2,735	22.55	4,158	34.29	12,127
2000	7,777	33.43	11,239	48.31	4,246	18.25	23,262
2002	7,222	28.96	12,538	50.28	5,177	20.76	24,937
2004	7,437	24.00	14,809	47.80	8,737	28.20	30,983
2006	4,556	18.53	13,007	52.90	7,025	28.57	24,588
2008	5,899	14.44	28,775	70.46	6,166	15.10	40,840
2009	6,361	9.03	57,437	81.53	6,655	9.45	70,453
2010	6,877	7.79	71,579	81.05	9,858	11.16	88,314
2011	7,402	7.63	78,683	81.15	10,876	11.22	96,961
2012	8,343	8.02	83,919	80.70	11,724	11.27	103,986

BE = business expenditure, GRI = public research institutes, IHL = institutions of higher learning.

Sources: Compiled from Malaysian Science and Technology Information Centre, *National Survey of Research and Development*, various years.

Patents granted

Innovation often translates into patents. Patent applications by Malaysians handled by the Malaysian Patent Office during 2000–2010 show a rising trend, with 206 applications in 2000, 531 in 2006, and 1,275 in 2010. However, they accounted for a small share of all applications at 3.3%, 11.1%, and 19.7%, respectively (Zeufack and Lim, 2013). Data from the US Patent and Trademark Office show that during 2002–2015, Malaysia acquired 2,156 patents. In comparison, Japan collected 575,208, Korea 131,129, China 37,442, and Singapore 8,041 (Table 5.8).

Table 5.8: Patents Granted by the United States Patent and Trademark Office

Year	Malaysia	Japan	Korea	Singapore	China
Pre-2002	251	485,962	21,706	1,261	1,091
2002	55	34,858	3,786	410	288
2003	50	35,515	3,944	427	297
2004	80	35,346	4,428	449	403
2005	88	30,340	4,351	346	402
2006	113	36,807	5,908	412	659
2007	158	33,354	6,295	393	770
2008	152	33,682	7,548	399	1,223
2009	158	35,501	8,762	436	1,654
2010	202	44,813	11,671	603	2,655
2011	161	46,139	12,262	647	3,174
2012	210	50,677	13,233	810	4,637
2013	214	51,919	14,548	797	5,928
2014	259	53,848	16,469	946	7,236
2015	256	52,409	17,924	966	8,116
Total (2002–2015)	2,156	575,208	131,129	8,041	37,442

Source: United States Patent and Trademark Office (2015).

5.2.3 Global rankings

The overall impacts of the macro indicators are broadly reflected in global innovation indices, two of which are the Global Innovation Index (GII) and the Global Competitiveness Index (GCI).

Global Innovation Index

The GII is a broad measure indicating the extent to which countries integrate innovation into their political, business, and social spheres. Malaysia is the only country in Table 5.9 to record a continuous decline in its ranking during 2011–2016. Furthermore, all the other countries improved during 2014–2016, but Malaysia was ranked 35th of the 128 countries listed in 2016. While other countries' scores rose (China, Japan, and Korea) or remained almost static (Singapore), Malaysia's score fell from 45.6 in 2014 to 43.4 in 2016.

Table 5.9: Global Innovation Index

Country	Score (0–100)			Rank			
	2011	2014	2016	2009	2011	2014	2016
Malaysia	44.1	45.6	43.4	25	31	33	35
Japan	50.3	52.4	54.5	9	20	21	16
Korea	53.7	55.3	57.1	6	16	16	11
Singapore	59.6	59.2	59.2	5	3	7	6
China	46.4	46.6	50.6	37	29	29	25

Note: Scores for 2009 are based on a 1–7 scale in which Malaysia scored 4.06, Japan 4.65, Korea 4.73, Singapore 4.81, and China 3.59.

Sources: INSEAD and Confederation of Indian Industry (2009); INSEAD (2011); Cornell University, INSEAD, and World Intellectual Property Organization (2014, 2016).

Malaysia's rank among upper middle-income countries dropped from first in 2014, to second place in 2016, behind China. In the Southeast Asia and Oceanic group, Malaysia was again just below China in seventh place in 2016.

Malaysia's ranking on innovation inputs, which records the impact of increasing inputs, such as R&D spending and researchers, fell to 32nd place in 2016 from 30th in 2014 (Table 5.10). The country's ranking on innovation output fell to 39th position (from 35th in 2014), suggesting some inefficiency in translating inputs to outputs (including patents, publications, and citations). The innovation efficiency ranking (the ratio of output sub-index to input sub-index) for Malaysia improved from 72nd place in 2014 to 59th in 2016. Malaysia was ahead of Japan and Singapore but behind China and Korea. But this must be viewed in context; Malaysia's scores in both sub-indices were smaller than those of the countries listed in the table.

Table 5.10: Innovation Efficiency Ratio, Innovation Input and Output Sub-indices

IER	Malaysia		Japan		Korea		Singapore		China	
	2014	2016	2014	2016	2014	2016	2014	2016	2014	2016
Score	0.74	0.67	0.68	0.65	0.78	0.80	0.64	0.62	1.03	0.90
Rank	72	59	88	65	54	24	121	78	2	7
Input										
Score (0–100)	52.5	52.1	62.2	66	62.2	63.5	72.3	72.9	45.8	53.1
Rank	30	32	15	9	16	13	1	1	45	29
Output										
Score (0–100)	38.7	34.7	42.6	43	48.4	50.8	46.6	45.4	47.3	48
Rank	35	39	27	24	15	11	18	20	16	15

IER = innovation efficiency ratio.

Sources: Cornell University, INSEAD, and World Intellectual Property Organization (2014, 2016).

Global Competitiveness Index

The GCI, published by the World Economic Forum, is another globally recognised ranking of country competitiveness. It is used as a tool for benchmarking country strengths and weaknesses (World Economic Forum, 2008). The index is calculated based on 114 indicators grouped into 12 pillars.¹⁰ Malaysia's ranking has changed little since the index was first computed in 2008, when it was ranked 21st (Table 5.11).

Table 5.11: Global Competitiveness Index, 2011–2016

Country	Score (1–7)			Rank		
	2011	2014	2016	2011	2014	2016
Malaysia	5.1	5.2	5.2	21	20	25
Japan	5.4	5.5	5.5	9	6	8
Korea	5.0	5.0	5.0	24	26	26
Singapore	5.6	5.6	5.7	2	2	2
China	4.9	4.9	5.0	26	28	28

Sources: World Economic Forum, *Global Competitiveness Index Report*, various years.

¹⁰ The CGI was first computed using this improved methodology in 2008 (World Economic Forum, 2008).

It stayed around that position until 2016, when it dropped to 25th (of 142 economies in 2011, 144 in 2014, and 138 in 2016). The scores indicate that the competitiveness of the country was growing slowly compared with competing economies. During 2011–2016, it lagged Japan and Singapore, and its advantage over China and Korea narrowed. Singapore has remained a very competitive economy, maintaining its second-place position since 2011, after improving from fifth place in 2008.

Two of the GCI pillars relate directly to innovation: technological readiness (pillar 9) and innovation (pillar 12). The technological readiness pillar has seven components, three of which relate to technology (availability of latest technologies, firm-level technology absorption, and FDI and technology transfer). Since 2014, Malaysia's ranking for FDI and technology transfer has been ranked in the top 10 of the 140 surveyed countries, but the rank for firm-level technology absorption was relatively low, despite improvements since 2011.

The rankings for the innovation-related pillar are of particular interest (Table 5.12). They are close to the overall GCI, hovering around the 21st to 24th positions. Of the seven components of this pillar, four selected ones are shown. The availability of scientists and engineers has improved significantly in recent years.

Table 5.12: Global Competitiveness Index Pillar Scores and Rankings of Malaysia, 2011–2016

Pillars/Selected Components	Score			Rank		
	2011	2014	2016	2011	2014	2016
Technological readiness	4.3	4.2	4.8	44	60	43
Availability of latest technologies	5.8	5.7	5.6	35	33	34
Firm-level technology absorption	5.6	5.6	5.5	28	24	19
FDI and technology transfer	5.3	5.5	5.4	12	8	8
Innovation	4.3	4.7	4.7	24	21	22
Capacity for innovation	4.3	5.2	5.4	19	13	13
Quality of scientific research institutions	4.9	5.2	5.3	24	20	23
Availability of scientists and engineers	4.9	5.2	5.3	22	9	7
Patent Cooperation Treaty patent applications per million population	7.2	12.6	11.3	32	32	36

FDI = foreign direct investment.

Note: The scores are measured on a scale of 1–7, except for Patent Cooperation Treaty patent applications.

Sources: World Economic Forum, *Global Competitiveness Index Report*, various years.

5.3 | Innovation Policies

In 1991, Malaysia announced its Vision 2020, with the ambitious goal of becoming a developed nation by 2020. The sixth of the nine strategic challenges to be met was that of establishing a scientific and progressive society that is innovative and forward-looking. Policies and actions since the late 1980s have contributed to increasing the pace of innovation in the country.

Malaysia's commitment to harnessing, utilising, and advancing science and technology is reflected in the following science, technology, and innovation (STI) policies: the First National Science and Technology Policy (NSTP1), 1986–1989; the Industrial Technology Development: A National Action Plan, 1990–2001; the Second National Science and Technology Policy and Plan of Action (NSTP2), 2002–2010; and the National Policy on Science, Technology and Innovation, 2013–2020. The various initiatives implemented under these policies include enhancing the national capabilities and capacities of R&D, forging partnerships between publicly funded research organisations and industries, enhancing commercialisation through the National Innovation Model (MOSTI, 2007), and developing new knowledge-based industries. In addition, the government adopted the NEM in 2009, with its various thrusts being implemented through the Economic Transformation Programme, incorporating, among others, 12 National Key Economic Areas and 6 Strategic Reform Initiatives.

5.3.1 First National Science and Technology Policy, 1986–1989

The main objective of the NSTP1 was to promote scientific and technological self-reliance. It included plans to upgrade local R&D capabilities and improve scientific and educational infrastructure. Emphasis was placed on the improvement of human physical and spiritual well-being, the balanced development of natural resources and ecology, and environmental preservation (Government of Malaysia, 1986).

5.3.2 Industrial Technology Development National Action Plan, 1990–2001

The main thrusts of the Industrial Technology Development National Action Plan were to strengthen institutions and support infrastructure for technological innovation, increase the application and diffusion of technology, and promote public awareness on the importance of science and technology.

5.3.3 Second National Science and Technology Policy, 2002–2010

The NSTP2 specified in detail the goal and objectives of the policy, set the policy directions for science and technology, and developed strategic thrusts and initiatives to address seven key priority areas. Its broad goal was to accelerate the development of science and technology capability and the national capacity for competitiveness. The two objectives to be met by 2010 were to increase R&D expenditure to at least 1.5% of GDP and to have at least 60 R&D personnel per 10,000 people in the labour force. Neither objective was met; in 2010, R&D expenditure was 1.07% of GDP, while the number of R&D personnel per 10,000 people in the labour force was 14.7. Fifty-five initiatives were listed to support the following priority areas: research and technological capacity, research commercialisation, human resource capacity, promotion of a culture for innovation, institutional framework, technology diffusion, and building competence for specialisation.

5.3.4 National Policy on Science, Technology and Innovation, 2013–2020

The National Policy on Science, Technology and Innovation stands on five foundations. The most important is to ensure all stakeholders, including ministries, agencies, universities, and private industry, accept and implement the policy. The second is to provide support by building STI capacity and capabilities in terms of institutions, mandates, management, personnel, and funding, and through transmitting and diffusing STI knowledge. The third seeks to strengthen private sector STI capabilities through various incentives and measures and to increase private–public research collaborations. The fourth is to adopt principles of good public sector governance to ensure a sound institutional and regulatory framework for the STI system. The fifth is to instil the belief that STI is essential for a stable, peaceful, prosperous, cohesive, and resilient society. The five foundations support six strategic thrusts: advancing scientific and social research, development, and commercialisation; developing, harnessing, and intensifying talent; energising industries; transforming STI governance; promoting and sensitising STI; and enhancing strategic international alliances.

The policy measures under these thrusts include increasing R&D expenditure to at least 2% of GDP, and the ratio of researchers per 10,000 workforce to at least 70 by 2020; facilitating knowledge transfer from research by public sector stakeholders to industry; providing greater autonomy to public institutions of higher learning and

research institutes to spur industry collaboration and entrepreneurship; raising the level of awareness on ethics and humanities in society; and establishing clear guidelines and standards to enhance the commercialisation of products from homegrown innovation.

5.3.5 Science, technology, and innovation sector policies

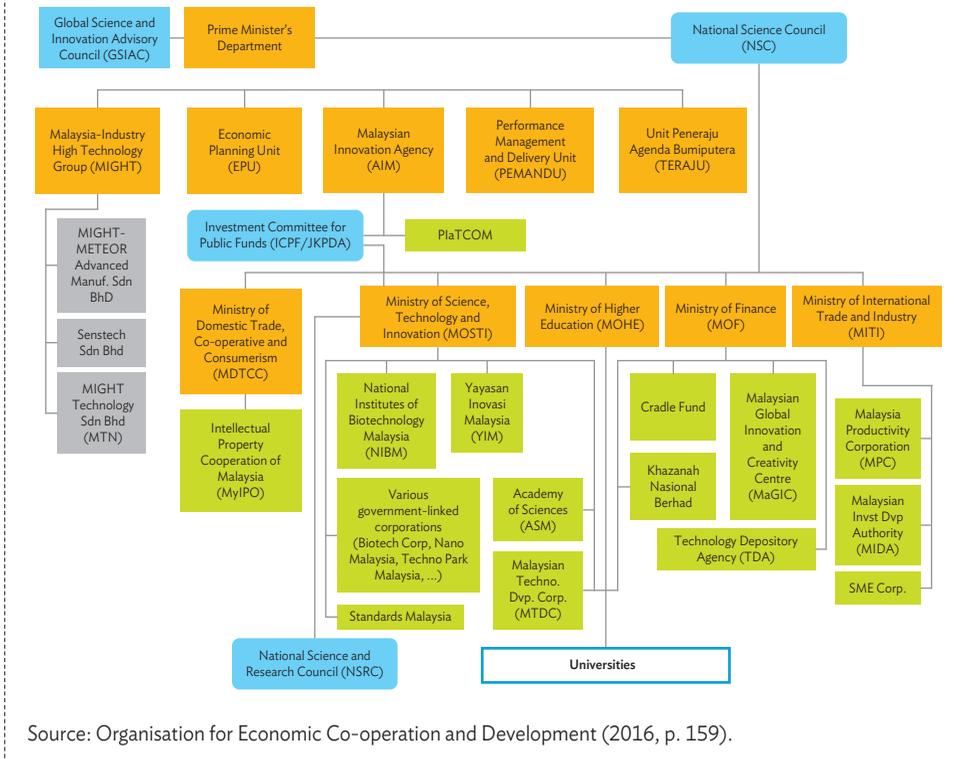
Several STI sectoral policies have been implemented since 2005. These include the National Biotechnology Policy (2005–2020), the Intellectual Property Commercialisation Policy for Research and Development Projects Funded by the Government of Malaysia (2009), and the Malaysia National Green Technology Policy (2009).

The National Biotechnology Policy is the most important. Its objective is to make the biotechnology sector into a key driver of economic growth, contributing 5% of GDP by 2020. Initiatives have been undertaken to focus on agriculture, healthcare, industrial biotechnology development, R&D and technology acquisition, human capital and financial infrastructure development, sound legislative and regulatory framework, the strategic positioning of Malaysia as a centre of excellence for biotechnology, and the establishment of an effective government agency for implementation. The policy is to be implemented in three phases: a capacity-building phase (2005–2010) concentrating on the establishment of advisory and implementation councils, the development of knowledge workers, and business development; a science-to-business phase (2011–2015) focusing on the development of local expertise and new products; and a global presence phase (2016–2020) that aims to take Malaysian companies to the global stage.

5.3.6 Malaysia's national innovation system

The concept of a national innovation system (NIS) rests on the premise that understanding the linkages among actors involved in innovation is the key to improving technology performance (OECD, 1997). Innovation and the technical progress of a country depend on the relationships among the actors or agents involved in producing, distributing, and applying various kinds of knowledge. The actors are people, private enterprises, universities, and research institutes. The flow of technology and information among them takes numerous forms, such as joint research, personnel exchanges, cross-patenting, and the purchase of equipment.

Figure 5.4: Key Public Actors in the National Innovation System, 2015



Malaysia's NIS has evolved gradually. The main actors are the government sector (including the ministries and public research institutes), the business sector (including private enterprises and government-linked companies), and institutions of higher learning (both public and private) (Figure 5.4).

The main government ministries involved in innovation are MOSTI and the Ministry of Higher Education (MOHE). MOSTI spearheads the development of STI in the country. It oversees more than 20 departments, agencies, and companies clustered into five focus areas: biotechnology, information and communication technology (ICT) policy, industry, sea to space, and science and technology core (Day and Amran, 2011). MOSTI provides most research grants through specialised schemes and established MASTIC to compile the national STI statistics and indicators. MOHE, on the other hand, seeks to establish Malaysia as a hub of excellence for higher education. It aims to develop at least 20 centres of excellence that are internationally recognised for research output, copyright, publications, and research collaborations.

Other publicly created institutions include the Malaysian Institute of Microelectronic Systems (MIMOS), which was set up in 1985 to sponsor basic and applied research in microelectronics. In 1993, the Human Resource Development Council was established to address the lack of skilled human resources. The Malaysia Technology Development Corporation was formed in 1992 to promote and commercialise local research and to introduce new technologies from abroad. In 1993, the Malaysian Industry–Government Group for High Technology was formed to coordinate industry–government partnerships in high technology. The Small and Medium Industries Development Corporation (renamed the SME Corp) was also established in 1996 to oversee the needs of SMEs and to include them in the initiatives.

In 1997, the Multimedia Development Corporation, a government-owned company, was formed to create an attractive environment for Malaysian and global firms in the ICT industry. It also oversees MSC Malaysia (formerly the Multimedia Super Corridor), which offers facilities and tax breaks to firms located in the multimedia corridor near the Kuala Lumpur International Airport.

Public research institutes also contribute to innovation and technology diffusion, especially in agriculture, health, forestry, and electronics. In 2011, there were 29 public research institutes, including statutory bodies, Cess-funded organisations, and a MOSTI-owned company; the rest were attached to ministries. The Malaysian Agricultural Research and Development Institute, the Malaysian Palm Oil Board, the Malaysian Rubber Board, the Malaysian Cocoa Board, and the Forest Research Institute Malaysia are key public research institutes in the primary commodities sector.

Public higher education institutions play a vital role in the Malaysia’s innovation system. In 2012, they provided 80% of the country’s research personnel and accounted for 29% of its total R&D expenditure (OECD, 2016). Private universities, hampered by the lack of funding and specialised staff, have not yet contributed significantly to the NIS.

In the business sector, there are several MNCs conducting high-end R&D. They are mainly in the electronics industry and include Intel, Motorola, Hewlett Packard, and Altera, which have all moved from labour-intensive assembly to R&D activities, including design and product development. In addition, numerous projects aimed at fostering high-tech clusters have been established. Among the government-linked companies, Petronas is by far the largest and best known. Besides engaging in intense R&D activities in the oil and gas industry, it also plays a strong role in supporting domestic R&D.

Besides the high-profile MSC Malaysia, which is the national ICT initiative designed to attract world-class technology companies, several science parks have been set up across the country. These include the Kulim High-Tech Park in 1993, targeting high-tech production, and Technology Park Malaysia in 1996, which is targeted more towards R&D-based businesses. The third-largest park is the ICT-focused cluster of Cyberjaya – located within MSC Malaysia – which has attracted MNCs such as Dell, Hewlett Packard, Motorola, and Ericsson.

5.3.7 Public funding for innovation

Government initiatives in support of R&D and innovation seek to address the public-good nature of innovation. Left to the market, investments in innovation would be below the socially optimum level because private gains from innovation fail to capture its spillover benefits to society. Several studies have shown the significant difference between private and social returns to R&D (Griffith, 2000; Dias and Dias, 2006). Dias and Dias (2006), for example, computed the social rate of return to R&D investment in Malaysia (54%), Thailand (57%), Singapore (58%), and Indonesia (64%). The high social rate of return in relation to the private return justifies the implementation of policies that reduce the gap between the actual and socially optimal levels of investments in innovation. Financial incentives, subsidies, and grants are commonly provided to encourage R&D in the business sector.

In Malaysia, several types of fund are available for the creation, research, development, and commercialisation stages of R&D (MOSTI, 2014b). Most of them are managed by MOSTI, although grants are also provided by other ministries. MOHE, for instance, provides different types of grants for research activities in universities. Under the Ministry of International Trade and Industry, the SME Corporation administers subsidy schemes for SMEs, while the Malaysian Investment Development Authority manages R&D investment incentives. Other ministries with financing schemes for R&D include the Ministry of Energy, Green Technology and Water, the Ministry of Agriculture and Agro-based Industry, and the Ministry of Finance. Many public agencies also provide funds for R&D and commercialisation, such as the Multimedia Development Corporation, the Malaysia Technology Development Corporation, and the Malaysian Biotechnology Corporation.

In addition to public funding, various assistance and training schemes are implemented by government agencies to facilitate innovation. The Malaysia Commercialisation Assistance Programme under MOSTI, for example, assists biotechnology companies

in commercialising technologies, products, and services (Day and Amran, 2011). The SME Corporation, together with the Malaysia Innovation Agency, provides technical assistance, market intelligence, incubation and testing facilities, and other services (SME Corporation, 2015). The Human Resources Development Fund (HRDF), established in 1993, aims to catalyse the development of a competent local workforce. Manufacturing firms with 50 or more workers, or 10–50 workers but RM2.5 million or more in paid-up capital, have a human resources development levy imposed of 1% of the monthly wages of each employee, which can then be claimed back through any of 11 different approved training programmes for skills upgrading. The HRDF helped almost 18,000 companies during 1993–2016 (HRDF, 2016).

5.3.8 Case examples

Besides providing funds, the public sector has initiated several schemes to encourage innovation. This section reviews a few examples of direct public sector initiatives.

The BioValley project

The BioValley project was initiated under the National Biotechnology Policy to spearhead the biotechnology industry. It was launched in 2003 at a cost of US\$160 million and aimed to attract large biotech companies to a centralised hub by offering cheap rent, good telecommunications infrastructure, and access to the country's rich biodiversity. It was envisioned as a potential source of innovation for new drugs and other products (Cyranosk, 2005).

Initially, three research institutes on genomics and molecular biology, pharmaceutical and nutraceutical biotechnology, and agro-biotechnology were planned. Although the project was to be completed by 2009 with hundreds of labs researching into different areas of biotechnology, it never really got off the ground. It was eventually replaced by the far less ambitious BioNexus scheme, which evolved around existing labs specialising in agricultural biotechnology, genomics, and molecular biology. BioNexus remains a part of the National Biotechnology Policy and is managed by the Malaysian Biotechnology Corporation. Qualified biotechnology companies are given fiscal incentives, grants, and access to capacity-building programmes and research facilities. The scheme has seen some progress, with the number of companies growing from 7 in 2006 to 210 in 2011. However, more than 90% of these companies are small companies that have little impact in the industry (MOSTI, 2014b).

The failure of the BioValley project was not entirely unexpected given the weak foundations in biotechnology research and the lack of skilled manpower. In contrast, the Biopolis biomedical research hub in Singapore, established at about the same time, has grown into an excellent biomedical park, hosting renowned companies such as Merck, Novartis, Procter & Gamble, Pfizer, and GlaxoSmithKline (A-STAR, 2013).

Science and technology parks

It is argued that locating firms in a science park will foster innovation by encouraging networking and collaboration among themselves and with external entities, such as universities and other research agencies (Malairaja and Zawdie, 2008).

The most prominent science and technology park in Malaysia is MSC Malaysia, set up in 1996. It offers tax breaks, financial assistance, business networking, and easy access to government projects for both foreign and local firms located in the multimedia corridor near Kuala Lumpur International Airport. One of the main objectives is to use the park to incubate local SMEs in an information technology industry that is currently dominated by MNCs (Suhaimi and Yusof, 2006). Other science parks have also been established across the country, including two high-tech parks. The Kulim High-Tech Park, established in 1993, houses firms engaged in clean, high-value-added activities; while the Senai High-Tech Park, established in 2011, attracts firms active in green technology and offers them incubator and laboratory facilities. Other science parks include Technology Park Malaysia (TPM), established in 1996, which encourages R&D in knowledge-based industries and R&D clusters of industries located within MSC Malaysia that focus on ICT.

Despite strong government support in terms of funding for infrastructure and the provision of tax incentives and grants, the science and technology parks have so far played only a minor role in knowledge transfer and establishing links with universities and other research agencies. A study of TPM showed that there is no significant difference in university links with firms in the science park and those located outside the park. Moreover, the limited links forged among firms in the park, universities, and other R&D agencies have not been effective in helping the science park firms upgrade their technological capabilities (Malairaja and Zawdie, 2008). The study also reported that most firms did not view university links as an important factor in their decision to locate in TPM. Another study on knowledge transfer in TPM and the Kulim High-Tech Park, found only a moderate level of knowledge transfer from foreign firms to local firms; and such transfers produced very few outputs, such as patents (Awang et al., 2013).

University–industry collaboration in research and development

All government policies on innovation have stressed the need for university–industry collaboration, and there have been many initiatives to foster greater links between the two. For universities, links with industry are important as the latter are a source of funding, knowledge, and information on the latest technology developments. For industry, links with universities are important as they can tap scientists and researchers to expand their innovation initiatives. However, establishing collaboration and links between the two parties has remained a major challenge, although some progress has been made. Table 5.13 shows the scores and rankings for university–industry R&D collaboration for Malaysia given in the GII and GCI.

Table 5.13: University–Industry Research and Development Collaboration, 2011–2016

Index, Pillar	Score			Rank		
	2011	2014	2016	2011	2014	2016
GII, Business sophistication (score 0–100)	61.7	67.0	72.1	21	15	12
GCI, Innovation (score 1–7)	4.9	5.3	5.2	21	12	11

GCI = Global Competitiveness Index, GII = Global Innovation Index.

Sources: INSEAD (2011); Cornell University, INSEAD, and World Intellectual Property Organization (2014, 2016); World Economic Forum, *The Global Competitiveness Report*, various years.

The university–industry R&D collaboration rankings of both indices are remarkably similar and show that the rankings have moved up a few rungs, from 21 in 2011 to 11 (in the GCI) and 12 (in the GII) in 2016. The improvement, however, does not mean that collaborative research between universities and industries is widespread. During 2006–2011, on average, 90% of university collaborative research funding went to collaborative work with government research institutions and agencies (Chandran, Sundram, and Santhidran, 2014); collaboration with industry accounted for just 3.7%–8.7% of total university collaborative funding (Table 5.14). Despite the slight improvement in collaborative funding, it remains low compared to other developing countries, such as China, where nearly 35% of innovative firms reported having R&D collaboration with universities (Fu and Li, 2011).

The low level of collaborative efforts between universities and industry can be attributed to the research gaps between both parties (Chandran, Sundram, and Santhidran, 2014). Universities are mainly involved in basic and fundamental research,

which are relevant to only a few industries such as the pharmaceuticals, biotechnology, and chemicals industries. Most industries are focused on incremental product and process innovation, which requires close links between firms and buyers and suppliers of technology, but not universities.

Table 5.14: Collaborative Research and Development Funding, 2006–2011 (%)

Year	Government	Industry	International
2006	93.5	5.0	1.4
2007	95.3	3.7	1.0
2008	90.1	6.9	3.1
2009	84.8	8.7	6.5
2010	88.4	7.7	3.9
2011	90.0	7.2	2.8

Source: Chandran, Sundram, and Santhidran (2014).

Industrial clusters

In theory, clusters facilitate the exchange of knowledge on markets and new innovations because competitors, suppliers, supporting industries, and public R&D agencies are located in the same region or district. This approach was emphasised in the Tenth (2011–2015) and Eleventh (2016–2020) Malaysia Plans, as well as the Second (1996–2005) and Third (2006–2020) Industrial Master Plans. Several industrial clusters have developed, such as the electrical and electronics (E&E) clusters in Penang and Negeri Sembilan; the information technology, creative content, and technologies clusters in MSC Malaysia; the palm oil industrial clusters in Sabah; and the automotive clusters in Perak and Selangor.

Only the E&E cluster in Penang has achieved some measure of success.

Excellent infrastructure, a skilled workforce, and good supporting industries have helped build the core competencies of several SMEs. A few of them have become global suppliers to MNCs (UNDP, 1994; Ariff, 2008; Athukorala, 2014). It has also been found that being in Penang was positively and significantly associated with innovation among SMEs (Hosseini, 2015). But this has not been the case with other clusters. Many MNCs concentrate on manufacturing and assembly by utilising technology from their parent companies with little R&D of their own. Thus, there is

little technology transfer or spillover benefits to local SMEs in the cluster. SMEs, on the other hand, lack the core technological competence to benefit from links, even when such opportunities arise. Furthermore, they lack skilled personnel and links with universities that could help them tap the expertise in these institutions. Few of them invest in R&D, despite the availability of incentives (UNDP, 1994; Narayanan and Lai, 2000). Another constraint that impedes R&D among them is their dependence on foreign firms (Abad et al., 2015).

Similar to the manufacturing sector, the ICT cluster in MSC Malaysia is dominated by MNCs. One of the main objectives of MSC Malaysia is to help local SMEs gain the benefits of knowledge spillovers from MNCs. With the adaptation of this knowledge through innovation, it is hoped that the SMEs can eventually produce indigenous ICT products and services. However, it is evident that there is little knowledge transfer between ICT MNCs and local SMEs (Sarif and Ismail, 2006). As usual, the problem lies in the low absorptive capability of the SMEs and their reluctance to engage in learning-by-doing.

Direct government participation

To upgrade technological capability, the government participates directly in high-tech industries in the E&E sector by providing training and support services as well as by directly manufacturing high-tech E&E products. The Malaysian Institute of Microelectronic Systems (MIMOS) was set up in 1985 to pursue research, development, and commercialisation activities in microelectronics. MIMOS currently has two subsidiaries: MIMOS Semiconductor, which provides integrated and advanced shared facilities for the E&E sector; and MIMOS Technology Solutions, which generates new technology ventures through innovation, investment, and the transfer of technology. MIMOS Wafer Fab, under MIMOS Semiconductor, provides a wide range of services, such as wafer fabrication, partial processing, failure analysis, wafer testing, and semiconductor wafer fabrication training. It has two R&D facilities, the first of which commenced operations in 1997. MIMOS Technology Solutions is involved in investing MIMOS' technologies into ventures, incubating technology companies, and developing and deploying MIMOS' products and solutions. It also transfers MIMOS' technologies to Malaysian companies for commercialisation.

Khazanah Nasional, the Government of Malaysia's investment arm, was set up in 1994 to manage the government's commercial assets and invest in strategic and high-tech sectors. Its subsidiary, Silterra Malaysia, established in 1995, began wafer fabrication in 2000. Silterra offers circuit design, layout, and simulation, and a broad

range of fabrication processes for integrated chips. Although in terms of revenue the company was one of the top 20 foundries in the world, it has been making losses consistently (Lee, 2014). To increase its competitiveness, Silterra entered into a partnership with MIMOS to produce power management integrated circuit wafers for its global market in 2012.

5.4 | Future Innovation Policies

Future innovation policy initiatives should address the weaknesses in existing structures and policies rather than introduce new ones. The following areas need attention.

5.4.1 Consolidating agencies and institutions in the national innovation system

Too many public agencies, ministries, and institutions are involved in the NIS (Figure 5.4). They implement a large variety of schemes, grants, and initiatives, the interconnectedness of which is not always clear. A recent survey by the Organisation for Economic Co-operation and Development (OECD, 2016) cites sources to suggest that no less than 44 agencies and 10 ministries are engaged in supporting STI. If a narrower perspective is adopted, this number is reduced to 14 agencies and 8 ministries. Regardless of the preferred perspective, there are redundancies and overlapping functions, resulting in a lack of direction in priority setting and the disbursal of research funds. Having too many actors, guided by the interests of their individual ministries, results in the fragmented implementation of policy measures, poor results, and a lack of direction in the national research agenda.

The governance structures of STI policies need to be rationalised to better integrate the agencies and ministries implementing the various schemes and incentives for innovation. Continuous monitoring and evaluation of implementation should be emphasised. It is not uncommon to observe frequent policy changes or new policy initiatives that have no regard for the outcomes of existing policies. The lack of a formal mechanism to systematically monitor and evaluate the outcomes of policies and agents tasked with implementing them is widely acknowledged. Efforts are underway to attempt to address these weaknesses.

5.4.2 Making research and development incentives work

Incentives and grants for R&D are certainly not lacking, but the level of awareness among industries regarding these incentives is either low, or, where awareness exists, the onerous bureaucratic requirements act as major disincentives to apply for them. In 2012, about one-third of manufacturing (and service) companies claimed that they were unaware of such government support, while another 13% found the process of getting assistance too complicated and time-consuming (MOSTI, 2014a).¹¹ As early as 1994, E&E firms in Penang cited the same issues with regard to the government assistance schemes on technology transfer (UNDP, 1994; Narayanan and Lai, 2000).

The dissemination efforts for subsidy schemes from various ministries and agencies need to be coordinated through a central agency in MOSTI, such as MASTIC. Online applications could ease access to available schemes. The complaint of bureaucratic application procedures could be resolved by simplifying procedures in consultation with industries.

5.4.3 Strengthening links

The issue of inadequate university links and ineffective knowledge transfer despite strong government support should be addressed urgently. To strengthen the links, universities must be permitted to operate in a more liberal environment with minimal government intervention. With liberal regulations, universities should prioritise research with commercialisation value. Universities should also be proactive in disseminating information through regular workshops, seminars, and the like to science park firms on the types of market-driven research and facilities available that can assist in their innovation efforts.

Universities must play an active role in identifying and encouraging opportunities for knowledge spillover, as this is extremely important as part of the network of institutions that build bridges between universities and industries located in both science parks and non-science parks. Public research agencies, including universities, should be allowed to operate freely without external interference; they should focus on research with commercialisation potential and must be provided with a platform to disseminate information quickly and efficiently.

¹¹ The vision of transforming the economy to one driven by innovation is a key element in the National Innovation Model (MOSTI, 2007). Yet, more than 60% of manufacturing and services companies surveyed in 2012 had neither heard of, nor understood, this model (MOSTI, 2014a).

To attract major investments from innovative MNCs is not an easy task, given the intense competition from other science and technology parks in the region. Nevertheless, the country must pursue an aggressive strategy to target foreign R&D investments that complement the country's research priorities, and focus on increasing the innovation capacity of local firms, particularly SMEs.

5.4.4 Improving the contribution of patents and intellectual property

The number of patent applications remains at a low level, despite some improvement in recent years (Table 5.4). A contributory factor is the lack of patent comprehension by public agencies. These agencies approve the government-subsidised projects of local manufacturers without requiring intellectual property (IP) creation (MOSTI, 2014c), even though IP creation is a government requirement for approval (MOSTI, 2009). Local firms, thus, do not see the urgency of applying for IP rights unless they are needed to obtain government research funds in the first place. A second factor is the inordinately long time taken to approve applications. Sometimes, inventions become dated by the time approval is granted.¹²

Besides the policy on IP commercialisation, there are many others, including the National Intellectual Property Policy (2007), the Patent Act (1983), and the Trade Marks Act (1976), that seek to protect innovation outcomes. However, strengthening the legal and operational aspects of the national IP system and efficient administration by the Intellectual Property Corporation of Malaysia have not resulted in widespread use of the system or stimulation of the innovation agenda (OECD, 2015).

To improve the contribution of the IP system, including patents, it is necessary to build a governance structure that ensures the coordination of programmes to support IP so that there is no duplication among the initiatives of the various stakeholders and that applications are quickly processed. In recent years, research in public agencies has improved significantly, particularly in universities, where they are evaluated based on performance in research output (publications and patents). The incentive programmes have been effective in creating a pool of researchers engaged in securing patents and other IP. Incentives have also helped create a network of industry partners that did

¹² Patent applications take, on average, about three years to process and approve. There have been cases of patents being granted after seven years, sometimes rendering the patent useless as new ideas have replaced the patented idea.

not exist previously. The incentive programmes should be further refined to focus on the quality rather than the quantity of IPs and patents. This will ensure a higher rate of successful commercialisation.

Collaborative research is the best avenue for SMEs to increase their absorptive capacities and innovation output (Table 5.4). Yet, only 16.5% of firms received technological support from outside institutions in 2005–2006 (Hosseini, 2015). The policy delivery system should be fine-tuned so that they engage SMEs and foster their links with universities and outside institutions. Policies would include providing advice on seeking IP protection for inventions, sourcing IP developed from elsewhere, and commercialising IP. As many SMEs do not have the capacity to create patents, other IP titles, such as trademarks, rights to designs, and utility models, may be more relevant. Policies should thus be broadened beyond the pursuit of patents to improve the innovation performance of SMEs.

5.4.5 Establishing a competitive business environment

Besides increasing resource allocation efficiency and decreasing the distortion in market prices, market competition stimulates invention and innovation as competitors strive to produce new and better products. This was corroborated in the Malaysian context by the PIC-2 study data, which showed that firms in competitive sectors were more likely to engage in innovation (Table 5.5). Creating a flexible, transparent, and secure business environment is also a means of attracting MNCs to relocate their R&D. The implementation of the Competition Act in 2012 was a step in the right direction.

5.4.6 Building the talent pool

A key factor accounting for the limited benefits reaped by SMEs from the advantages of clustering or collaborative research is their inability to absorb new technology. This is directly linked to the lack of skilled talent. Although this aspect has not been discussed in this chapter, the shortage of talent must be addressed. Countries such as Australia, Canada, China, and Singapore have opened their doors to worldwide talent (Zeufack and Lim, 2013); Malaysia should consider doing the same as a short-term measure to ease the talent constraint. In the longer term, the curricula of tertiary education in science and engineering must be reviewed regularly to meet the nation's needs. The enrolment of science and engineering students must also be increased without sacrificing content or quality.

5.5 | Conclusion

Emphasis on innovation received a late start, becoming evident in the late 1980s. Surveys suggest that the incidence of firm-level innovation rose from 21% in 1997 to about 64% in 2006, which is encouraging. However, the lack of maturity of innovation is evident from the fact that the largest concentrations of innovating firms (both large firms and SMEs) were in rubber and plastics and food processing. These are relatively low-tech industries (UNDP and World Bank, 1995). Furthermore, most firms were engaged in adaptation, not creation. There was also a negligible presence of innovating SMEs in the more sophisticated E&E subsector. Most firms in the sector remain as parts suppliers to MNCs, leaving little room for independent innovation.

Patent counts were low, although they have been rising. Even so, the patent counts fail to recognise the differences in technologies underlying these patents (Gayle, 2001). Product differentiation leads to numerous patents of minor changes to existing technologies or products. These become patents for product differentiation rather than for new ideas.

Firm-level innovation was largely through collaborative research and technology from the parent establishment; access to technology through SME links with MNCs was not widespread. In addition, although horizontal and vertical (backward) spillovers from foreign firms exist, forward spillovers were not detected.

Macro indicators of innovation also showed improvements over time, although they still lag China, a relative latecomer. These improvements, however, did not bolster Malaysia's global standing, as measured by innovation indices. During 2014–2016, Malaysia's rankings in both the GII and the GCI fell.

Several weaknesses in the implementation, monitoring, and application procedures with respect to innovation policies and schemes have undermined their effectiveness. The NIS, too, has developed in an ad hoc manner and needs urgent rationalisation. Addressing these weaknesses can help Malaysia increase its momentum in innovation.

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Innovation Policy in the Philippines

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6.1 | Introduction

Philippine industries are facing the challenge of a rapidly changing global environment brought about especially by developments in technology, as well as advancements in research and data science that have created new products and services. These forces have modified how Filipino firms do business. Now, more than ever, the innovation agenda is taking root since there is growing recognition that innovation is a game changer. Firms practising innovative behaviour are more productive, and the country and its people can remain competitive if more firms are part of an innovation ecosystem (Llanto and del Prado, 2015).

Often equated with research and development (R&D), innovation is actually distinct from R&D; it is better viewed as the application of new products, processes, or methods in business, the workplace, or external relations (OECD/Eurostat, 2005). In developing countries, such as the Philippines, innovation is often not about something brand new but something new to society, which, if and when broadly disseminated, can bring significant economic, social, or environmental change. It can lead to the establishment of new businesses and new business processes, consequently contributing to growth through increased employment opportunities in firms that practice innovation. New processes can lead to production techniques that make more efficient use of a country's resources. In order for the Philippines to reap the potential benefits of an innovative industrial sector, a national innovation strategy is critical. The strategy would identify the roles and links of key stakeholders in the innovation ecosystem – academe, industry, government, and the external sector.

This chapter aims to provide inputs for the formulation of an innovation strategy for the Philippines by firstly looking at the current state of innovation activity across business and industry in the country based on a survey conducted by the Philippine Institute for Development Studies (PIDS). It will also review past policies and discuss exemplary cases of innovation activities that can be helpful to draw lessons for formulating a coherent set of policies that foster innovation.

6.1.1 Outline

The chapter is organised as follows. The first section presents an overview of innovative behaviour among local firms using the results of the 2015 PIDS Survey of Innovation Activities (PSIA). It describes the determinants of innovation activity (including wider forms of innovation), making use of firms that responded to both the 2015 PSIA and the pilot 2009 Survey of Innovation Activities (SIA).¹ It also discusses the importance of knowledge management activities, cooperation partners, and the sources of innovation of firms. Building on the profile of innovation activities in Philippine firms presented in the first section, the second section presents the evolution of innovation policy in the country from the 1990s to the present. The third section then describes notable cases of innovation policy or innovation activity from which lessons on building a national innovation strategy can be drawn. The last two sections summarise lessons from the earlier sections and provide some concluding remarks.

6.2 | Current Situation of Innovation of Local Firms

6.2.1 Description of innovation activity

In 2009, the Department of Science and Technology (DOST), in cooperation with the then National Statistics Office and the PIDS, and with funding support from the International Development Research Centre, conducted a pilot SIA. More than five years later, the PIDS conducted the 2015 PSIA² with the assistance of the Philippine Statistics Authority.

¹ See Albert et al. (2013) for details on the 2009 SIA.

² See Albert et al. (2017) for a discussion on the results of the 2015 PSIA.

The results of the 2015 PSIA show that about two-fifths (43%) of establishments in 2015 were innovation active (Table 6.1). A firm is deemed to be innovation active if it is:

- (i) a product innovator that introduced new or significantly improved goods or services;
- (ii) a process innovator that introduced (a) new or significantly improved methods of manufacturing or producing goods or services; (b) new or significantly improved logistics, delivery, or distribution methods for their inputs, goods, or services; (c) new or significantly improved supporting activities for their processes, such as maintenance systems or operations for purchasing, accounting, or computing;
- (iii) engaged in innovation projects that are either not yet complete or abandoned; or
- (iv) engaged in expenditure on innovation activities for internal or outsourced R&D, training, acquisition of external knowledge, machinery, equipment, or software linked to innovation activities, market introduction of innovations, and other preparations to implement innovations.

The 2015 figure is lower than the corresponding statistics from the 2009 SIA, which suggest that 54.4% of sampled firms in 2009 were innovation active. The difference in the survey results is partly a result of the lack of comparability in survey designs. The 2009 SIA, being a pilot run, only targeted about 500 firms from four select study areas in three purposely chosen industries – food manufacturing, electronics manufacturing, and information and communication technology (ICT) – that were likely to practise innovative behaviour. The 2015 PSIA, on the other hand, was designed to be more nationally representative, with sampled firms chosen from four industries – food manufacturing, other manufacturing, ICT, and business process outsourcing (BPO) – with twice the sample size of the 2009 SIA and with all of the 2009 SIA firms targeted for interview. Consequently, the results for the 2009 survey are descriptive, while those from 2015 may be inferred across a broader population of firms in the country.

Disaggregating by establishment size shows that in 2015, large establishments were more likely to engage in innovation activities than micro, small, and medium-sized enterprises (MSMEs), given that two-thirds of large establishments were innovation active. In contrast, only about one-third of micro establishments were innovation active (Table 6.1). Similar findings are observed in the 2009 SIA.

Roughly one-third of the establishments (30.6%) were process innovators (Table 6.2). A similar proportion of firms were product innovators (30.7%). While local firms more commonly engaged in process innovations than product innovations in the 2009 SIA, this was no longer the case in the 2015 PSIA.

Table 6.1: Key Statistics on Innovation by Activity and Major Industry

Innovation Activity	Food Manuf.	Other Manuf.	ICT	BPO	All Firms
Proportion (%) of establishments that are/have:					
Innovation active	35	47	57	34	43
Product innovators	24	35	38	13	31
Of which share with new-to-market products	21	21	23	7	21
Process innovations	27	37	26	10	31
Of which share of those that developed process innovation within the establishment or enterprise	27	36	25	10	30
Both product and process innovators	23	30	17	10	25
Either product or process innovators	29	43	47	13	37
Ongoing innovation activities	27	32	36	26	30
Abandoned innovation activities	9	10	11	4	9
Innovation-related expenditure	26	24	36	27	27
Memo note:					
Average annual expenditures for innovation activities (₱ thousand)	855	4,185	3,724	12,462	2,935
Proportion of expenditure on innovation from total gross sales (%)	5	3	16	3	6
Proportion (%) of establishments that are/have:					
Public financial support for innovation	2	4	4	2	3
Innovation cooperation	37	45	38	55	41
Organisational innovations	34	39	47	21	38
Memo note:					
Average share of employees affected by establishment's organisational innovations (%)	55	48	62	67	54
Proportion (%) of establishments that are/have:					
Marketing innovators	38	38	48	16	39
Knowledge management practices	44	38	51	59	43
Government support or assistance to innovation	38	31	24	42	32

BPO = business process outsourcing, ICT = information and communication technology, manuf. = manufacturing.

Source: 2015 Philippine Institute for Development Studies Survey of Innovation Activities.

Table 6.2: Key Statistics on Innovation by Activity and Size

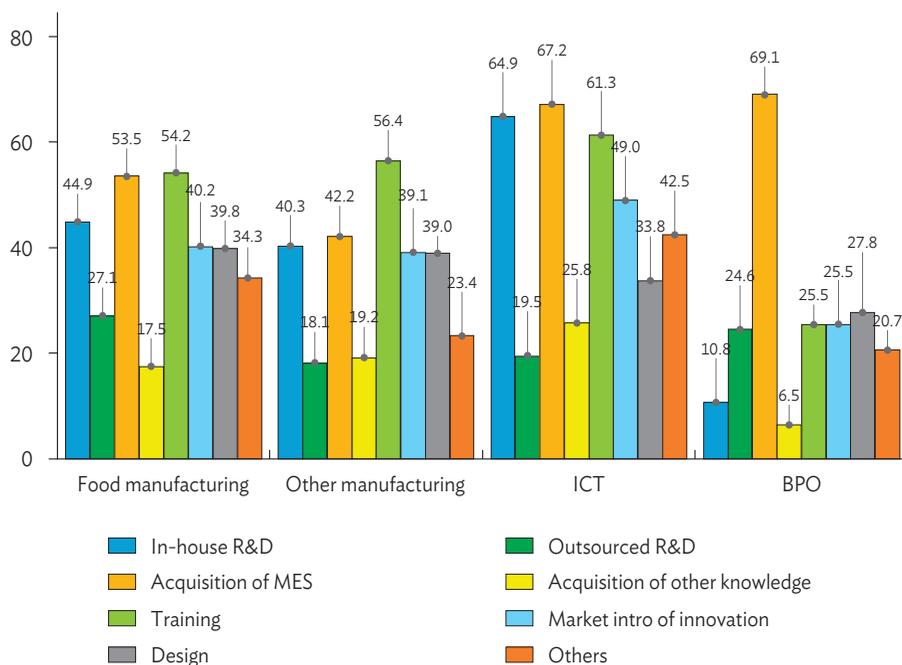
Innovation Activity	Micro	Small	Medium	Large	All Firms
Proportion (%) of establishments that are/have:					
Innovation active	34	50	46	63	43
Product innovators	27	34	30	39	31
Of which share with new-to-market products	19	23	19	23	21
Process innovations	23	37	36	47	31
Of which share of those that developed process innovation within the establishment or enterprise	22	36	34	44	30
Both product and process innovators	21	27	27	34	25
Either product or process innovators	29	43	39	52	37
Ongoing innovation activities	20	38	36	51	30
Abandoned innovation activities	8	10	5	16	9
Innovation-related expenditure	21	30	29	43	27
Memo note:					
Average annual expenditures for innovation activities (₱ thousand)	209	2,392	7,547	30,494	2,936
Proportion of expenditure on innovation from total gross sales (%)	10	3	2	3	6
Proportion (%) of establishments that are/have:					
Public financial support for innovation	1	5	1	4	3
Innovation cooperation	35	47	44	32	41
Organisational innovations	34	40	41	53	38
Memo note:					
Average share of employees affected by establishment's organisational innovations (%)	60	49	47	55	54
Proportion (%) of establishments that are/have:					
Marketing innovators	37	40	37	43	39
Knowledge management practices	35	47	60	67	43
Government support or assistance to innovation	25	37	43	37	32

Source: 2015 Philippine Institute for Development Studies Survey of Innovation Activities.

One observation that persisted from the pilot 2009 SIA to the 2015 PSIA is the concurrent conduct of product and process innovations during the same period by a number of firms. Of the establishments that had product innovation, a bigger share also had process innovation than those that only had product innovation. The same can be said for process innovation.

Across industries, manufacturers of goods and services other than food, and the ICT industry are the most innovation active, with about half of firms being innovation active. In contrast, the BPO sector is the least innovation active among the four industries: about 3 in 10 firms were reported to be innovation active. Despite this observation, BPO firms have an average annual expenditure for innovation activities of about ₱12.5 million – the highest expenditure for innovation activities across industries. Other manufacturing is a distant second with an average annual expenditure of ₱4.2 million.

Figure 6.1: Breakdown of Innovation Activities by Industry Group (%)

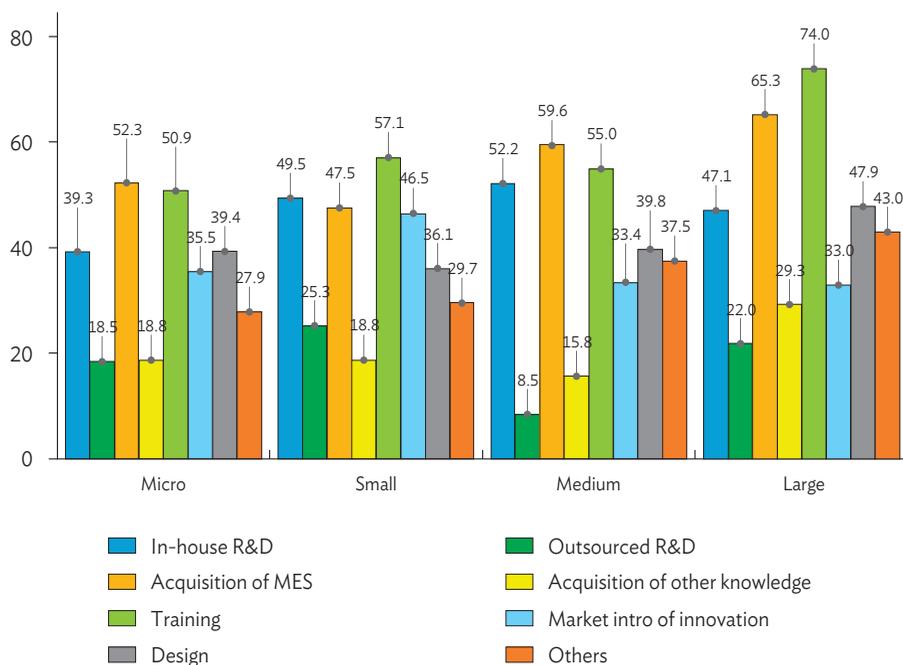


BPO = business process outsourcing; ICT = information and communication technology; MES = machinery, equipment, and software; R&D = research and development.

Source: 2015 Philippine Institute for Development Studies Survey of Innovation Activities.

In 2009, 40% of all establishments had some innovation-related expenditure, but in 2015, the corresponding proportion was only 26.7%. Figures 6.1 and 6.2 show how innovation-related expenditure was allocated. In general, training was the most common innovation activity in which firms invested during the survey period. For BPO firms, the acquisition of computer hardware was the most common innovation activity, while in-house R&D and the acquisition of knowledge from other sources was the least common. For the other industrial groups, the most common innovation activities were training; the acquisition of machinery, equipment, and software; and in-house R&D. Regardless of industry group, the acquisition of knowledge from other sources was the least common innovation activity for firms (Figure 6.1). Training; the acquisition of machinery, equipment, and software; and in-house R&D were common innovation activities for all firms, regardless of size (Figure 6.2). For micro and small establishments, allocating innovation expenditure for the introduction of innovations to the market was quite common; something which, in contrast, was not observed for medium-sized or large firms.

Figure 6.2: Breakdown of Innovation Activities by Size (%)



BPO = business process outsourcing; ICT = information and communication technology; MES = machinery, equipment, and software; R&D = research and development.

Source: 2015 Philippine Institute for Development Studies Survey of Innovation Activities.

6.2.2 Sources of information, cooperation, and knowledge management

Technical advice, guidance, or even inspiration for innovation may come from a number of sources, both internal and external. In order for the government to formulate policies and interventions for improving information exchange, it is necessary to obtain information on the degree to which firms engage with external sources of innovation-related information. Table 6.3 presents firms' responses regarding the degree of relationship with their sources of information on innovation. The sources of information can be grouped into four main categories: internal sources, the market as an information source, institutional sources, and other sources.

Table 6.3: Proportion of Establishments Rating Information Sources as of Medium or High Importance, by Size of Establishment (%)

Information Source	Subcategory	Micro	Small	Medium	Large	All Firms
1. Internal source	a. Within the establishment or enterprise	68	64	72	75	67
2. Market source	a. Suppliers of equipment, materials, components, or software	75	58	61	60	64
	b. Clients or customers	72	69	63	63	69
	c. Competitors or other establishments in the sector	53	42	58	45	47
	d. Consultants, commercial laboratories, or private research and development institutes	25	24	41	36	26
3. Institutional source	a. Universities or other higher education institutions	21	17	17	18	19
	b. Government or public research institutes	30	13	26	19	20
4. Other source	a. Conferences, trade fairs, exhibitions	44	40	52	51	43
	b. Scientific journals and trade/technical publications	32	21	34	36	26
	c. Professional and industry associations	32	30	48	39	32

Source: 2015 Philippine Institute for Development Studies Survey of Innovation Activities.

For all establishments, regardless of size, the sources of information that were considered most important for the firms were the firm itself (internal), its customers, and its suppliers. Regardless of size, the least important sources of information were institutional: universities and government. Interestingly, 30% of micro establishments – a rather large proportion – saw government or public research institutes as important sources of information because, given their limited resources, these firms found value in receiving free assistance from government or public research institutes (Table 6.3).

Most establishments sourced information on innovation and technology internally (67%) or from the market (69%), i.e. clients, followed closely by suppliers (64%) of equipment, components, materials, or software (Table 6.4). Similar patterns can be seen in almost all industries. The exception is the BPO sector, where the most important sources of innovation information were suppliers, clients, and competitors.

Table 6.4: Proportion of Establishments Rating Information Sources as of Medium or High Importance, by Type of Industry (%)

Information Source	Subcategory	Food Manuf.	Other Manuf.	ICT	BPO	All Firms
1. Internal source	a. Within the establishment or enterprise	65	73	57	32	67
2. Market source	a. Suppliers of equipment, materials, components, or software	70	62	55	78	64
	b. Clients or customers	74	68	64	78	69
	c. Competitors or other establishments in the sector	48	45	48	74	47
	d. Consultants, commercial laboratories, or private research and development institutes	20	28	32	25	25
3. Institutional source	a. Universities or other higher education institutions	16	17	29	15	19
	b. Government or public research institutes	29	16	14	15	20
4. Other source	a. Conferences, trade fairs, exhibitions	52	38	38	25	43
	b. Scientific journals and trade and technical publications	30	25	22	25	26
	c. Professional and industry associations	31	32	38	26	32

BPO = business process outsourcing, ICT = information and communication technology, manuf. = manufacturing.

Source: 2015 Philippine Institute for Development Studies Survey of Innovation Activities.

These survey results echo those of the 2009 SIA: for innovation-related information, firms tended to rely on their own experience and knowledge as well as information from customers and suppliers.

For innovation-active establishments, about two-fifths (42%) cooperated with other establishments or with non-commercial institutions when they implemented their innovation activities. Cooperation in innovation was highest among BPO firms and least common in food manufacturing establishments (Table 6.1). Examining cooperation by firm size, we find that small and medium-sized firms had more frequent cooperation engagements than micro or large firms (Table 6.2).

Among innovation-active collaborators, most had agreements that operated within the country (domestic agreements). These firms were least likely to cooperate with companies in the Association of South East Asian Nations (ASEAN) Member States. The most common partners for cooperation among innovation-active firms were their suppliers (93%), other establishments within its enterprise (90%), and private sector clients (85%). Government or public research institutes (61%), and universities or higher education institutions (64%) were the least likely partners for cooperation on innovation (Table 6.5).

Table 6.5: Proportion of Innovative and Cooperative Firms by Cooperation Partner (%)

Cooperation Partner	Local	Other ASEAN	All Other Countries	Any
1. Other establishments within the enterprise	87	2	9	90
2. Suppliers of equipment, materials, components, or software	81	10	21	93
3. Clients or customers from the private sector	78	2	8	85
4. Clients or customers from the public sector	70	0	2	72
5. Competitors or other establishments in the sector	75	1	5	79
6. Consultants, commercial laboratories, or private research and development institutes	68	-	3	69
7. Universities or higher education institutions	64	-	1	64
8. Government or public research institutes	61	-	1	61

ASEAN = Association of Southeast Asian Nations.

Source: 2015 Philippine Institute for Development Studies Survey of Innovation Activities.

Since innovation is driven by the generation and diffusion of knowledge, it is also important to look at knowledge management practices as these practices involve activities related to the capture, use, and sharing of knowledge in organisations. Almost 30% of all firms performed regular updates of internal databases and manuals of good practices, lessons learned, or expert advice, while about 28% of firms had a written knowledge management policy. Also worth highlighting is that the proportion of BPO firms that regularly updated their internal databases of good working practices, lessons learned, or expert advice (56%) was much higher than the corresponding proportion of firms in other industries (Table 6.6).

Table 6.6: Knowledge Management Practices by Sector

Proportion (%) of firms having:	Food Manuf.	Other Manuf.	ICT	BPO	All Firms
1. A written knowledge management policy	28	26	26	42	28
2. Incentives for employees to share knowledge within the establishment	27	20	32	44	25
3. Dedicated resources to monitor and obtain knowledge from outside the establishment	24	19	23	41	22
4. A policy to bring in external experts from universities, research institutes, or other establishments to participate in project teams as needed	17	14	13	34	15
5. Regular updates of internal databases or manuals of good working practices, lessons learned, or expert advice	26	30	35	56	30

BPO = business process outsourcing, ICT = information and communication technology, manuf. = manufacturing.

Source: 2015 Philippine Institute for Development Studies Survey of Innovation Activities.

As firm size increases, the conduct of knowledge management activities also tends to increase. For instance, fewer than 23% of micro firms had a written knowledge management policy or regularly updated databases or manuals of good practices, but for small, medium-sized, and large firms, the proportions undertaking such knowledge management activities were about 34%, 44%, and 57%, respectively. The least-popular practice across all firms, regardless of size, was having a policy on the use of external experts from universities, research institutes, or other establishments (Table 6.7).

Another indicator of innovation activity is applications for intellectual property, especially inventions and utility models. In general, intellectual property applications have been very low across all industries and all types of intellectual property.

Table 6.7: Knowledge Management Practices by Firm Size

Proportion (%) of firms having:	Micro	Small	Medium	Large	All Firms
1. A written knowledge management policy	23	30	41	42	28
2. Incentives for employees to share knowledge within the establishment	20	28	33	42	25
3. Dedicated resources to monitor and obtain knowledge from outside the establishment	17	25	35	37	22
4. A policy to bring in external experts from universities, research institutes, or other establishments to participate in project teams as needed	11	19	21	20	15
5. Regular updates of internal databases or manuals of good working practices, lessons learned, or expert advice	22	34	44	57	30

Note: Numbers are weighted shares.

Source: 2015 Philippine Institute for Development Studies Survey of Innovation Activities.

Table 6.8: Proportion of Firms with Intellectual Property Applications (%)

Type of Application	Food	Electronics and Other Firms	ICT	BPO	All Firms
Patent	6	6	7	3	6
Trademark	12	10	11	3	11
Copyright	1	6	10	5	5
Utility model registration	1	7	4	3	4
Design registration	3	8	4	3	5
Brand name	19	11	16	3	14

BPO = business process outsourcing, ICT = information and communication technology.

Note: Numbers are weighted shares.

Source: 2015 Philippine Institute for Development Studies Survey of Innovation Activities.

Utility model applications are lowest among the types of intellectual property applications, while brand names and trademarks are the highest (Table 6.8). This is understandable as it is quite common for firms to rely on secrecy to maintain or increase their competitiveness (Table 6.9).

6.2.3 Determinants of innovation activity

To obtain information on the determinants of innovation activity, we conducted panel data analysis on the firms that were interviewed in both rounds of the innovation surveys (2009 and 2015). Using panel logit random effects models, we identified

Table 6.9: Proportion of Firms Using Intellectual Property Products to Maintain or Increase Competitiveness (%)

Intellectual Property Product	Food Manuf.	Other Manuf.	ICT	BPO	All Firms
Patents	14	10	16	5	12
Utility model registration	9	11	14	3	11
Design registration	12	12	15	3	12
Copyright	8	12	21	3	12
Trademarks	20	15	22	1	18
Lead time advantages	19	18	25	5	19
Complexity of goods	24	16	28	8	21
Secrecy	16	15	20	8	16

BPO = business process outsourcing, ICT = information and communication technology, manuf. = manufacturing.

Note: Numbers are weighted shares.

Source: 2015 Philippine Institute for Development Studies Survey of Innovation Activities.

whether or not a variable helps explain how likely it is for establishments to be product innovators, process innovators, or innovators in general. We also used econometric models to examine the likelihood of firms having wider forms of innovation, such as marketing innovations or organisational innovations. Following Albert et al. (2013), the following variables were included in the panel logit model: employment size, age of the firm, geographic market, share of foreign capital participation, major industry group, location (i.e. whether or not a firm is in an export processing zone), and engagement in knowledge management practices.

The results of the panel data estimation are presented in Table 6.10. The practice of knowledge management is an adequate determinant of innovation behaviour for the ratios for innovation active, product innovator, process innovator, marketing innovator, and organisational innovation. The size of the company is also a significant determinant of being innovation active and particularly of process innovation. Other things being equal, food manufacturing establishments are more likely to be innovation active, product innovators, or process innovators relative to BPO firms. Electronics manufacturing or ICT establishments are equally likely to innovate as BPO firms, all other things being equal. The area where firms are located, particularly whether or not the establishment is located in an export processing zone, is not a significant determinant of innovation activity, product innovation, or process innovation, but it is marginally significant in explaining marketing innovation behaviour.

Table 6.10: Determinants of Innovation Activity Using Panel Data, Odds Ratios

Variables		Odds Ratios Estimated Using Panel Logit Regression				
		Innovation Active	Product Innovator	Process Innovator	Marketing Innovator	Organisational Innovator
Km	Indicator variable whether or not firm practises knowledge management	4.718*** (1.33)	4.177*** (1.09)	5.046*** (1.40)	4.869*** (1.37)	10.43*** (3.06)
Local	Indicator variable whether or not firm's geographic market is only local market	1.20 (0.37)	0.96 (0.27)	1.36 (0.37)	1.01 (0.27)	1.32 (0.35)
Foreign	Share of foreign capital participation in establishment	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.000** (0.00)
Femshare	Share of employment of women to total employment	1.00 (0.01)	1.00 (0.01)	1.00 (0.01)	1.00 (0.01)	1.01 (0.01)
Age	Number of years since establishment of firm	1.00 (0.01)	1.00 (0.01)	1.01 (0.01)	1.00 (0.01)	0.99 (0.01)
Foodgrp	Indicator variable whether or not firm is in food manufacturing	3.270** (1.62)	2.671** (1.32)	2.251* (0.93)	1.69 (0.70)	1.49 (0.61)
Othmanufgrp	Indicator variable whether or not firm is in other manufacturing, including electronics manufacturing	1.48 (0.68)	1.95 (0.91)	1.52 (0.63)	0.80 (0.32)	1.29 (0.55)
Ictgrp	Indicator variable whether or not firm is in ICT	1.87 (0.77)	1.92 (0.91)	1.68 (0.65)	1.09 (0.39)	0.95 (0.40)
Logsize	Log of employment size	1.218** (0.11)	1.11 (0.10)	1.162** (0.09)	0.91 (0.08)	1.10 (0.09)
Peza	Indicator variable whether or not firm is located in an export processing zone	1.22 (0.40)	1.01 (0.33)	1.15 (0.32)	0.576* (0.17)	0.82 (0.27)
Constant	Constant	0.0658*** (0.05)	0.0594*** (0.05)	0.0562*** (0.04)	0.469 (0.31)	0.109*** (0.07)
Observations		464	464	464	464	464
Number of id		232	232	232	232	232

() = robust standard error, ICT = information and communication technology.

*** p<0.01, ** p<0.05, * p<0.1.

Source: Authors' calculations using 2009 Survey of Innovation Activities and 2015 Philippine Institute for Development Studies Survey of Innovation Activities.

The earlier discussion raises important policy issues, particularly about cooperation between universities, the government, and firms. The following sections provide the context on how the policy environment might affect the innovation behaviour of firms.

6.3 | History of Innovation Policy in the Philippines

A survey of Philippine development plans from the 1990s reveals that the country's planners did not see the need for an explicit national innovation strategy until recently.³ Even the measurement of innovation in the country has been only conducted recently, starting with the pilot SIA in 2009, whereas its ASEAN neighbours, Malaysia, Singapore, and Thailand, conducted their first innovation surveys in 1995, 1999, and 2003, respectively. The Government of the Philippines, however, recognised the importance of science and technology (S&T), especially in terms of the sector's contribution to industrial development and poverty reduction. Fiscal constraints have led public expenditures in R&D in the country (relative to gross domestic product) to fall behind the corresponding spending rates in Malaysia, Singapore, and Thailand.

Since the Ramos administration (1992–1998), many S&T plans and projects have been formulated. In 1993, the Science and Technology Agenda for National Development Plan was initiated. The goal of the plan was to support the seven sectors identified by the Department of Trade and Industry (DTI) as export winners: computer software; fashion accessories; gifts, toys, and housewares; marine products; metal fabrication; furniture; and dried fruits. The plan also identified, through the Presidential Council for Countryside Development, 11 key domestic needs: food, housing, health, clothing, transportation, communication, disaster mitigation, defence, environment, manpower development, and energy. Three supporting industries – packaging, chemicals, and metals – were also identified to be key sectors because of their link with most, if not all, of the sectors mentioned. Finally, the coconut industry was especially identified for support. Also during the Ramos administration, several key pieces of legislation related to S&T were passed: the Magna Carta for Scientists, Engineers, Researchers, and Other Science and Technology Personnel in Government, or Republic Act (RA) 8439; the Science and Technology Scholarship Act of 1994 (RA 7687); the Investors and Inventions Incentives Act (RA 7459); and the Intellectual Property Code of the Philippines (RA 8293) (Cororaton, 2002; Ancog and Aquino, 2007).

³ Macapanan conducted an innovation survey in 1999 covering the food processing; textile and garments; metals and metal fabrication; chemicals; and electronics and electrical sectors. However, documentation of sampling design is not available in the final report. Thus, the first national survey of innovation activity that is considered in this review is the SIA conducted by the then National Statistics Office.

The Estrada administration (1998–2000) built on the work of the Ramos administration by incorporating the government’s poverty alleviation agenda into its S&T plan, entitled *Competence, Competitiveness and Conscience: The Medium-term Plan of the DOST (1999–2004)* (Cororaton, 2002). Programmes under this Estrada S&T plan included S&T interventions for the poor, vulnerable, and disabled, and those for the development of Mindanao, acknowledged then as one of the poorest areas in the country. Despite being short-lived, the administration saw the passage of the Electronic Commerce Act (RA 8792), which provided opportunities for the emergence of new Internet-driven businesses.

During the Arroyo administration (2000–2010), the National Innovation Strategy was coined as ‘Filipinnovation’ (Albert et al., 2013; Llanto, 2013). It focused on four components: strengthening human capital investments; stimulating science, technology, and innovation (STI); enhancing the management of the STI system; and upgrading the Filipino mindset. Table 6.11 presents specific courses of action for each of these components.

The DOST also spearheaded several programmes aimed at achieving the aforementioned components through the Small Enterprise Technology and Upgrading Program (SETUP), which aimed to improve the productivity and efficiency of MSMEs by addressing their technological needs and limitations. The program’s innovation support system allowed MSMEs to acquire industry-standard equipment, thereby, upgrading their facilities and production efficiency (Alabastro, 2004). The Technology Incubation for Commercialization (TECHNICOM) Program was launched in response to the need to fast-track the transfer and commercialisation of promising R&D results.

For the administration of Benigno Aquino III (2010–2016), innovation policy was subsumed within the goal of achieving globally competitive and innovative industries and services sectors (NEDA, 2014). To improve local industries’ competitiveness, four strategies were identified in the Philippine Development Plan 2011–2016: (i) broadening the access of small-scale entrepreneurs to modern, cost-effective, and appropriate technologies; (ii) providing publicly funded state-of-the-art facilities open to local companies pursuing the creation of new products or other innovation activities; (iii) leveraging ICT as a means of providing more economic opportunities; and (iv) strengthening networks to foster cooperation and information exchange among Filipino scientists and engineers.

Table 6.11: *Filipinnovation* Strategies, Tactics, and the Action Agenda

Strategy	Tactics	Action Agenda
Strengthening human capital	Formation of multi-sectoral consortia of institutions and/or experts working towards achieving strong technological research and development capabilities (tech) and management or services skills (non-tech) that will influence industries and public policy	<ol style="list-style-type: none"> 1. Initiating competitive innovation in basic education 2. Establishing multi-stakeholder links 3. Upgrading skills and knowledge to better adapt to local and global demands through postgraduate education and other forms of lifelong learning 4. Developing human resources with advanced knowledge and expertise
Supporting business incubation and acceleration efforts	Encourage industry participation in incubation and human capital collaboration to ensure productivity and returns through innovation	<ol style="list-style-type: none"> 1. Identifying and managing avenues for collaboration 2. Increasing government investments in physical infrastructure to support business technology innovation and acceleration 3. Engaging available existing Filipino talents and resources for business incubation and acceleration, including those of the overseas Filipino community 4. Adopting a new business incubator model
Regenerating the innovation environment	Engage stakeholders in the creation of clear government policies and efficient procedures that encourage innovative behaviour	<ol style="list-style-type: none"> 1. Creating an innovation strategy championed by public and private sector executives 2. Increasing innovation awareness and understanding in legislation 3. Levelling the playing field by setting a policy environment that supports competition (i.e. a sound intellectual property regime)
Upgrading the Filipino mindset	<i>Filipinnovation</i> : branding Filipino competitive innovation for sustainable development and global positioning	<ol style="list-style-type: none"> 1. Increasing the role of multimedia in highlighting the essence and benefits of innovation in society 2. Having an intellectual property regime that is neither restrictive nor regulatory, but rather serves as a repository of innovative ideas that can inspire others to innovate competitively as well 3. Aid in increasing public awareness that competitive innovation entails a multidisciplinary approach 4. Foster a culture of entrepreneurship through innovation

Source: Velasco (2009) as cited by Llanto (2013).

Also during the Aquino administration, the DOST released the Harmonized National R&D Agenda 2013–2020, which aligned its R&D policy with that of the Philippine Development Plan 2011–2016. It also updated the National Science and Technology Plan 2002–2020, providing more substance to the long-term plan. Innovation policy was also embedded in the use of S&T for attaining the following key results areas: poverty reduction and empowerment of the poor and the vulnerable, rapid and

inclusive and sustained economic growth, and integrity of the environment and climate change adaptation and mitigation. Related to the strategy for poverty reduction, the government identified eight key industries where STI was expected to have large contributions: semiconductor and electronics, healthcare, IT and business process management, agriculture, mining and minerals processing, transport, manufacturing, and metals engineering. For climate change mitigation and adaptation, the key R&D areas included weather and flood forecasting and climate change modelling, water security, climate-resilient agriculture, climate change mitigation, urban planning, and disaster risk reduction.

Related to these strategies was the establishment of government facilities to support domestic industries. Examples include:

- the Advanced Device and Materials Testing Laboratory, catering to the needs of the semiconductor and electronics industry;
- the Die and Mold Solutions Center, servicing the needs of the metals industry; and
- the Electron Beam Irradiation Facility at the Philippine Nuclear Research Institute, which caters to the needs of industries in the spices and dehydrated foods, cosmetics, packaging, and medical devices sectors.

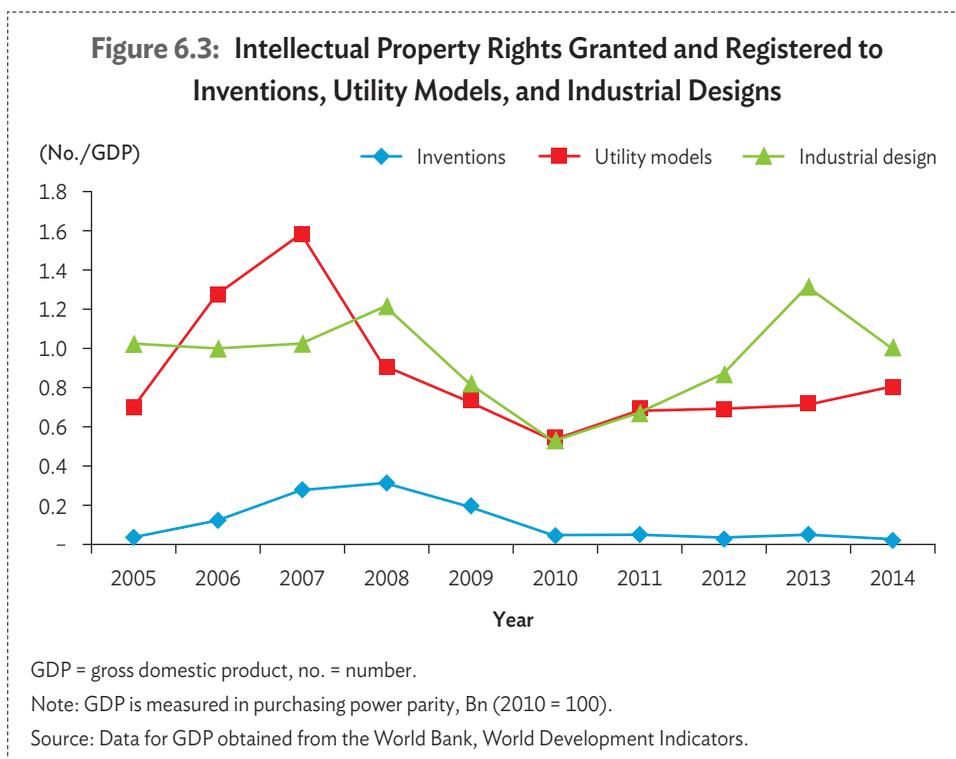
These publicly funded facilities aim to enable local industries to move up their respective value chains and become more competitive by providing services that might otherwise be too costly for MSMEs (DOST, 2014).

The current Duterte administration (2016–2022) sees STI as a means of establishing the foundation for strategic growth, a high-trust and resilient society, and a globally competitive knowledge economy. The strategy is two-pronged: to promote and accelerate the use of technology and innovation in all production sectors, and to increase innovation by enhancing the capacity to generate knowledge and strengthen collaboration across the STI ecosystem (NEDA, 2017). Under this administration, the DOST is implementing four new programmes:

- The Collaborative Research and Development to Leverage Philippine Economy (CRADLE) Program aims to create a synergistic relationship between academe and industry by providing funding to higher education institutions (HEIs) or R&D institutions undertaking research to solve problems troubling private sector industries.

- The Niche Centers in the Regions For R&D (NICER) Program intends to capacitate HEIs in regions of the Philippines to conduct quality research by providing institutional grants to improve the HEIs' S&T infrastructure.
- The R&D Leadership Program (RDLead) attempts to engage experts to be in charge of strengthening the research capabilities of the HEIs or R&D institutions. Together with the NICER Program, RDLead aims to help HEIs improve and hasten the use of research results that will contribute to the development of the country.
- The Business Innovation through S&T for Industry Program aims to facilitate Filipino companies' acquisition of strategic technologies by providing financial assistance that can be used for the acquisition of high-tech equipment and machinery, technology licences, and/or patent rights.

Despite these well-thought-out interventions and the accomplishments of major programmes of the DOST, S&T indicators have seen only very small improvements. For instance, gross expenditure on R&D as a percentage of gross domestic product has remained at about 0.15% – way below the 1% prescribed by the United Nations Scientific, Educational and Cultural Organization. Another tell-tale sign of a beleaguered S&T sector is the stagnant registering and granting of patents for inventions and utility models (Figure 6.3).



There are bright spots, however. The number of graduates in science and engineering is increasing, as is the number of capable young researchers. A slight improvement in the number of collaborations among HEIs and industry has also been observed despite some industries finding collaborations with HEIs complicated (STRIDE, 2014).

Tracing the Philippines' STI policy through the years reveals several issues in STI governance. First, STI policy has always been viewed as a supporting actor in the quest for economic and social development. S&T programmes have always been viewed in relation to priority sectors in the Philippine development plans. Second, there is a dearth of empirical studies on the effectiveness of the plans, which has resulted in S&T development objectives being retained across administrations (Mani, 2002; Ancog and Aquino, 2007). Finally, the S&T plans by themselves are clearly not making a dent given the limited resources being incorporated in them. Often, the plans already take into account the limited R&D spending in the country.

Regardless of the policy environment, the private sector has managed to conduct innovation activities. The following sections present successful cases of innovation collaborations from which lessons can be learned. These lessons can feed into new plans to foster the innovation ecosystem and mainstream innovation in the policy context.

6.4 | Case Studies of Successful Innovation Activities and Policies

6.4.1 Framework for the selection of case studies

This section presents case studies of successful innovation activities. The cases were chosen to illustrate some of the examples identified by Fukugawa (2017) on how to help firms innovate. Fukugawa (2017) identified the importance of a patent system that guarantees that inventors are able to exclude others from the patented technology, especially for technological fields where the social rate of return to R&D is high but the private return is low.

The cases of the automotive, food processing, and pharmaceutical sectors illustrate how firms in these sectors use external sources of knowledge. They highlight how firms in these sectors learn from various channels. In several of these cases, public research institutes are important innovation intermediaries. Government projects, science

parks, and innovation hubs function as innovation intermediaries that can facilitate innovation by providing physical and social capital, which the firm may be lacking. The case study of QBO and UP–Ayala Land TechnoHub shows how supporting entrepreneurship is a key to innovation.

6.4.2 Innovation in the automotive sector

Despite its relatively small contribution to manufacturing gross value-added, the automotive sector is a key sector identified in the country's industrial plan because of its industrial links and the potential for employment generation. The case study by Quimba and Rosellon (2011), covering nine automotive firms (parts and components manufacturers and assemblers), urged the DOST to continue and strengthen its technology transfer programmes, such as SETUP and TECHNICOM, to assist automotive parts manufacturers in translating their awareness of the importance of technology and innovation into actionable plans and innovation activities (Box 6.1). Three firms ranked highly in assessing and selecting technology. This underscores the importance of having strong connections with local research institutions and government agencies as these are common sources of information on technology and innovation. External links helped build the capacity of the three high-ranking firms to improve the level of technology and expertise in their respective companies.

The case study also revealed the common issue of automotive parts manufacturers relying on parent companies for their technology upgrading. Parent companies choose to transfer technology, albeit with some apprehension, to their subsidiaries or affiliates in the country in order to improve their technical capabilities and production efficiency. To allay the concerns of foreign parent companies regarding the transfer of technology to local manufacturers, a consistent and reliable policy on intellectual property rights is required.

6.4.3 Innovation in the food manufacturing sector

Del Prado and Rosellon (2017) identified the successful case of a partnership between a firm and its suppliers, supported by government and other innovation intermediaries (Box 6.2). The experience of Firm B, a small, locally owned fruit juice manufacturer, highlights the value of engaging with government institutions. Firm B benefitted from its partnership with the Industrial Technology Development Institute, one of several R&D institutions under the DOST, which provided referrals for machine suppliers and assistance for plant layout and new product development.

BOX 6.1

TRANSLATING INNOVATION AWARENESS INTO INNOVATION ACTIVITY

Despite improvements shown by the Philippine automotive industry, the industry has lagged behind those of neighbouring countries. Quimba and Rosellon (2011) presented some issues that might have contributed to the rather slow development of the automotive industry in the Philippines.^a The study found that knowledge transfer and technology activities were critical in advancing the industry's development.

Nine automotive firms were interviewed in Quimba and Rosellon's case study. Using the instrument developed by Bessant et al. (2001), information on innovation activities within each firm was gathered, quantified, and analysed.^b Information focused on aspects including awareness of the need to improve; the ability to formulate technology strategies for business, assess technological solutions, and take advantage of links with a network of suppliers and collaborators; and implementation and effective use of technologies.

The results of the study show that all surveyed firms had relatively high awareness of the importance of technology, but some were not able to use this to improve their technological competence or innovation. The study thus highlights the importance of technology transfer, which, to some extent, was addressed by different programmes initiated by the government through the DOST. Also, firms that relied on mother companies were observed to have less technology activity. These firms tended to be less innovative as they depended on the R&D activities of the mother company.

External links were utilised more by Filipino-owned firms. This might be explained by the absence of restrictions that would usually be imposed on foreign mother companies. The connections enabled Filipino firms to improve their levels of technology and expertise. In addition, the study recognised the importance of creating an information environment where firms of the same type of product would affect other firms by benchmarking based on their knowledge of the types of technology available to them and their competitors.

Recognising the weakness of the Philippine automotive industry in terms of undertaking technology activities, the authors raised the need to strengthen innovation policy in the country. Improving links with R&D and higher education institutions was found to be critical. Strong R&D capacities contribute to the better flow of knowledge and technology transfer from the institutions to the industry. Aside from a focus on institutions, the study suggested the need for bigger investments in R&D personnel and scientists and increased public R&D spending.

^a Quimba, F. and M. Rosellon (2011), *Innovation in the Automotive Sector of the Philippines*. Philippine Institute for Development Studies. <https://serp-p.pids.gov.ph>

^b Bessant, J., H. Rush, and M. Hobday (2001), 'Assessing Technological Capabilities: An Audit Tool'. Report to World Bank: Project on Korea and the Knowledge-based Economy.

Source: Adapted from Quimba and Rosellon (2011).

Unfortunately, the case of Firm B may not be generalised to all firms in the food manufacturing industry. Innovation in Firm A, a large, locally owned, export-oriented enterprise, is driven by the specific needs of its customers. Firm A's international customers shared with it information on the tastes and preferences of their end buyers.

BOX 6.2

TECHNOLOGY TRANSFER IN THE FOOD MANUFACTURING SECTOR

The food manufacturing sector is the largest manufacturing subsector in the Philippines, with a 39% share of total establishments in 2012. The subsector also contributes 21% of the manufacturing sector's total employment and 16% of its total value-added.

Despite the contribution of the sector to total employment generation and manufacturing value-added, the sector is viewed as a low-technology subsector because it is less capital-intensive and does not require high-skilled workers. The sector also has difficulty establishing strategic and efficient partnerships because product development and production processes are driven by secret recipes and family-grounded procedures. The risk of appropriability and the leakage of highly specific assets deters firms from embracing collaborative arrangements and developing external ties even though the potential benefits to business expansion and growth are greater.

The cases of a large, locally owned, export-oriented food manufacturer (Firm A) and that of a small, locally owned, fruit juice manufacturer (Firm B) are compared and contrasted.

Firm A, a large, locally owned manufacturer of fruit purees and concentrates, caters to other food companies in China, Hong Kong, and Japan. Information from their international customers' knowledge on new products and technology is transferred through product samples. Firm A's local customers are also able to obtain some nontechnical knowledge from Firm A in the form of product development support. Firm A's production processes and techniques are not shared with their customers, local or international. Because of the international links, Firm A is able to learn about the taste preferences of customers from other countries and upgrade its processes to cater to international standards and preferences.

Firm B, on the other hand, is a small, locally owned manufacturer of ready-to-drink fruit juices, concentrates, and purees. Most of its production is exported to Canada, the United Arab Emirates, and the United States, while about 40% is sold to the domestic market. Firm B's major partner in knowledge sharing is a local small-scale machine supplier that it has worked with for some time. Transfer of knowledge related to the machinery involves training the operator and after-sales service personnel. Firm B shares details of machine parameters with its supplier in order to obtain equipment calibrated for new product variants. Firm B has benefitted from the knowledge-sharing partnerships with the supplier by obtaining specially calibrated machines based on the firm's needs.

One of the key findings is that there is great potential for businesses to share knowledge and upgrade the capabilities of local firms. The transfer can be from a big foreign company to a big local company (Firm A) or from one small firm to another (Firm B). For a large firm, support from the government may not be expected, but the policy environment for large firms should be conducive to technology transfers. For a small firm, support from the government is needed, especially for getting access to technological knowledge.

Source: Adapted from del Prado, F. and M. Rosellon (2017). *Achieving innovation without formal R&D: Philippine case study of garment firms*. Philippines Institute for Development Studies. <https://serp-p.pids.gov.ph>

Firm A is then put to task to meet these requirements, but limited technical support or knowledge is transferred from the international customers. Despite this less-than-ideal situation, Firm A is able to meet its international customers' requirements, an indication of Firm A's high level of (internally sourced) innovation capability.

Common to both firms is the role of trade shows and food fairs, which are important sources of information for both firms. Firm A gains new clients by participating in food fairs, while Firm B obtains ideas for improving production processes and information on the latest machinery and equipment available. For Firm B, these pieces of information are then passed on to its local machine supplier whenever it wants to upgrade its production processes.

6.4.4 Technology transfer and innovation in the pharmaceutical industry

The experience of the DOST's National Integrated Research Program on Medicinal Plants (NIRPROMP) in the commercialisation of *lagundi*, a native shrub traditionally used as a herbal medicine, presents several lessons on innovation. One of these is that innovation begins with good research that is rooted in the culture and experiences of the society whose needs it is trying to address. The establishment of NIRPROMP was motivated by the need for a more affordable source of medicine. Recognising that herbal medicine has been the go-to medication for many Filipinos living in rural areas, NIRPROMP investigated the medical composition of several herbal plants with the goal of improving the formulation of herbal medicine in the country and, consequently, providing cheaper alternative medicines for Filipinos (Box 6.3).

The foresight of researchers to conduct studies on commercialisation and consumer preferences in the early stages of the research process benefitted the translation of the research from product development to commercialisation. The underlying principle behind such foresight is the understanding that research should result in an innovation – a product or process that can benefit society.

Innovation takes a long time to materialise and can be very challenging. NIRPROMP was established in the 1974, a survey of *herbolaryo*⁴ was undertaken in the 1980s, the medical compound was isolated in 1995, and the utility model for the herbal pharmaceutical composition based on *lagundi* was issued in 2001. The entire process took about 37 years. Also, several companies expressed interest and proceeded with commercialisation, but, during the early stages of commercialisation, the DOST's royalties were small. In such cases, an environment that is tolerant of long-gestating R&D projects is necessary to allow the product to penetrate the market, otherwise the full potential of the product might not be realised.

⁴ Traditional healers who use their knowledge of herbs to administer herbal medicine.

BOX 6.3

INNOVATING HERBAL MEDICINE

The traditional knowledge in the use of *lagundi* (*Vitex regundo*), passed on through *herbolaryos* (traditional herbalists), was developed into modern medicine when the National Integrated Research Program on Medicinal Plants (NIRPROMP) successfully identified the medicinal properties of each part of the plant, paving the way for the development of a *lagundi*-driven formula for a clinically tested cough and asthma medicine.

The research and development work that went into the development of the symptomatic drug, including the clinical trials, was spearheaded by researchers Dr Nelia Maramba and Dr Conrado Dayrit, both of the University of the Philippines Manila campus. Dr Dayrit also conducted research on commercialisation as well as on the leading causes of morbidity during that time.

Lagundi has four active ingredients that can be used as a powerful cough syrup without any side effects. By 1993, the researchers from NIRPROMP had developed a *lagundi*-based cough medicine in tablet form. They further worked to develop a formulation for *lagundi* cough syrup to cater to children and the elderly.

Because NIRPROMP researchers were funded by the Department of Science and Technology (DOST) and the work was a collaboration between the University of the Philippines and the Philippine Council for Health Research and Development (PCHRD), all intellectual property was managed and owned by the DOST. To protect the intellectual property behind the *lagundi* cough syrup formula and promote its commercialisation, the DOST applied for a utility model with the Intellectual Property Office of the Philippines for a herbal pharmaceutical composition based on *lagundi*. The utility model was approved and issued in February 2001. Because the PCHRD was responsible for the commercialisation of the *lagundi* cough medicine, they organised information fora to pique the interest of local pharmaceutical companies. Many of them expressed interest, prompting the PCHRD to adopt a nonexclusive agreement. Under the agreement, the licensee pays an upfront fee for technology, and royalties are paid based on gross revenues less taxes and discounts.

Despite not being the first licensee, Pascual Laboratories, a large Filipino pharmaceutical company, is arguably the most successful licensee of *lagundi* technology. Pascual Laboratories' product based on the PCHRD *lagundi* formula was approved by the Bureau of Food and Drugs in 1996. To overcome scepticism about the product's efficacy, Pascual Laboratories submitted the drug to the 1997 International Exhibition of Inventions, New Techniques and Products in Geneva, Switzerland. The silver certificate for research and development awarded for the drug was used to help win over medical professionals and sceptical consumers.

Inspired by Pascual Laboratories' success, other companies joined the fray, prompting Pascual Laboratories to apply for a trademark in January 2011. By early 2011, the company's *lagundi* cough medicines had become the second-most-popular cough medications in the Philippines.

Source: World Intellectual Property Organization. From Herbal Folklore to Modern Medicine: National Integrated Research Program on Medicinal Plants, Philippines. <http://www.wipo.int/ipadvantage/en/details.jsp?id=3661>

Innovation does not end with product development and commercialisation. Products need to be used by consumers in order to have an impact. Before consumers use the products, they need to be convinced about their efficacy. Pascual Laboratories' effort to advertise and promote the products gives an invaluable lesson on how to

handle product innovations. Winning a silver medal in the International Exhibition of Inventions, New Techniques and Products, gave the product an international seal of product quality, helping to gain consumer confidence. The government, with its massive resources, can promote innovation by procuring a new product or service. This was the strategy used by Pascual Laboratories during the initial phase of commercialisation. The firm promoted the use of *lagundi* medication to government-funded rural clinics.

6.4.5 Supporting micro, small, and medium-sized enterprises

All of the development plans discussed earlier and even the academic literature (Llanto, 2013; STRIDE, 2014) have recognised the importance of MSMEs in development and the role STI plays in increasing their competitiveness. MSMEs drive innovation through their R&D and product and process development activities (STRIDE, 2014; Albert et al. 2013). At the Inclusive Innovation Conference held on 31 May–1 June 2017, the DTI Secretary emphasised that government policy should focus on pushing MSMEs to innovate (Lopez, 2017). This case study highlights the SETUP Program, one of the government projects implemented to support MSMEs (Box 6.4).

The programme is worth highlighting because it implements the strategies that were laid out in the development plans. The components of the SETUP Program cater specifically to the support MSMEs need to upgrade their level of technology in order to improve their competitiveness. The programme has become the bridge to ensure that technological upgrading results in economic development through the creation of jobs.

The concentration of industries in urban areas has been one of the factors cited for the lack of STI development in the country (Llanto, 2013). SETUP is implemented regionally, ensuring that all the areas outside Metro Manila can also access innovation-related services.

The effectiveness of the SETUP Program is intensified because of its continuity. It has been providing services to MSMEs since 2002, encompassing three administrations. As a testament to the value of the programme, administrations have continued to expand its implementation to reach more MSMEs. SETUP has continued to deliver on its promise, as evidenced by increasing the number of firms receiving support and, consequently, the number of jobs generated.

BOX 6.4**SUPPORTING SMALL AND MEDIUM-SIZED ENTERPRISES THROUGH THE YEARS**

The Small Enterprise Technology Upgrading (SETUP) Program, launched by the Department of Science and Technology (DOST) in 2002, aims to help micro, small, and medium-sized enterprises (MSMEs) adopt technology to boost their productivity and competitiveness. The project also puts together in a single unit all existing programmes and projects, including the Manufacturing Productivity Extension for Export Modernization, Consultancy for Agriculture Productivity Enhancement, the Science and Technology Enterprise Assistance Mechanism/DOST-Academe, and the Technology-Based Enterprise Development Program. The DOST regional offices implement SETUP and are primarily responsible for selecting client MSMEs. They also manage the project interventions for the client, including innovation system support, the technology needs assessment, technical training of the MSME workforce, technical consultancy services, product improvement and development, and packaging and labelling.

Llanto (2013) found that innovation system support was the intervention most commonly accessed by MSMEs (76% of all projects in the first half of 2010). Packaging and labelling services intervention came a distant second at 17.2%. In 2003, 781 small and medium-sized enterprises received assistance from SETUP, resulting in increased production and, consequently, the creation of 3,779 new jobs.

The Aquino administration expanded the SETUP Program to priority geographic locations in order to address poverty. According to the 2015 DOST annual performance report, the project has provided 1,021 technical interventions to 4,510 firms, resulting in the creation of 34,512 jobs. The Philippine Development Plan 2017–2022 promises to expand support to the SETUP Program so that it can cater to more MSMEs requiring government assistance.

Sources: Alabastro (2004); DOST (2014, 2015); Llanto (2013); NEDA (2017).

6.4.6 Supporting entrepreneurship

Innovation is at the core of entrepreneurship (Lopez, 2017). Thus, the government has jump-started a number of technology business incubators in order to provide support to entrepreneurs who want to start their own company. Unfortunately, the performance of these publicly run incubators had been poor (Macdonald and Joseph, 2001). The two cases presented here are good practices from which a number of lessons may be learned (Box 6.5).

QBO and the UP–Ayala Land TechnoHub both offer opportunities to expand the network of start-ups. QBO’s workspace allows start-ups to engage with one another and obtain mentors from established entrepreneurs. The management of QBO is handled by experienced people from the private sector who are extremely knowledgeable on issues pertaining to start-ups. Managers are always on hand to assist entrepreneurs.

BOX 6.5

PUBLIC-PRIVATE PARTNERSHIPS IN BUSINESS INCUBATION

QBO. Collaboration between the Department of Trade and Industry (DTI), the IdeaSpace Foundation, the Department of Science and Technology, and the JP Morgan Foundation gave birth to QBO. The QBO Innovation Hub, which is located in the DTI International building in Makati City, is the DTI's way of supporting the start-up community with particular attention to those that have viable business propositions. The QBO Innovation Hub is led by Rene 'Butch' Meilly, who also heads the Philippine Disaster Resilience Foundation, a private sector vehicle for disaster management that has become a role model for the United Nations' Connecting Business initiative. Katrina R. Chan of IdeaSpace serves as executive director of the hub.

The QBO Innovation Hub will also serve as the venue for micro, small, and medium-sized enterprises to explore the opportunities disruptive technologies bring. The hub is the logical next step in the IdeaSpace Foundation's efforts to elevate the Philippine start-up scene to global standards. QBO offers a range of programmes to the start-up community, such as networking events, mentor-matching (where entrepreneurs can consult with senior corporate executives), basic start-up classes, advanced workshops, and group feedback sessions. Qualified start-ups can also participate in the JP Morgan incubation program.

UP-Ayala Land TechnoHub. Ayala, a private business entity, established UP-Ayala Land TechnoHub as a facility for business incubation. The firm has also provided commercial spaces to generate income for sustaining the technology hub operations while providing a good venue for industry-academe links. The facility has been developed to be conducive to nurturing family bonding, group meetings, and relationships between entrepreneurs and their employees. The hub not only provides locators with an environment conducive to growing their businesses but also provides support in terms of modern facilities.

Unlike the traditional one-phased incubation process, the UP-Ayala Land TechnoHub follows three major stages in its incubation process. The start-up would first be housed in the incubator area. After 3-4 years, the locator – if it becomes successful – would graduate and move to multitenant buildings, where it would enjoy larger office space and can have more opportunities to expand. If the company grows further, it could eventually move to its own building, also in the vicinity of the UP-Ayala Land TechnoHub. At present, the technology hub has available facilities for small, medium, and large businesses to accommodate the changing needs of start-up businesses.

By allowing big and established companies to locate in the facility, the UP-Ayala Land TechnoHub is able to maintain the convenience they provide to their locators and at the same time provide locators with opportunities to expand their business networks, which is crucial for building their capacities and capabilities.

Sources: Department of Trade and Industry (DTI) (n.d.), *DTI, IdeaSpace Launch the QBO Innovation Hub*. www.dti.gov.ph; Beng Hui et al. (n.d.), *Privatization of Business Incubation: Initiatives to Achieve Sustainability and Success*. http://www.dlsu.edu.ph/research/centers/aki/_pdf/_publications/Hui_Fernandez_Sio.pdf

This addresses the issue raised by Macdonald and Joseph (2001) of technology business incubator (TBI) managers' lack of qualifications and many responsibilities other than managing the TBIs.

The mixture of start-ups with established companies in the UP–Ayala Land TechnoHub also fosters an environment where collaboration among the locators can be pursued effectively. Similarly, the common area provided by QBO allows the transfer of tacit knowledge to entrepreneurs. Allowing the private sector to manage technology hubs and TBIs as business ventures taking into consideration sustainability ensures that facilities and support services are accessible to locators or users of those TBIs. For the locators, these facilities and support services are at least as important as an indirect subsidy through lower-cost office space.

The management of the UP–Ayala Land TechnoHub also teaches locators how to become less dependent on support and learn the real-world situation of managing businesses. This helps incubators become more independent in managing their businesses through exposure to real-world situations while at the same time having the advantages of the facilities and services offered in a TBI.

6.4.7 A new framework for industry–academe collaboration

In a presentation for the 2017 Inclusive Innovation Conference, Dr Ricardo E. Rotoras, first president of the University of Science and Technology of Southern Philippines (USTP) and incumbent President of the Philippine Association of State Universities and Colleges, described the current situation of (state) university–industry collaborations. In a survey of 63 state universities and colleges, Rotoras found that one-fifth (13) had no academe–industry collaborations. Most (57%) of the institutions had between two and six collaborative projects, corroborating the results of the 2015 PSIA about the lack of network links of firms and industry on innovation. Rotoras pointed to three major reasons why universities and colleges score so poorly on industry research collaboration: (i) faculty rewards and incentives for collaboration with industry are insufficient, (ii) leadership fails to appreciate the value of collaborating with industries, and (iii) existing government policies do not encourage academe–industry collaboration. On the other hand, demand-side issues must also be raised, including the relevance of the R&D work being done by the academic community to the market and business opportunities as perceived by firms, issues on the potential commercialisation of products or processes, and the cost of accessing university talent and expertise.

The formation of the USTP through Republic Act 10919 provided a concrete policy framework on which academe–industry collaboration can be pursued. The law has a number of provisions pertaining to collaboration with industry. The legislation allowed

the USTP's board of trustees to enter into public-private partnerships in the areas of research, instruction, and extension. These can be in the form of joint curriculum, research, or business ventures.

BOX 6.6

LEGAL FOUNDATION FOR UNIVERSITY-INDUSTRY LINKAGES: THE CASE OF THE UNIVERSITY OF SCIENCE AND TECHNOLOGY OF SOUTHERN PHILIPPINES

Republic Act No. 10919 was passed to provide a legal basis for the amalgamation of the Mindanao University of Science and Technology and the Misamis Oriental State College of Agriculture and Technology. This legislation established the University of Science and Technology of Southern Philippines. The law, however, anticipated the need to also establish partnerships with the private sector and industries and, thus, provisions related to collaboration with the private sector were included.

Section 17 of the act enumerated the powers and duties of the Board of Regents, the governing body of the university. Section 17(s) gives the Board of Regents the power 'to develop mechanisms for the efficient adoption of public-private partnerships in the areas of research, instruction, extension, and in the acquisition of facilities and structures of the University, such as

(1) Joint curriculum ventures: sandwich programmes for students in specialized science and technology (S&T) courses, faculty development curriculum in collaboration with partner industries, staff development of the industries to be run by the University and other such similar projects; and

(2) Joint research ventures: outsourcing of the research components of the industries to the academe's graduate programmes; product/service research and similar research endeavours.'

Succeeding sections also mentioned the powers of the board related to industry collaboration. Section 17 discusses the powers '(t) To enter into joint ventures with business and industry for the profitable development and management of the economic assets of the University, the proceeds of which shall be used for the development and strengthening of the University; (u) To develop consortia and other economic forms of linkages with local government units (LGUs), institutions, and agencies, both public and private, local and foreign, in the furtherance of the purposes and objectives of the University; (x) To setup the adoption of modern and innovative modes of transmitting knowledge such as the use of information technology, the dual training system, open distance learning and community laboratory for the promotion of greater access to education.'

Other legal provisions are aimed at providing an enabling environment for university-industry links to develop. Section 28 designated the Alubijid and the Clavera Campuses as S&T parks for the long-term development of the academic and research facilities of the university in strong partnership with industries. Section 29 identifies the incentives that industries can enjoy should they locate their operations in the university S&T parks. Section 31 identifies the university as a research partner of partner industries providing the possibility of the university allocating funds to support joint collaborative research with partner industries.

Source: Government of the Philippines, Republic Act 10919.

Other provisions of the law opened the USTP to the entry of industries as it designated the Alubijid and Clavera campuses as S&T parks. Incentives are provided to attract industries and businesses to locate in these parks. A number of collaborations have started in the USTP, such as the Business Incubation Technology Entrepreneurship and Start-ups and Food Innovation Center. The former is a collaboration of the Philippine Council for Industry, Energy and Emerging Technology Research and Development, Cagayan de Oro ICT Business councils, and the USTP. The services they offer include incubation monitoring and coaching, training, networking events, and other basic services. Examples of start-up companies located at the USTP are the Hyperstack, Wela (Bai Web and Mobile Lab), Scribbles, Tome, XGN, Shoplocal, and CarlShift Web Technologies. The USTP's Food Innovation Center is the product of collaboration among the DOST, the DTI, and private companies. It offers product development services. Other services that are provided include intellectual property assistance, training, consultancy, research assistance, and assistance on labelling and packaging. The Food Innovation Center has already assisted 200 MSMEs, developed 40 products, and provided consultants to 32 clients.

6.5 | Future Innovation Policy in the Philippines

This section attempts to provide some guidelines for fostering a better innovation ecosystem in the Philippines and having innovation mainstreamed in the policy environment. The guidelines do not attempt to be comprehensive but will focus specifically on addressing the issues identified in the current status of innovation activity in the country and the case studies described in this chapter.

A national policy should veer away from the linear innovation model⁵ to one that is defined in consultation with all stakeholders. The type of national innovation policy that should be pursued is one that supports various forms of collaboration taking into consideration the sector-specific characteristics of firms. Data from firms' innovation behaviour show that larger firms tend to rely on internal sources for their information and innovation. Case studies from the food processing and automotive sectors confirm this. Only a few automotive firms have links with universities and the government. Similarly, smaller food processing firms are more open to knowledge transfer than larger firms.

⁵ A linear innovation model assumes that R&D leads to the innovation and commercialisation of mature R&D outputs, product technologies, and, consequently, economic growth (Ancog and Aquino, 2007).

This implies that a policy to support collaboration is important, but the strategies should consider the specific characteristics of firms, as firm behaviour changes depending on the size and type of industry.

Ensuring that intellectual property in the Philippines is protected is also essential. The importance of intellectual property rights can be seen in the case of the pharmaceutical industry, where the trademark filed by Pascual Laboratories resulted in improved product recognition and increased sales. However, the experience of firms relying on secrecy to protect their innovations is a signal that intellectual property rights in the Philippines should be strengthened by appropriate policies that solidify the intellectual property environment. Similarly, the case of automotive firms having limited innovation because technology is not transferred by the parent company due to intellectual property concerns should be addressed by a strong intellectual property rights policy. To encourage technology transfer, balancing the restrictions and incentives on foreign direct investment cannot be emphasised enough. The right balance needs to be struck between protecting domestic industries and at the same time appeasing the mindset fearful of foreign companies.

HEIs should be encouraged to pursue R&D without being encumbered by myopic internal policies that fail to see the long-term benefits of research. Similarly, they should be incentivised to pursue partnerships with private firms for product development and commercialisation.

The start-up environment should be enabling with the appropriate incentives and support for start-ups to thrive, but, at the same time, it should allow businesses to learn from real-world experiences. TBIs bring together the resources of the three major stakeholders related to innovation: the government, start-ups and private firms, and academe. Because these three would be directly affected by policies on start-ups, any national policy should be made in coordination with, and with inputs from, all three groups of stakeholders.

Policies should be explicit about the inputs needed to elevate the country's innovation ecosystem to international standards. This is a lesson that can be inferred from the review of development plans undertaken in this chapter. While the strategies and even indicators of STI are monitored in these plans, the plans are often silent on the budget required to support STI. R&D expenditures need to be scaled up in both the public and private sectors. Innovation indicators, including traditional R&D indicators, should also be produced more regularly for the country to be able to assess its progress

in developing the innovation ecosystem. Related to this, it is important to conduct a review of the effectiveness of the STI plans and an assessment of the impact of these programmes.

6.6 | Summary and Conclusion

This chapter presents the patterns of STI policy in the Philippines over time. While innovation is recognised as an important driver of competitiveness and a means of expanding employment opportunities, innovation policy needs to be substantially mainstreamed. The results of the 2015 PSIA show that in 2015, only less than half of firms were engaged in innovation activities. Given the public good character of R&D, innovative firms prefer to conduct R&D by themselves or only in cooperation with those in their value chain. The government should foster the innovation ecosystem, but specific actions and time-bound plans must be formulated in close collaboration with other innovation actors while ensuring that complementary factors for innovation are present. The selected case studies highlight some successful innovation policies and strategies that the country can pursue to scale up innovative programmes and projects.

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Innovation Policy in Singapore

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7.1 | Introduction

Singapore has achieved rapid economic development through continuous industrial restructuring and technological upgrading. After independence in 1965, growth was largely driven by labour-intensive manufacturing by multinational companies. These companies were attracted to invest in Singapore by the business-oriented government policies, such as relatively low taxes, a productive labour force relative to its wages, harmonious industrial relations, and transparent and effective macroeconomic management. Following the success of labour-intensive industrialisation, subsequent industrial policies gave high priority to capital- and skills-intensive foreign direct investment. In addition, Singapore's rapid development as an important business, financial, transport, and communication services hub had provided important value-added to its gross domestic product by the late 1980s. Nonetheless, the manufacturing sector remains a very important and strategic element of Singapore's national innovation policy and its drive for technological development and skills upgrading.

Singapore has made significant progress in developing its science, technology, and innovation capability over the more than 50 years since political independence in 1965. This effort was initially based on an evolving national system that emphasised attracting and leveraging multinational companies to transfer increasingly advanced technological operations to Singapore, and developing infrastructure and human resources to absorb and exploit new technologies rapidly. In the 1990s, Singapore started to shift towards a more balanced approach, with increasing emphasis on developing its indigenous research and development (R&D) and innovation capability.

To position Singapore as a knowledge-based, innovation-driven economy, the government started to invest in R&D to develop capabilities, infrastructure, and talent. As a result, 'Research, Innovation, and Enterprise' has become the theme of Singapore's national system to support the continuum from research to value capture.

In 2016, the government unveiled the Research, Innovation and Enterprise 2020 Plan for an investment of S\$19 billion over five years starting from 2016.¹ This was an 18% increase over the previous five-year tranche, aiming to more effectively leverage science and technology to build the innovation capacity of the private sector and address national challenges. Under the plan, funding for 'White Space', which refers to emerging research, innovation, and enterprise activities, will be bumped up to S\$2.5 billion, a more than 50% increase from 2015. The National Research Foundation will also build a renewal mechanism through White Space to ensure that resources are reprioritised to deserving areas, such as those of national need, economic opportunity, and competitive capabilities.

Another important aspect is the doubling of the percentage of open competitive funding for public R&D to S\$4 billion to find the best ideas and most deserving needs in four 'technology domains' – advanced manufacturing and engineering, health and biomedical sciences, services and digital economy, and urban solutions and sustainability – and in academic research (Government of Singapore, 2016). Since 2006, public expenditure on R&D has increased by 9.1% annually and reaching S\$3.7 billion in 2015. Singapore's research intensity continues to rise, increasing from 2.2% of gross domestic product in 2014 to 2.4% in 2015 (Government of Singapore, 2015). Details of expenditures and other characteristics of R&D are in the Appendix.

The Research, Innovation and Enterprise 2020 Plan seeks to support and translate research into solutions to national challenges, build up innovation and technology adoption in companies, and drive economic growth through value creation. The sixth five-year roadmap for research, innovation, and enterprise will be more targeted in its funding approach as the National Research Foundation looks to capitalise on technology in which Singapore has a comparative advantage as well as build capabilities in areas deemed to have a greater national need. Conceptually, this is intended to focus efforts in areas where national need, economic opportunity, and competitive capabilities intersect, as well as to create value from R&D investments. Instead of broadly categorising funding into 'private R&D' and 'public R&D' as in the past, the new approach focuses on the four primary technology domains.

¹ The plan was unveiled by Prime Minister Lee on 16 January 2016.

The domains seek to deepen the technological capabilities and competitiveness of Singapore's manufacturing and engineering sectors, advance human health and wellness, and leverage the country's digital capabilities to raise productivity and meet national priorities, such as developing a reinforced cyber security infrastructure and system to fend off cyber threats. The four domains will be supported by three 'cross-cutting programmes' – academic research, manpower, and innovation and enterprise – that aim to ensure excellent science and a strong pipeline of manpower and value creation.

7.2 | Conceptual Framework

The focus of this chapter is to describe and analyse the diffusion of knowledge over successive economic restructuring and technological development phases in Singapore's industrial development. This process can be observed through the upgrading of an existing industrial cluster, as in the case of marine offshore engineering, and the creation of a new biomedical science cluster. Singapore has achieved significant technological capability development, particularly since 2001. R&D was quite limited in the late 1980s, with a gross expenditure on R&D (GERD) to gross domestic product ratio of only 0.86% in 1987. However, the government subsequently increased the GERD, and by 2015, Singapore's GERD had reached a high of S\$9.5 billion (Government of Singapore, 2015). This was supported by increased business expenditure on R&D, which reached S\$5.8 billion in 2015 (Government of Singapore, 2015). However, important though it is, increased expenditure on R&D is only part of the story. More significant is how increased expenditures for R&D are managed, coordinated, and diffused to form innovation clusters. A conceptual framework for analysing the link between innovation and knowledge-based industrial clusters was applied in Singapore to develop electronic, logistics and transportation, business and finance, marine offshore engineering, and biomedical and healthcare clusters.

A knowledge-based industrial cluster is one that derives significant value creation from the creation and use of advanced knowledge. These two elements are important and necessary, requiring both the creation of knowledge-intensive output and the use of knowledge-intensive processes in generating this output. Theoretically, a knowledge-based cluster has several components. First, a knowledge infrastructure is required in terms of R&D institutes and universities as the lead generators of knowledge to conduct basic research and training. Second, links to lead users of knowledge are

critical; without them, public research institutes and universities risk producing innovations that are irrelevant to industries. Third, for the cluster to be sustainable, critical knowledge-commercialising and innovating firms are required. Fourth, the cluster requires supporting industries and services. Fifth, the cluster must be supported by a regulatory framework and business environment in which to operate. These five components can be considered as the ecosystem for an industrial cluster to grow to become an innovation-conducive environment (Wong et al., 2010).

The main element of Singapore's innovation policy is the tripartite 'Home' strategy, which refers to 'Home for Business', 'Home for Innovation', and 'Home for Talent' as part of the innovation strategy. Home for Business provides an overall framework for the talent and innovation strategies. The Home for Business strategy extends to every industry, not just those of the modern innovation powerhouse. In other words, Singapore places as much emphasis on consumer goods manufacturing, electronics, chemicals, and energy as it does on information technology (IT) and digital media. The Economic Development Board (EDB) has become a one-stop shop that works to create the right conditions to attract talent and investment. When those conditions were lacking, Singapore has taken great pains to create them. Take the IT and Internet technology space, for example: the entrepreneurial scene in Singapore was barren in this area until recently.

The Home for Innovation entrepreneurial ecosystem is being created in Singapore. In 2015, it had more than 42,000 starts-ups, and almost 1 in 10 people of working age in Singapore was trying to start a company (Government of Singapore, 2016). The question is, why has Singapore not yet had a breakout of major start-up tech companies? Incubators, such as Block 71, are intended to produce them.

The Home for Talent strategy adopts Singapore's innovation strategy to respond to broad macro trends happening in global markets. Singapore has benefited from its geographic location close to rapidly emerging economies, such as China, India, and Indonesia. As a result, Procter & Gamble are making Singapore their regional hub for consumer and beauty products. Huge United States multinational companies, such as DuPont, General Motors, and Archer Daniels Midland, continue to make Singapore an important part of their growth strategy, attracted by Singapore's proximity to China and its ability to tap Asia's future growth. A strong commitment to science and education in Singapore means there is a constant influx of new talent for any multinational company looking to expand into Asia's rapidly emerging economies. Singapore's goal is to always be relevant for companies that see Asia as the source of fastest growth.

7.3 | Key Processes in Developing Knowledge-based Clusters

7.3.1 Key knowledge-cluster components

Singapore adopts a flowchart approach to industrial cluster formation. This approach attaches high importance to systematic arrangement and consideration, and is based on the concept of economies of sequence, which dictates the order in which segments of the industry cluster are formed. Such an approach generates important positive externalities by establishing backward and forward linkages between industry and other economic sectors. To create a knowledge cluster, the following four components must be in place (Kuchiki and Tsuji, 2010).

Public knowledge infrastructure. This may involve creating new universities and public research institutes, restructuring existing institutions, or creating new programmes within them to prioritise the fields of research and education needed for the cluster under development. More concretely, Singapore has established the Biomedical Research Council (BMRC), which has seven research institutes and five research consortia under its umbrella, and the Science and Engineering Research Council (SERC), with seven research institutes and one centre. The BMRC and the SERC are under the Agency for Science, Technology and Research (A*STAR), which has also set up the A*Star Joint Council to facilitate interactions between the BMRC and the SERC to foster interdisciplinary and cross-council research. The physical proximity of the BMRC and the SERC is deliberate: the BMRC is in Biopolis and the SERC is in Fusionopolis, just 600 metres apart.

Inducements for private companies to cluster. The development of the private sector can take the form of both attracting foreign firms to set up operations in the country and nurturing local firms and industry to upgrade their knowledge intensity. The government has provided incentives to attract well-established international pharmaceutical firms to set up operations in Singapore and undertake joint research with public research institutions. For example, Procter & Gamble has vast investments in making Singapore a regional hub for consumer and beauty products, and Jurong Island is being redeveloped into an innovation showcase for energy and chemical firms, such as Exxon Mobil. Such links could take the form of anchoring foreign lead-user firms in the country, and then encouraging intra-firm technology transfer between the parent headquarters and the overseas subsidiaries of transnational companies.

A complementary strategy is to build international links through international R&D consortia, common technical standards coalitions, cross-licensing of technologies, or long-term supplier–buyer relationships.

Knowledge flows and network links among key actors in the cluster. This includes inter-sector networks, such as between universities, public research institutes, and private firms, as well as creating platforms and mechanisms for inter-firm collaboration within the private sector. Examples include R&D alliances and industry consortia.

A regulatory framework and business environment. A regulatory framework with rules and regulations that are transparent and fair to all stakeholders must be created and a competitive business environment established to facilitate and encourage creative efforts and innovation.

7.3.2 Role of the state in developing knowledge clusters

The state can play a significant role in facilitating the development of knowledge-based clusters through its policies and investment programmes. This can be seen in Singapore's industrial strategy since the start of industrialisation to present day innovation policy. Given the diverse strategies that can be adopted in the development of clusters, the strategic choices taken by the government, such as the choice of actors to promote and the timing of entry into emerging technologies, can have significant impacts on the resulting dynamics of cluster development.

In its choice of actors to promote, the state can focus on either local or foreign resources in developing the cluster. Through the EDB and A*STAR, the Government of Singapore has become the major focal point in attracting foreign firms and foreign talents to develop the selected clusters.

In terms of timing its entry into emerging technologies, the state can enter the global market while the technology is still in its infancy or wait until the market and technology are more mature. In the case of Singapore, most of the technologies are already developed and mature in Europe and the United States, but they are relatively new in Singapore and in Southeast Asia. Often, established technologies are adapted to meet emerging regional demand for the products and services.

In developing knowledge clusters, the government also faces the choice of upgrading the knowledge intensity of existing clusters or creating entirely new clusters for emerging technologies. Regardless of the strategy adopted, there will be common elements in the strategies used as the key processes for cluster development are common to both new and existing clusters. However, the timing of government intervention, and therefore the specific role of the state, would be different depending on the maturity and nature of the cluster to be developed. Developing an offshore marine engineering cluster and integrated logistics hub is an example of a more mature cluster that has evolved from the shipbuilding and repair industry and transport and air services. Developing knowledge in the biomedical sciences, on the other hand, requires an entirely new industrial cluster.

7.4 | Case Studies

7.4.1 Developing a mature cluster: The offshore marine engineering cluster

Singapore's offshore marine engineering cluster is based on an industrial cluster that has already become one of the world's leading hubs for offshore oil and gas platform production. Thus, the transformation of Singapore's maritime services cluster into the International Maritime Centre (IMC) involved upgrading the knowledge of existing industries. Singapore's maritime cluster is well established in one of the world's most important port and shipping locations. The impetus to upgrade and enhance the IMC was to position Singapore as a leading international maritime centre in the wider Asia region.

Singapore's maritime cluster comprises two sectors: core maritime transport and the non-core maritime sectors, including services that support marine transport. The core maritime transport sectors are those that derive their revenue entirely from maritime-related activities. Non-core sectors are those for which maritime activities form only a part of their total operation. The IMC has experienced strong growth in value-added, employment, and labour productivity since the government launched the upgrading of the offshore maritime cluster. The continued growth of Singapore's maritime cluster has been achieved despite increasing regional and global competition. This can be attributed to an increase in labour productivity and knowledge intensity in key maritime sectors.

The maritime engineering industry, which comprises the shipbuilding and repair sectors, has upgraded technological capabilities and increased knowledge intensity in the maritime cluster. Traditionally, this sector was mainly involved in providing repair and overhaul services to vessels calling at the Port of Singapore. The industry was able to transform itself by successfully diversifying into offshore oil and gas construction and marine engineering services. With strong assistance and incentives provided by the state, Singapore has broadened its traditional shipbuilding activities to become a global leader in the offshore construction business. In addition, the marine industry (i.e. non-core maritime sector) that has achieved strong growth through increased productivity and knowledge intensity is bunkering and logistics services. Growth in this sector has also provided an impetus for the development of maritime finance and insurance services. How has Singapore implemented its innovation policy to upgrade the maritime industry so effectively?

The Maritime and Port Authority of Singapore (MPA) was appointed as the 'champion agency' for the comprehensive development of Singapore from primarily a sea-transport hub into the leading comprehensive integrated IMC in Asia. At the outset, the government, through the Ministry of Transport, spelled out a vision of Singapore as the leading maritime hub in Asia with a vibrant IMC cluster that not only complements Singapore's hub port status but also serves as an additional engine of growth for Singapore's economy.

The MPA plays a leading role in IMC development in the context of a multi-agency coordination approach. The institutional framework for IMC development involves several ministries and government agencies as well as industry participation through associations and the Singapore Maritime Foundation. The presence of multiple agencies and stakeholders ensures an integrated development approach. Two strategic initiatives and continued port upgrading in infrastructure and facilities are required to steer the development of Singapore as an IMC. First, the MPA as the champion agency has the task of overseeing the expansion of Singapore's maritime activities from core port and shipping services into bunkering, ship brokering, logistics support, and surveying activities. Second, maritime ancillary services are developed, such as marine insurance, maritime finance, and maritime legal services. To achieve these interrelated strategic initiatives, the continued vibrancy of the port and shipping services sectors is critical, and investment in port upgrading and technological improvement must be undertaken simultaneously.

Diversification into new areas has opened up opportunities for R&D and IT projects and provides additional incentives to attract maritime ancillary services. The MPA has instituted a number of initiatives in line with the Ministry of Transport's vision. In this context, the MPA has initiated a memorandum of understanding between the MPA and the Research Council of Norway, which has an excellent reputation in maritime-related research, education, and training. This framework provides for the MPA and Research Council of Norway to collaborate on several business- and user-oriented maritime R&D and education and training projects. The scope of the memorandum of understanding includes a broad range of activities, such as exchange programmes and industrial attachments, education and training courses, and cooperation in commercialising the results of the maritime R&D and education and training projects.

In addition to establishing memoranda of understanding with well-known foreign institutions in maritime R&D, the MPA launched and administers the Maritime Innovation and Technology Fund, which is designed to support development programmes under the Maritime Technology Cluster Development Roadmap. The fund supports the following programmes and schemes:

- (i) The Trident Platform. This is a platform for developing and testing, or 'test-bedding', maritime innovations. The programme supports companies and tertiary and research institutions in undertaking maritime-related R&D and innovation development using Singapore's port and maritime facilities as test-beds for innovation.
- (ii) The Maritime Seed Fund. The fund targets new and emerging maritime companies seeking to bring technologies or innovation from concept to commercialisation, as well as established maritime technology companies seeking to embark on further R&D, set up facilities in Singapore, or venture overseas.
- (iii) Joint tertiary research institute and MPA research programmes. Universities and polytechnic students are encouraged to participate in the joint research programmes of the MPA and tertiary research institutes.
- (iv) Technology professorships. Universities are encouraged to provide technology resources for industries' contributions through dollar-for-dollar matching governmental funding.
- (v) The Maritime Industry Attachment Programme. This programme aims to immerse engineering, IT, and science students from tertiary research institutes in the maritime industry. Students' suggestions on technology development and innovation will be awarded prizes if they are accepted. Postgraduate R&D projects will be funded by the Maritime Innovation and Technology Fund.

Singapore's innovation policy and programmes have been very successful in diversifying traditional shipbuilding and repair into offshore construction and marine engineering services. The country has emerged as one of the world's leading offshore and marine engineering clusters, boasting 70% of the global market share for the conversion of floating production storage and offloading vessels and 7% of the world market share in jack-up rig construction (Wong et al., 2010). This remarkable success in innovation policy and strategy is based on standard key principles and processes in developing knowledge-based clusters and industrial development. It should be noted, however, that without suitable institutions, legal framework, and a capable and effective public administration, applying these standard principles and processes might not yield the level of success experienced by Singapore. Innovation policy and processes must be implemented under a favourable ecosystem, in a sustainable manner, and by competent public administrators to promote competitive and entrepreneurial business sectors. Every segment of the process is important and plays a different strategic role at different stages while consistently moving towards the achievement of a common vision and objectives.

7.4.2 Creating a new cluster: The biomedical sciences cluster

From the start of its industrial development, Singapore has always relied on attracting foreign direct investment from global multinational companies and leveraging it to exploit technologies and know-how created by developed countries. This strategy has worked in developing electronics manufacturing and information technologies. The same leveraging strategy was used in developing the pharmaceutical industry, where it appears to have been equally effective in terms of total value-added to manufacturing output.

The vision and mission in developing a biomedical sciences cluster were conceived as a strategic shift to diversify from a high dependence on IT and electronics manufacturing. The objective is for life sciences to become a key pillar of Singapore's economy, together with electronics, engineering, and chemicals. The vision is to transform Singapore into a major hub of biomedical sciences with world-class capabilities across the entire value chain, from basic research to clinical trials, product and process development, full-scale manufacturing, and healthcare delivery. The state's role remains a critical factor both in upgrading the existing cluster in offshore marine services and in developing the new biomedical sciences cluster. However, much greater investment and effort are required to develop the biomedical sciences cluster.

The two government agencies responsible for establishing the biomedical sciences cluster are A*STAR and the EDB. A*STAR, through the BMRC, concentrates on putting in place the appropriate policies, resources, and research and education architecture that will build biomedical science competencies internally, including funding and supporting public research initiatives. The EDB is responsible for bringing in investments and generating long-term economic value in the sector. The EDB's Biomedical Sciences Group, charged with developing industrial, intellectual, and human capital in support of biomedical sciences, and Bio*One Capital, charged with functioning as an investment arm, work together to attract biomedical sciences companies to establish R&D operations in Singapore and develop the local biomedical sciences manufacturing sector.

Due to the lack of an existing local biomedical sciences cluster, the government has tapped extensive international biomedical sciences talent to develop the cluster. The Biomedical Science Executive Committee, which leads the initiative, is advised by the International Advisory Council, comprised of eminent scientists from the global scientific community. Another high-level advisory body, the Bioethics Advisory Committee, was formed to develop recommendations on the legal, ethical, and social issues of human biology research. Its recommendations have led to a regulatory environment in Singapore that is broadly supportive of biomedical sciences. Clear legal support for stem cell research, combined with compliance with strict international guidelines, provides Singapore with a competitive advantage in stem cell research, particularly in dealing with the National Institutes of Health in the United States, which allows the federal government to fund research that uses Singapore-produced stem cells. After 15 years of consistent cluster development and innovation, Singapore is ranked as one of the leading centres for biomedical sciences, particularly on stem cell research.

The key elements of Singapore's strategy for biomedical sciences hub development are as follows:

Attracting foreign pharmaceutical firms. Through the EDB, Singapore has successfully attracted world-class pharmaceutical multinational corporations to carry out manufacturing, R&D, clinical trials, and other knowledge-intensive services. All the largest pharmaceutical manufacturing firms operating in the cluster are foreign majority-owned. To move these foreign investments into the higher-value-added segments of the biomedical industry value chain, the EDB encourages foreign companies to set up R&D or clinical research operations in Singapore.

This is facilitated by easy access to resources from public research institutes and universities. An important emerging branch of medical research is ‘translational research’. This is a new approach to the development of drug treatments that attempts to connect basic research directly with patient care. Singapore’s biomedical sciences development has moved beyond establishing basic life sciences infrastructure and industry to developing translational and clinical research. Recent foreign investment from leading pharmaceutical firms has been directed to this segment.

Developing physical infrastructure. Singapore has developed integrated physical infrastructure to house the biomedical sciences research cluster. ‘Biopolis’, as the cluster is named, is dedicated to biomedical R&D activities and designed to foster a collaborative culture among the institutions and with the National University of Singapore, the National University Hospital, and Singapore Science Park. Biopolis also provides integrated housing and recreation facilities for the many resident foreign scientists. The government hopes that creating the cluster will encourage informal networks for knowledge sharing to flourish, and accelerate the growth of a critical mass of biomedical expertise in Singapore and an R&D hub for the Asian region.

Locating public research institutes in the cluster. Singapore’s seven public research institutes all have a presence in Biopolis. This is intended to attract biomedical multinational corporations, start-ups, and support services, such as lawyers and patent agents, to locate there.

Attracting foreign talent and training young local talent. Attracting foreign talent has become a major thrust of the government’s biomedical sciences cluster strategy. The strategy is to attract internationally well-known scientists (‘whales’) to head research in biomedical sciences in public research institutes. In turn, these renowned scientists attract young scientists (‘guppies’) locally and globally to work under their leadership (the ‘whales and guppies approach’). In addition, the government sends top students from local institutions to leading research institutes all over the world. Scholarships provided by A*STAR are given to a wide range of undergraduate and graduate students and medical specialists to study biomedical sciences. In the long term, it is expected that local universities and public research institutes will be bolstered by their alliances with established world-class research institutes and can grow their own bioscience human resources capabilities.

Promoting biotechnology firms, biomedical start-ups, and a venture capital industry.

The measures to create a vibrant biomedical sciences cluster in Singapore are intended to lead to the promotion of technology commercialisation activities through start-ups and spin-offs from the public research institutions and universities. The availability of venture funding and financial resources for technology-based firms is a critical factor for supporting such activities.

The government has played a very important role in developing a specialised biomedical sciences venture capital industry. Since Singapore had little expertise and experience in venture capital, it was particularly critical for the government to take a lead role in setting up a number of life-sciences-related funds. These were eventually centralised under Bio*One Capital, a private equity and venture capital firm dedicated to investments in the biomedical sciences industry. In addition to bringing overseas biomedical sciences investments to Singapore, the work of Bio*One and other support mechanisms has resulted in the emergence of a biotech firms sector in Singapore. This includes a number of spin-offs from local universities. The main focus area for dedicated biotech firms is drug discovery and development. These firms are still relatively small compared to those in leading biotech clusters around the world (Finegold et al., 2004).

Expanding clinical research capabilities in the healthcare sector. The first phase of Singapore's biomedical sciences development focused on establishing a foundation of basic biomedical research in Singapore. The second phase moved into the development of capabilities in clinical and translational research while continuing to strengthen basic science. In this regard, Singapore's tactical advantage in clinical research is its good healthcare system. Despite this advantage, there are still relatively few clinical trials taking place in Singapore as it does not have a large domestic market for pharmaceutical products. Recent developments show further advancement in clinical capabilities. The development of clinical research involves developing translational research, which aims to build links between basic science conducted by other public research institutes and clinical research programmes in Singapore's public hospitals, disease centres, and universities. Two other schemes recently initiated by A*STAR are the Singapore Translational Research Investigator Award, which aims to recruit world-class clinical scientists to undertake clinical and translational research in Singapore, and the Clinician Scientist Award, which targets top local clinical researchers with proven leadership potential in research. Progress in clinical research has been made possible by Singapore's good healthcare system and high medical standards.

Promoting links between R&D, universities, and the healthcare services sector.

In the development of clinical and translational research capabilities, there has been a deliberate strategy of forming and promoting collaborations between clinical researchers and scientists in multiple agencies. The consortia, initiated by the BMRC to promote translational research links between biomedical sciences, public research institutes, and the healthcare sector, have been set up for this primary objective. The Singapore Cancer Syndicate, the Singapore Stem Cell Consortium, and the Singapore Immunology Network are some of the consortia established to promote translational research links in the biomedical sciences cluster. These consortia have engaged in joint training and the establishment of research infrastructure and links between local and overseas universities and well-known research centres.

The government played a vital role in initiating the biomedical sciences cluster and coordinating multiple agencies, as it did in the marine engineering cluster. It aimed to develop biomedical science through conducting investment and R&D promotion, developing public R&D institutes, and providing private sector companies with incentives for R&D, infrastructure development, and workforce development. Another important element for both clusters' development is attracting a critical mass of anchor firms or institutions to jump-start the clusters. In the offshore engineering cluster, firms in the traditional shipbuilding and repair sector were diversified into offshore construction activities. For the biomedical sciences cluster, foreign pharmaceutical multinational firms were given huge incentives to establish operations for knowledge-intensive services. In addition, the building of a critical mass in close proximity to the BMRC at Biopolis and the SERC at Fusionopolis, within 600 metres of one another, is deliberately designed to promote interdisciplinary research activities and other interactions.

However, the strategy and intensity of the government's role were different in developing an existing development cluster compared to a completely new cluster, and the role played by R&D and innovation varied depending on the stage of cluster development. For the biomedical sciences cluster, the establishment of R&D capabilities, the generation of intellectual property, and the subsequent commercialisation were critical right from the start. By contrast, the development of the marine offshore engineering cluster started with manufacturing, learning-by-doing, and the gradual accumulation of tacit process knowledge and innovation capabilities; and the role of public R&D institutions and the creation of intellectual property were not critical early on. Because early-stage start-ups are the key drivers for biomedical sciences, the availability of venture capital and global talent were more critical than

foreign investment to build the expertise needed. For the marine offshore engineering cluster, leveraging the local production base was more effective in stimulating cluster growth.

Therefore, the degree of success in developing the marine offshore engineering cluster is more evident and cost effective compared to developing biomedical sciences, which requires a more complex process and hinges on global market growth opportunities rather than local and regional ones.

7.5 | Conclusion

Singapore's experience in developing industrial clusters clearly shows that it is possible to accelerate the development of knowledge-based industrial clusters through innovation and effective public policy.² The case studies of marine offshore engineering and biomedical science cluster development suggest that cluster development is possible through a coordinated, strategic approach involving multiple government agencies and investment sustained over a long period of time. Innovation development through industrial clusters is not based on straightforward principles and rules. Rather, it is critically dependent on multiple factors, such as the nature of the technologies or processes involved, the market environment, and a conducive 'innovation ecosystem' of good governance to provide the required correct legal system, infrastructure, human resources development in education, and research both in the public and private sectors. In the case of Singapore, the government is the main driver and the critical element for the success of innovative knowledge-based development. In the next phase of innovation development, the involvement of private sector entrepreneurs will be critical to competitiveness and sustainability.

Singapore's National Innovation System is certainly the most advanced in Southeast Asia. As a small economy, the key challenge for Singapore is to move nimbly and strategically to stay ahead of regional competitors as they develop capabilities in selected science and technology clusters. Specifically, Singapore is dependent on its continuing ability to attract global talent, especially the innovative and entrepreneurial talent that is crucial to achieving the next level of its national innovation objectives.

² This chapter's findings and conclusions are supplemented and reinforced with interviews with the BMRC at Biopolis and the SERC at Fusionopolis.

Empirical evidence shows that R&D investment in Singapore has had a significant impact on its total factor productivity performance in the last 20 years and established a long-term equilibrium relationship between R&D investments and total factor productivity (Ho et al., 2009). However, the lower estimated elasticity values show that the impact of R&D investment on economic growth in Singapore is not as strong as that of members of the Organisation for Economic Co-operation and Development (Ho et al., 2009). This suggests that Singapore still has some way to go to catch up with other advanced industrial countries in terms of R&D productivity. In other words, Singapore must not only increase its level of R&D intensity, but, equally important, it must also be more efficient in exploiting domestic R&D with a view to increasing its value creation through enterprise, especially in the private sector.

What lessons can the member states of the Association of Southeast Asian Nations (ASEAN) learn from Singapore's experience? Each ASEAN Member State has its own unique approach to developing and managing its innovation policy based on its social, political, and economic characteristics and stage of development. However, there are some basic common denominators that less-developed member states can learn from Singapore's rapid development and experience in planning and managing its remarkable innovation development. The existence of a strong and consistent higher level of political leadership in planning, formulating, financing, and managing successive changes in innovation policy is a necessary but not sufficient condition. Successful innovation also requires a complex ecosystem of effective institutions, laws, rules, and regulations that are managed by able and effective public officials and strongly supported by the private sector in a competitive market environment. The involvement of an entrepreneurial private sector is another indispensable element for sustainable and competitive innovation policy, particularly at the later stage following the pioneering public sector outlays in innovation infrastructure and human resources acquisition.

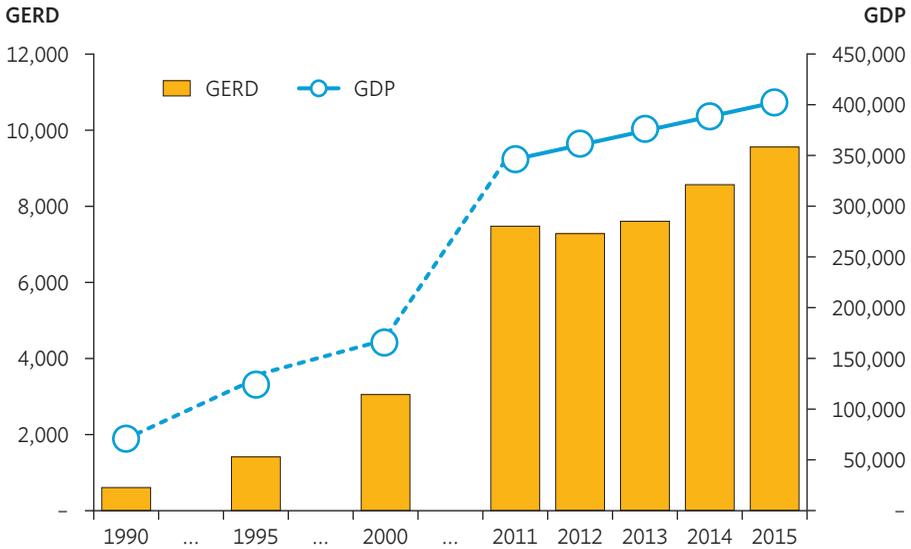
In projecting Singapore's future innovation path, the government must be more efficient in allocating resources for innovative knowledge-based development. For example, in the Global Innovation Index 2015, Singapore was ranked in seventh place, but in terms of the innovation efficiency ratio, which shows how much output a country is getting for its inputs, Singapore ranked poorly (Yahya, 2014). While the government has played a vital and significant role in guiding science and technology capability development as an integral part of its overall economic development strategy, the emergence of a more vibrant technological entrepreneurial community is likely to be critical to Singapore's continuing transition from technology adopter to

innovator. As a small economy, the key challenge is for Singapore to move continually upward in industrial development through an innovative knowledge-based industrial cluster strategy.

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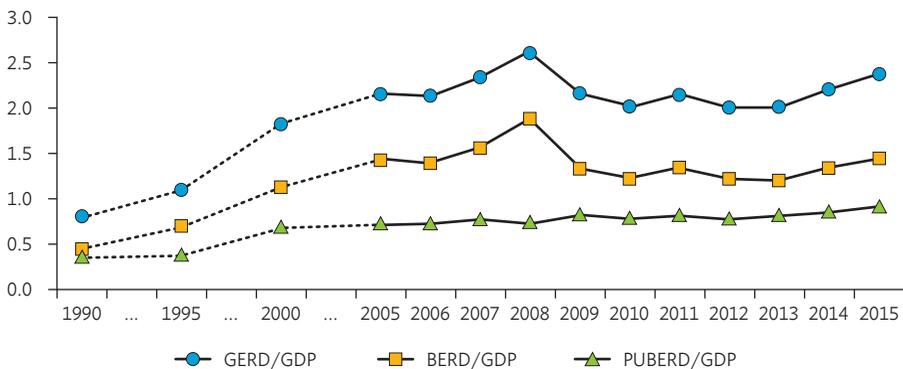
Figure A7.1: Gross Domestic Product Growth and Gross Expenditure on Research and Development, 1990–2015 (S\$ million)



GDP = gross domestic product, GERD = gross expenditure on research and development.

Source: National Survey of Research and Development in Singapore, 2015 (published in December 2016). <https://www.a-star.edu.sg>.

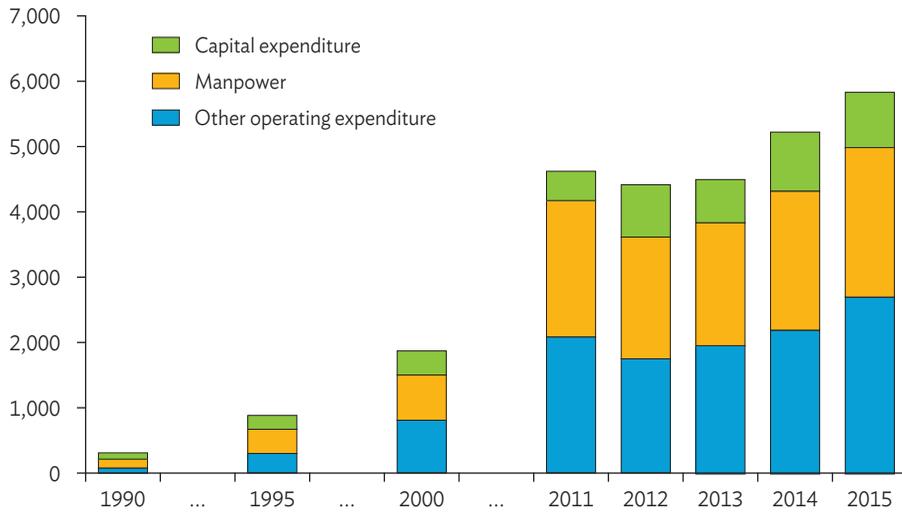
Figure A7.2: Gross Business and Public Expenditure on Research and Development as a Percentage of Gross Domestic Product, 1990–2015 (%)



BERD = business expenditure on research and development, GDP = gross domestic product, GERD = gross expenditure on research and development, PUBERD = public expenditure on research and development.

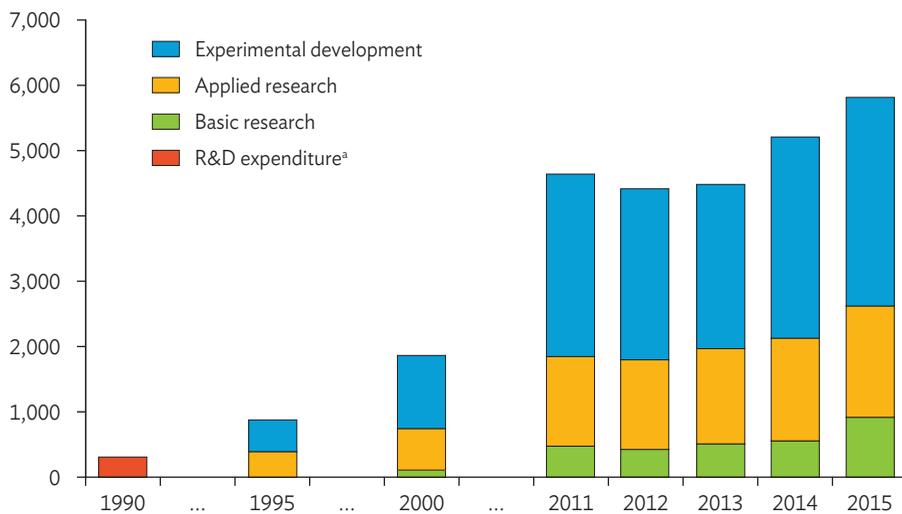
Source: National Survey of Research and Development in Singapore, 2015 (published in December 2016). <https://www.a-star.edu.sg>.

Figure A7.3: Business Expenditure on Research and Development by Type of Cost, 1990–2015 (S\$ million)



Source: National Survey of Research and Development in Singapore, 2015 (published in December 2016).
<https://www.a-star.edu.sg>.

Figure A7.4: Type of Business Expenditure on Research and Development, 1990–2015 (S\$ million)

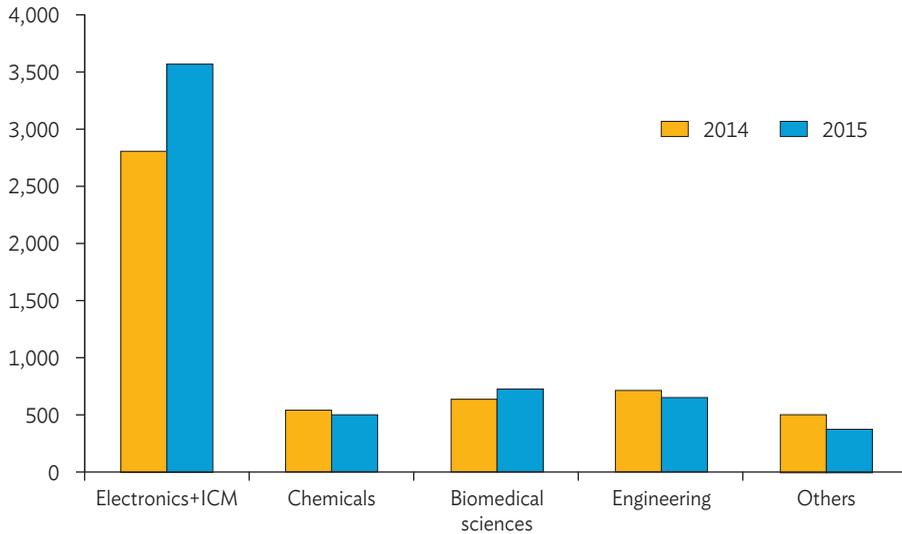


R&D = research and development.

^a Expenditure data not collected in the same manner in 1990.

Source: National Survey of Research and Development in Singapore 2015 (published in December 2016).
<https://www.a-star.edu.sg>.

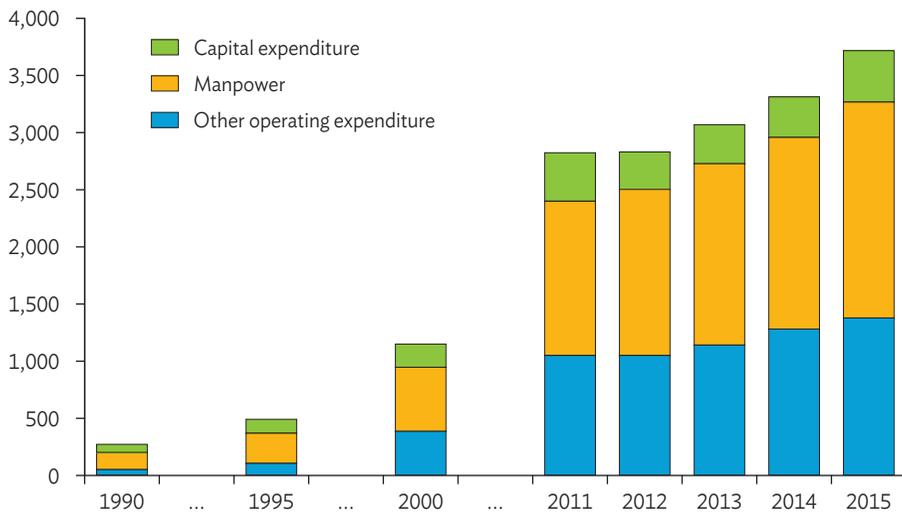
Figure A7.5: Business Expenditure on Research and Development by Fields of Science and Technology, 2014–2015 (S\$ million)



ICM = infocommunications and media.

Source: National Survey of Research and Development in Singapore 2015 (published in December 2016). <https://www.a-star.edu.sg>.

Figure A7.6: Public Expenditure on Research and Development by Type of Cost, 1990–2015 (S\$ million)



Source: National Survey of Research and Development in Singapore 2015 (published in December 2016). <https://www.a-star.edu.sg>.

Innovation Policy in Thailand

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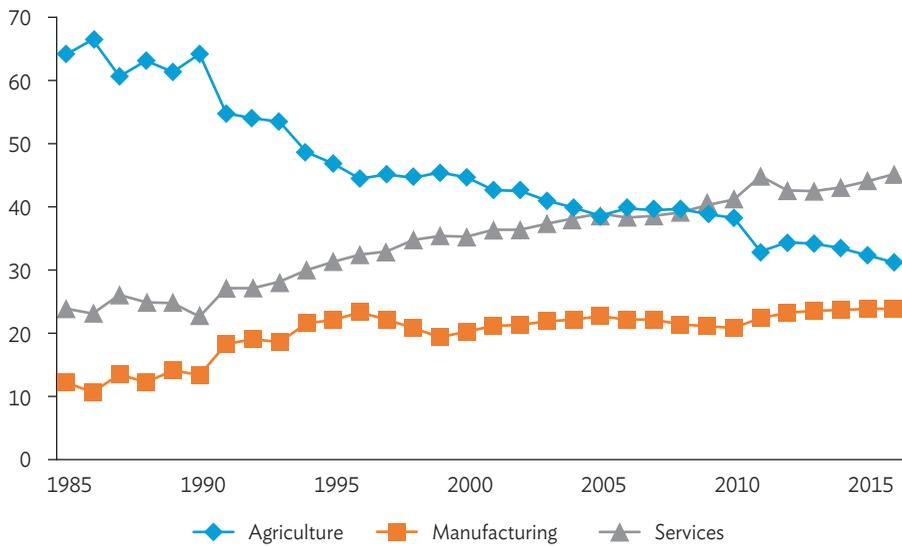
8.1 | Introduction

From the 1960s to the mid-1990s, Thailand experienced remarkable success in its economic development, with average gross domestic product (GDP) growth of more than 6% per year. The country has transformed itself from a traditional agrarian economy into a modern one, as reflected by the changes in its labour force composition (Figure 8.1). While the service sector constitutes the largest share of the country's GDP, Thailand's growth has always been driven by the export of manufactured products. With manufacturing value-added contributing 26.9% of its GDP in 2015, Thailand has become a major 'factory of the world', nearly on par with China and the Republic of Korea (henceforth, Korea) (Figure 8.2). The success of Thai manufacturing is due to Thailand's ability to attract foreign direct investment and Thai companies' ability to participate in global value chains, mainly as subcontractors of multinational companies.¹

Over time, Thailand has also been successful in diversifying its exports in terms of both products and markets (Figure 8.3a). This diversification makes the Thai economy less susceptible to demand shocks in the global economy compared with countries such as Malaysia and Viet Nam, which export fewer product items and concentrate their export markets in fewer countries (Figure 8.3b).

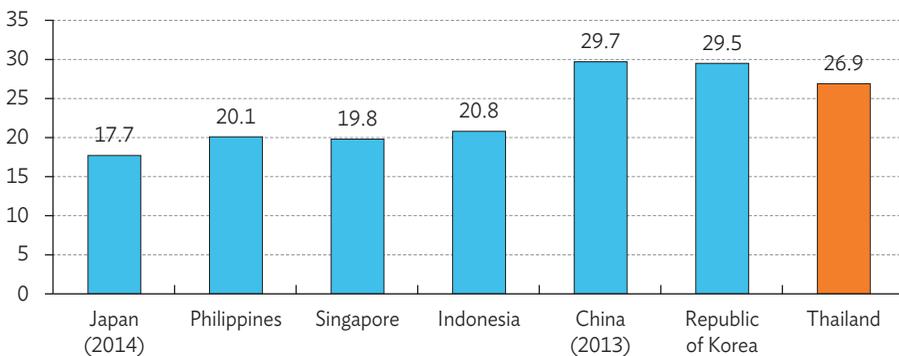
¹ The authors would like to thank Mr Sunthorn Tunmuntong, Mr Pathit Ongvasith, and Mr Wuttipong Tunyut for their excellent assistance in gathering data and preparing this paper. They also would like to thank commentators and participants of the Economic Research Institute for ASEAN and East Asia's workshops on innovation policy in ASEAN for providing many useful comments.

Figure 8.1: Distribution of the Labour Force across Sectors, 1985–2016 (%)



Source: National Statistical Office of Thailand, Labour Force Survey, various years.

Figure 8.2: Manufacturing Value-added Share of Gross Domestic Product, 2015 (%)



Source: World Bank. Databank. Manufacturing, value added (percentage of GDP). <http://data.worldbank.org/indicator/NV.IND.MANF.ZS> (accessed 10 November 2016).

Most Thai manufacturing companies are original equipment manufacturers (OEMs) that supply parts, components, or finished products to be marketed by multinational companies that own brands. As such, they generally have low profit margins as they face continuous pressure to reduce their prices, improve the quality of their products, and deliver on time. Many have not survived and have had to exit the market.

Figure 8.3a: Diversification of Thailand's Exports and Markets, 2001–2016
(%)

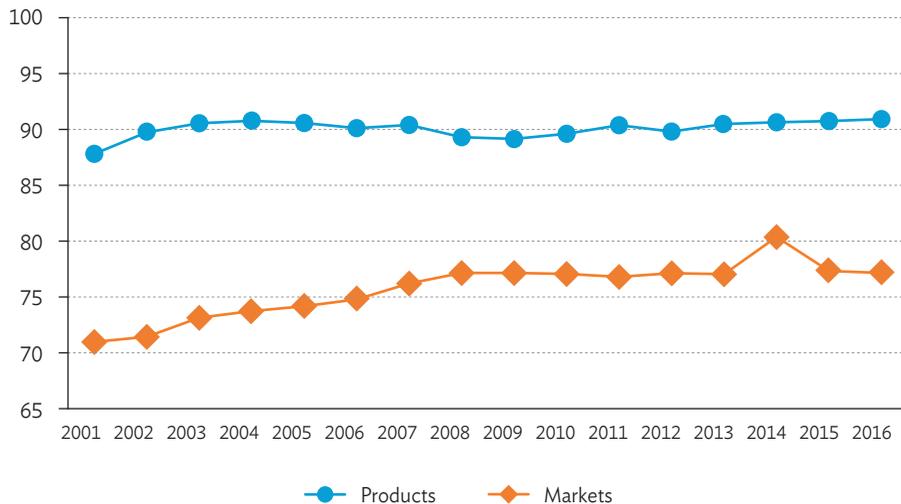
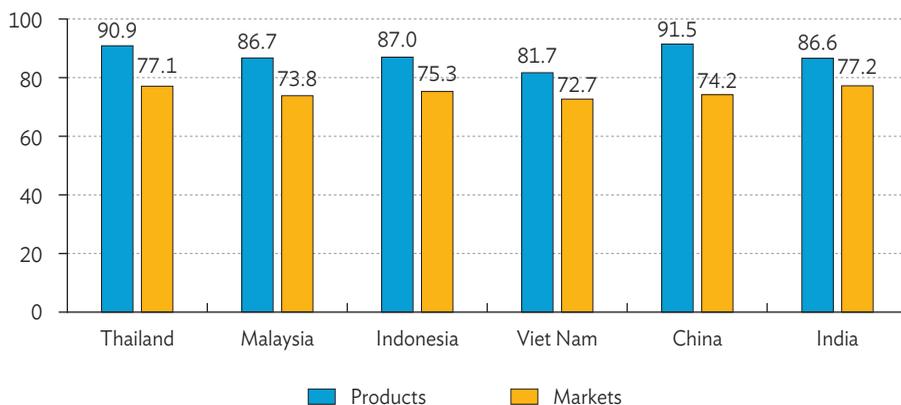


Figure 8.3b: Degree of Export Diversification in Products and Markets, 2016
(%)



Note: The level of diversification of export products is $100 \times \left(1 - \sqrt{\sum_i \left(\frac{X_i}{X} \right)^2} \right)$, with X representing the total value of all exported products and X_i representing the total value for a particular exported product (i). The level of diversification of export markets is defined similarly.

Source: Authors, from UN Comtrade data.

Those that have managed to survive are generally quite efficient as they have adopted 'lean production' techniques pioneered by Japanese automotive assemblers.² The techniques are usually spread from Japanese companies investing in Thailand to their suppliers (Suehiro, 2008). Box 8.1 provides a case study on how foreign direct investment has facilitated technology transfer in the automotive and parts industries in Thailand.

While there is still much room for improvement in lean production, especially among small and medium-sized enterprises, large companies have mastered the techniques. Many have also introduced automation and robots into their factories as Thailand is increasingly facing labour shortages. The country imported 2,556 units of industrial robots in 2015 (International Federation of Robotics, 2016).

While Thailand has a relatively high degree of participation in global value chains, its ability to generate domestic value-added is still below average (Figure 8.4). To achieve higher growth rates, the country can no longer rely only on the movement of its labour force from agriculture to manufacturing, further diversification of its exports, and incremental improvement of its production system. As argued by Doner et al. (2005), industrial upgrading must replace diversification for a country to sustain high growth in the long run. Thus, the only way forward is to increase productivity through innovation. In particular, Thai companies must develop design, branding, and marketing capabilities. While innovation usually goes far beyond the confines of research labs to users, suppliers, and other external parties, research and development (R&D) remains a key instrument to absorb, integrate, and create the new knowledge employed in most innovation activities.³ For Thailand to be innovative, far greater investment in R&D is indispensable.

² Under the lean production system, inventory levels were kept at an absolute minimum so that costs could be shaved and quality problems quickly detected and solved; bufferless assembly lines assured continuous flow production; utility workers were conspicuous only in their absence from the payroll. If a worker was absent without notice, the team would fill in; repair areas were tiny as a result of the belief that quality should be achieved within the process, not within a rectification area (Krafcik, 1988).

³ The relationship between R&D and innovation can be highly complex. There are many steps linking R&D to product innovation, process innovation, marketing innovation, and organisational innovation. There are also many feedback loops between these steps. Innovation does not necessarily require progression through all steps in a successive linear fashion as there are multiple entry points to the process (National Science Foundation, 2012).

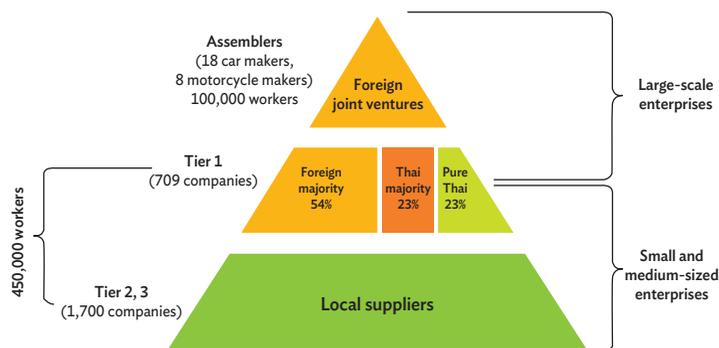
BOX 8.1

FOREIGN DIRECT INVESTMENT AND TECHNOLOGY TRANSFER IN THE THAI AUTOMOTIVE AND PARTS INDUSTRIES

The development of the automotive and parts industries in Thailand has been driven by foreign direct investment by foreign assemblers, especially Japanese carmakers, and their first-tier suppliers. Besides possessing brand and component manufacturer networks, these companies own the technologies to produce key automotive components, such as engines, transmissions systems, and electronic control systems. Major foreign assemblers in Thailand include Toyota Motors, Honda Automobile, Nissan Motors, Mitsubishi Motors, Suzuki Motors, Isuzu, Mazda, General Motors, Ford Motor, BMW Manufacturing, and Tata Motors.

According to the Thai Auto Parts Manufacturers Association, the automotive and auto parts industries in Thailand have 709 tier 1 suppliers, including foreign-majority companies (54%), Thai majority companies (23%), and wholly owned Thai companies (23%) (Figure). There are around 1,700 tier 2 and 3 suppliers, most of which are local suppliers.

Structure of the Thai Automotive Industry

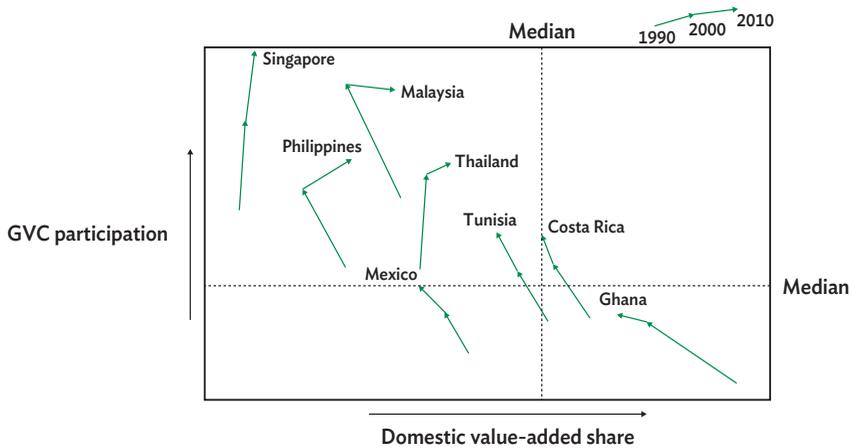


Source: Thai Auto Parts Manufacturers Association (2014), 'Study on the Parts and Components Structure of the Thai Automobile Industry' (in Thai). http://data.thaiauto.or.th/iu3/images/stories/PDF/Research/RD_Supply_Chain.pdf

Local tier 2 and 3 suppliers usually produce unsophisticated parts, such as seats or bodywork for automobiles. They are required to source raw materials and machinery based on the requirements of higher-tier producers. To win more orders, lower-tier suppliers must constantly increase the productivity of their production processes. They must master 'lean production' techniques, such as the Toyota Production System, both from self-learning and through knowledge transfer from the assemblers. Some local suppliers, such as Thai Summit Group, Summit Group, PCS, and Somboon Advance Technology, have mastered the technologies and become tier 1 suppliers.

Working closely with assemblers also allows suppliers to access product technologies. Tier 1 suppliers are being increasingly contracted to conduct research and development, design, and testing in cooperation with the assemblers. Some Thai tier 1 suppliers have set up in-house research and development units. Suppliers that have not been able to upgrade have become replacement equipment manufacturers or traders.

Figure 8.4: Global Value Chain Participation and Domestic Value-added Share of Selected Countries, 1990–2010



GVC = global value chain.

Source: United Nations Conference on Trade and Development (2013).

R&D is increasingly important as Thailand will face many challenges in the near and medium term. The most important challenges will be demographic ones. Under the medium-fertility case, the country is forecast to become an aged society by 2022, with over 14% of its population aged 65 or above, and a hyper-aged society by 2032, with over 21% aged 65 or above (NESDB, 2013). Thailand will age faster than all Asian economies, except Japan, Korea, Hong Kong, Singapore, and Taiwan. However, while these economies have already reached high-income status, Thailand is still a middle-income country. Thailand’s population aged 65 or older will equal those aged 15 or below by 2025. China, Viet Nam, and Malaysia are forecasted to reach that stage in 2030, 2040, and 2050, respectively, whereas Indonesia and the Philippines will not have reached that stage by 2050, almost three decades after Thailand (Magnus, 2014).

As Thailand’s birth rate declines, its population is projected to decrease to about 63.8 million by 2045,⁴ a situation which is likely to create a severe shortage of labour. The Thai labour supply already began to decline in 2016, and the country has reached its ‘Lewis turning point’ – a point at which there is almost no surplus rural labour to move into the manufacturing or service sectors. This, in turn, typically causes urban

⁴ In 2016, the population in Thailand was 68.86 million (World Bank Database).

wages to rise dramatically. A study by the Asian Development Bank (2016) points out that Thailand has suffered a significant decline in its potential output growth rate, which is now one of the lowest in Southeast Asia. Thailand's annual potential output growth declined by 0.9% between 2000–2007 and 2008–2013 (Table 8.1), mainly due to the decline in labour force growth.

Table 8.1: Change in Potential Output Growth and Its Components between 2000–2007 and 2008–2013 (%)

	Annual Potential Output growth	Trend Labour Force Growth	Potential Labour Productivity Growth
China	-1.0	-1.3	0.3
India	0.1	-0.3	0.4
Indonesia	1.0	0.0	1.0
Japan	-1.4	-0.5	-0.9
Malaysia	-0.4	-0.5	0.1
Philippines	0.3	-0.2	0.5
Singapore	-0.3	0.8	-1.1
Republic of Korea	-2.1	0.2	-2.3
Thailand	-0.9	-0.6	-0.3
Viet Nam	-1.4	-0.8	-0.6
Cambodia	-1.8	-0.7	-1.1

Source: Asian Development Bank (2016).

In addition, as Thailand rapidly becomes an aged society, its social security fund is expected to become insolvent by around 2045. This can only be prevented if the fund is drastically reformed in time. The huge fiscal burden will also increase as the cost of healthcare rises while the number of people paying taxes shrinks.

In conclusion, Thailand will face various challenges as the country becomes an aged society. This will have negative impacts on all Thai people. Thus, the country must develop its economy and avoid the 'middle-income trap'⁵ within the next decade,

⁵ The middle-income trap can be described as a trap of policy misdiagnosis when countries fail to match their growth strategies with the prevailing structural characteristics of their economies. Middle-income countries can fall into two types of common traps. One is sustaining labour-intensive manufacturing export-led growth despite the competitive disadvantage caused by higher wages. Another is trying to leapfrog prematurely into 'knowledge economies', with none of the institutional infrastructure in place to accomplish this (Gill and Khara, 2015).

or Thai people will grow old before the country becomes affluent enough to build an adequate social safety net to accommodate these issues. It is widely believed that Thailand will fall into the middle-income trap and will be unable to escape it in the near future. This is because the country has industrialised without developing its own technological capabilities. Instead, it emphasises exporting by suppressing labour wages to be competitive in the global market. This development model means that the population has both low income and low purchasing power. Consequently, income distribution is highly uneven. Finally, the current development model is also not environmentally friendly as businesses prefer to suppress production costs as much as possible rather than protect the environment.

In summary, Thailand may have successfully shifted from a development model centred on exploiting natural resources to transition towards a model built upon efficiency. However, Thailand will soon have to concentrate on developing an economy based on knowledge creation and innovation if it wants to become a high-income country.

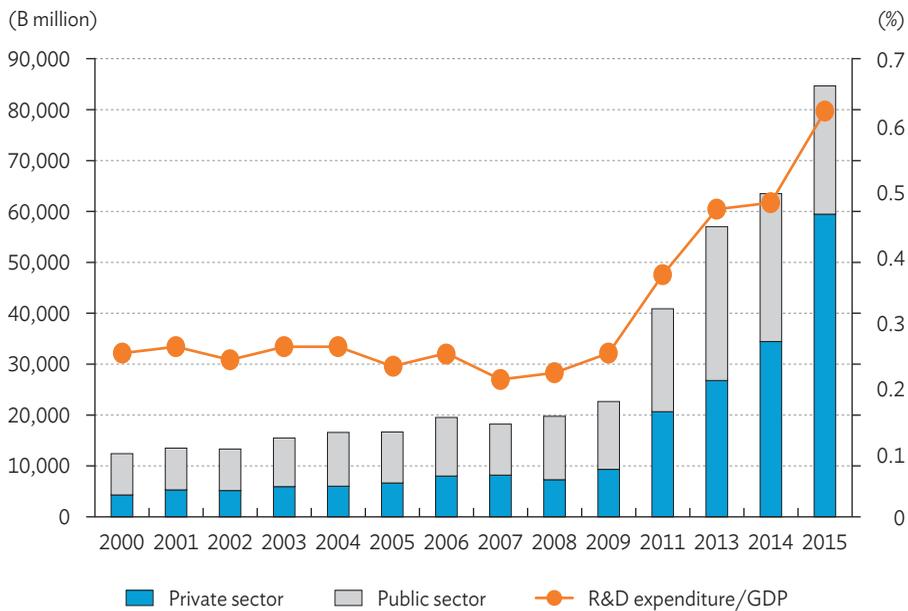
The following sections will analyse the current state of innovation in Thailand, discuss the country's innovation policies, and provide policy recommendations on how to encourage more innovation in Thailand.

8.2 | State of Innovation in Thailand

In this section, we briefly discuss the state of innovation in Thailand by first analysing two major inputs to the R&D system: the R&D investment budget and R&D human resources. We then discuss the outputs derived from these inputs and assess the efficiency of the Thai R&D system. Finally, we provide examples of local companies that are engaged in R&D and innovation and the benefits of such activities.

8.2.1 Research and development inputs

Investment in R&D is an important input for creating technological innovation. Although Thailand's R&D investment has gradually increased, it remains very small, at around 0.62% of GDP in 2015 (Figure 8.5). This is far below the levels of advanced economies in Asia, such as Korea (4%), Japan (3.6%), Taiwan (2.9%), and Singapore (2.3%). Nonetheless, a positive sign is that private R&D investment is rising quickly and has surpassed public investment since 2011.

Figure 8.5: Research and Development Investment in Thailand, 2000–2015

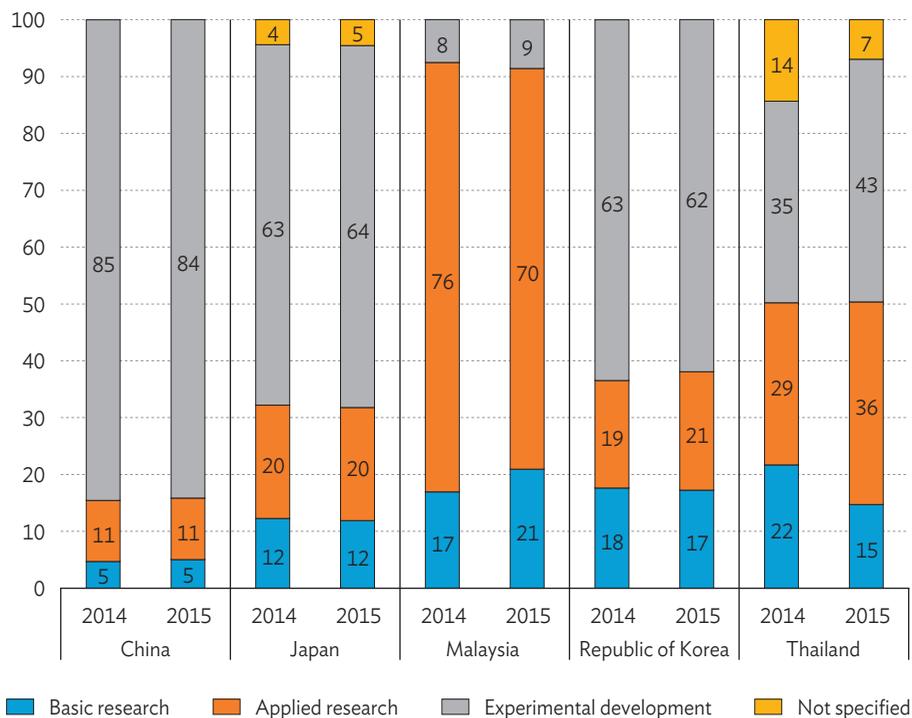
GDP = gross domestic product, R&D = research and development.

Source: National Research Council and National Science Technology and Innovation Policy Office.

There are at least three types of R&D activities: basic research, applied research, and experimental development (OECD, 2015).⁶ Compared with other countries, Thailand invests a higher portion of its research budget in basic research (Figure 8.6). Such research is sometimes called frontier research, fundamental research, or blue skies research. The outcome of basic research is inherently unpredictable and generally cannot be applied to real-world problems, at least in the short term. While most developed countries can strongly commit to undertaking basic research, it is probably unwise for Thailand to invest so heavily in basic research as it is still a developing country.

⁶ Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. Applied research is also original investigation undertaken to acquire new knowledge, but it is directed primarily towards a specific practical aim or objective. Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed at producing new materials, products, or devices; installing new processes, systems, and services; or improving substantially those already produced or installed (OECD, 2015).

Figure 8.6: Composition of Research Investments, Classified by Type of Research, 2014-2015 (%)



Sources: United Nations Educational, Scientific and Cultural Organization and National Research Council (accessed 15 January 2018).

Another important input to the R&D system is R&D personnel. The full-time equivalent number of Thai R&D personnel almost tripled from 32,011 in 2001 to 89,617 in 2015, accounting for a compound annual growth rate of 8% (Table 8.2). The ratio of private sector R&D personnel to the total R&D personnel also rose significantly from 30% to 55% in the same period. As nearly half of all R&D personnel are employed in the public sector – especially in public universities, government research institutes, and other public agencies – the private sector is experiencing a shortage of R&D personnel as it tries to continue to increase its R&D investment.

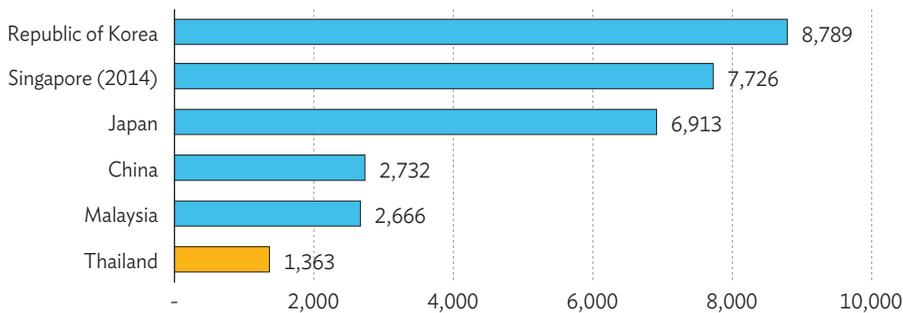
Despite the rapid increase, the number of R&D personnel per million population is still considered very small by regional standards. At about 1,363 per million population in 2015, the ratio is significantly lower than that of Malaysia (2,666), China (2,732), Japan (6,913), Singapore (7,726), and Korea (8,789) (Figure 8.7).

Table 8.2: Thai Research and Development Personnel, 2001–2015
(full-time equivalent)

Year	Number (persons)			Ratio (%)		Number per Million Population
	Private	Public	Total	Private	Public	
2001	9,710	22,301	32,011	30.3	69.7	514
2003	7,010	35,369	42,379	16.5	83.5	672
2005	7,750	29,217	36,967	21.0	79.0	592
2007	8,645	33,979	42,624	20.3	79.7	676
2009	11,846	48,496	60,342	19.6	80.4	950
2011	22,245	30,877	53,122	41.9	58.1	829
2013	25,513	45,173	70,686	36.1	63.9	1,091
2014	39,043	45,173	84,216	46.4	53.6	1,293
2015	49,004	40,613	89,617	54.7	45.3	1,363

Sources: National Research Council and National Science Technology and Innovation Policy Office.

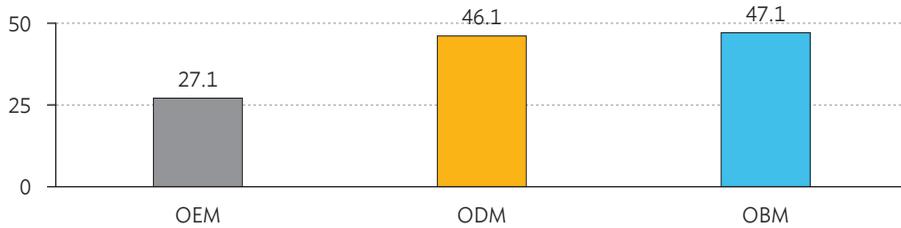
Figure 8.7: Research and Development Personnel, 2015
(number per million population)



Sources: United Nations Educational, Scientific and Cultural Organization and National Science Technology and Innovation Policy Office.

To understand R&D activities among Thai firms, we turn to the Research, Development and Innovation Survey conducted by the National Science, Technology and Innovation (NSTI) Policy Office. According to the survey, Thai manufacturers engaged in R&D activities were still in the minority in 2014, accounting for only 36.2% of total Thai manufacturing firms. Firms engaged in R&D comprised 27.1% of OEMs, 46.1% of original design manufacturers (ODMs), and 47.1% of original brand manufacturers (OBMs) (Figure 8.8).

Figure 8.8: Share of Firms Engaged in Research and Development, Classified by Firm Type, 2014 (%)



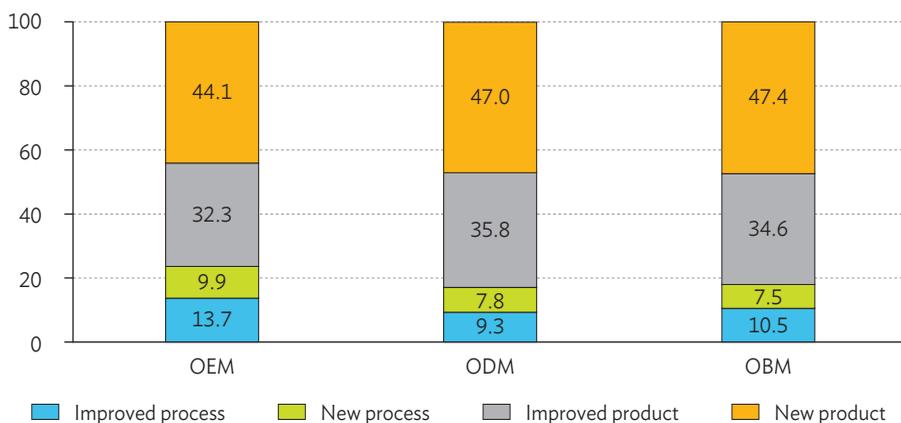
OBM = original brand manufacturers, ODM = original design manufacturers, OEM = original equipment manufacturers.

Note: Here, OEMs are defined as firms with at least 50% revenue from manufacturing products without their own design or own brand. ODMs are those with at least 50% revenue from manufacturing products with their own design. OBMs are those with at least 50% revenue from manufacturing products with their own brand.

Source: Authors, from the National Science, Technology and Innovation Policy Office’s Research, Development and Innovation Survey data.

The survey also shows that all firm types conducted R&D to improve their products more than to improve their production processes (Figure 8.9). However, OEMs tended to invest in R&D to improve their production processes more than OBMs and ODMs.

Figure 8.9: Objectives of Research and Development among Firms, 2014 (%)



OBM = original brand manufacturer, ODM = original design manufacturer, OEM = original equipment manufacturer.

Note: Here, OEMs are defined as firms with at least 50% revenue from manufacturing products without their own design or own brand. ODMs are those with at least 50% revenue from manufacturing products with their own design. OBMs are those with at least 50% revenue from manufacturing products with their own brand.

Source: Authors, from the National Science, Technology and Innovation Policy Office’s Research, Development and Innovation Survey data.

8.2.2 Research and development outputs and efficiency

At the aggregate level, given its much smaller inputs, it is not surprising that the Thai R&D system produces smaller outputs. Here we are interested in outputs that are related to commercial applications, which can be proxied by the number of patents.⁷ As shown in Table 8.3, the number of resident applications for patent from Thailand was about 15 per million population in 2014, which was considerably lower than those of Malaysia (45), Singapore (238), and China (587).

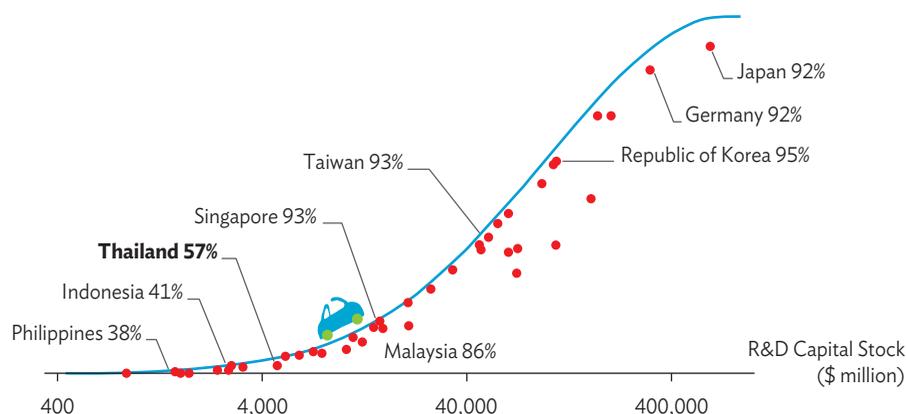
Table 8.3: Resident Applications for Patent by Origin, 2010–2015
(number per million population)

Country	2010	2011	2012	2013	2014	2015
Japan	2,265	2,250	2,250	2,134	2,092	2,039
Republic of Korea	2,668	2,773	2,962	3,186	3,254	3,305
United States	782	795	856	910	894	897
Germany	910	895	919	900	912	887
China	219	309	396	519	587	706
Singapore	176	204	203	212	238	265
Malaysia	44	38	38	41	45	42
Thailand	18	14	15	23	15	

Source: World Intellectual Property Organization Statistics Database.

However, Thailand's smaller R&D outputs were also due to its lower R&D efficiency. Based on a stochastic frontier analysis of input–output data during 2002–2010, Tangkitvanich, Rattanakhamfu, and Rakkiatwong (2013) found that the efficiency of the Thai R&D system was only 57% of the maximum obtainable output given the levels of input (Figure 8.10). The Thai efficiency rate was also considerably lower than the rates for Malaysia (86%), Japan (92%), Singapore (93%), Taiwan (93%), and Korea (95%).

⁷ Patent ownership is neither necessary nor sufficient for the commercialisation of R&D because only a small proportion of patents can be used for commercialisation. Many patents are also filed for 'defensive' and other purposes. In some cases, companies resort to using trade secrets, rather than patents, to protect their innovations. Still, patents are widely used as proxies for commercial innovation as the data on patents are publicly available.

Figure 8.10: Comparing Efficiencies of Research and Development Systems


Source: Tangkitvanich, Rattanakharnfu, and Rakkiatwong (2013).

Thailand's low R&D efficiency can be attributed to at least three main reasons. First, the system remains largely supply driven as a result of the relatively low private R&D investment share. In a supply-driven setting, publicly funded R&D projects are set up based on the academic interests of the researchers involved rather than on the demands of the economy and society. Many of these research projects are basic in nature and are intended for journal publications. As a result, the research outputs tend to have little application value, at least in the short term. This is reflected in the small number of licensing agreements between Thai research universities and the private sector, and the modest amount of licensing revenue (Table 8.4).

Second, it is difficult to hold universities and government research institutes accountable as they usually have multiple mandates. For example, Thai research universities have mandates not only to conduct research but also to educate a large number of undergraduate students and to provide community services. There are some cases of successful university–industry collaboration in Thailand, such as those between Betagro and King Mongkut University of Technology Thonburi, Thai Union Frozen Products and Mahidol University, and Lion Corporation (Thailand) and Chulalongkorn University (Table 8.5). However, these are still exceptions rather than normal practices, and their overall impact remains small.

Government research institutes have more research time, human capital, and research facilities than their private counterparts. Thus, they are expected to play important roles in promoting the diffusion and use of new and existing knowledge in the economy.

Table 8.4: Licensing Agreements and Licensing Revenue of Research Universities in Thailand

Item	CU	MU	KU	KK	CMU	SUT	PSU	KMUTT
Year of establishment of TLO	1995	1998	1996	2006	2007	2007	2007	1995
Number of staff engaged in licensing and related activities	4	n/a	n/a	2	2.5	2	2.5	2
Number of staff engaged in patent filing and related activities	6	n/a	6	4	4.5	6	4	n/a
Licensing agreements (2008–2011)	42	n/a	19	n/a	n/a	10	n/a	n/a
Revenue from licensing out (B million) (2008–2011)	19.5	n/a	10.4	1.7	5.9	3.2	0.9	1.2
Number of invention disclosures	51	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Local utility patents 2011–2012 (applied/granted)	44/1	0/2	12/0	14/0	n/a	17/0	21/0	14/0
Cumulative local utility patents (applied/granted)	n/a	(n/a)/34	209/28	71/4	(n/a)/67	96/4	(n/a)/51	162/14

n/a = not available, CMU = Chiang Mai University, CU = Chulalongkorn University, KK = Khon Kaen University, KMUTT = King Mongkut University of Technology Thonburi, KU = Kasetsart University, MU = Mahidol University, PSU = Prince Songkla University, SUT = Suranaree University of Technology, TLO = Technology Licensing Office.

Source: United Nations Conference on Trade and Development (2016).

They can also perform a bridging role that links research activities with those producing products (Intarakumnerd, 2014). However, this expectation has not been fulfilled in the case of Thailand. For example, the National Science and Technology Development Agency (NSTDA) – the organisation that has been allocated the largest budget and has the largest number of talented researchers – has a broad set of legally mandated missions, including policy studies; R&D; product quality testing and calibration; reviewing and assessing imported technologies; developing basic R&D infrastructure; and developing R&D human resources. It is also unclear how the NSTDA should prioritise its work to respond to the potentially competing demands from the commercial and social sectors. Moreover, the NSTDA is run by scientists with limited industrial experience (Intarakumnerd, 2014). As a result, R&D conducted by the NSTDA has largely yielded prototypes that could not be scaled up for commercial application.

Table 8.5: Examples of University–Industry Collaboration

Private Business and University (source)	Nature of Collaboration
Betagro and King Mongkut University of Technology Thonburi (KMUTT) (Pittayasophon and Intarakumnerd, 2015)	The Betagro Group was founded in 1967 to produce and distribute animal feed. Initially, Betagro and KMUTT jointly initiated the Food Engineering Practice School Program master’s degree in 2006, aimed at training students to solve problems in real situations before pursuing their research work. From 2006 to 2015, KMUTT sent about six master’s students to Betagro every semester. Betagro proposed several research topics and assigned staff members to be co-supervisors. Each semester, students presented to executives of both parties.
Lion Corporation and Chulalongkorn University (Junhasavasdikul, 2010)	Lion Corporation was established in 1967 to produce powder detergent and shampoo in Thailand to substitute Japanese imports. The university research team discovered a method of generating Silver Nano from silver nitrate, which could stop the growth of bio-organisms in wet conditions and could be applied in a detergent. The joint research team then developed low-cost silver raw materials that could substitute imports and applied for an invention patent. The new product, Pao Silver Nano, was brought to the market.
Thai Union Frozen Products (TUF) and Mahidol University (Ono, 2014)	TUF was founded in 1977 as a canned-tuna processor and exporter. It has grown organically and through mergers and acquisitions to become the world’s largest canned-tuna producer. It already has research and development centres near its production facilities that develop products with better taste and packaging. In 2014, TUF and Mahidol University’s Faculty of Science jointly set up a \$3.3 million research and development centre at Mahidol campus. The new centre focuses on longer-term research. In particular, it conducts research on consumption patterns, tuna processing technology, tuna nutrition and varieties, and using all fish parts for additional revenue.

Sources: Pittayasophon and Intarakumnerd (2015); Junhasavasdikul (2010); Ono (2014).

Third, the private sector lacks the sufficient human resources to expand its R&D activities, even if it were willing to invest more. This is because most researchers are employed by public universities, government research institutes, and government agencies. According to the NSTI Policy Office’s 2015 survey, 54.7% of R&D personnel are employed by the public sector, while only 45.3% are employed by the private sector. As these public agencies are almost fully funded by the public budget, they lack an incentive to respond to the needs of the private sector. Intarakumnerd and Charoenporn (2013) argue that government research institutes and public universities in Thailand have not provided much assistance to local companies to enhance their technological capabilities.

With smaller inputs and lower R&D efficiency, Thailand will not be able to catch up with advanced East Asian economies and it risks falling into the middle-income trap. Thus, there is an urgent need for the country to encourage more R&D investment and improve the efficiency of its R&D and innovation system by implementing better policies.

8.2.3 Local companies active in innovation

As Thailand's growth has slowed and it is facing greater resource constraints, an increasing number of Thai companies have recognised the challenges and have begun to be proactive. Many are now conducting R&D and other innovation activities, as shown in Table 8.6.

Table 8.6: Examples of Thai Companies Active in Research and Development and Innovation

Company	Activities	Benefits of Innovation
Siam Cement Group (SCG) is a leading business conglomerate in Thailand. Founded in 1913 to produce cement, the main building material for infrastructure projects, SCG has grown continually. It has three core business units: cement-building materials, chemicals, and packaging. After restructuring and recovering from the Asian financial crisis in 1997, SCG entered a new phase of investing in research and development (R&D) to create a competitive edge. It has also expanded overseas, especially in Association of Southeast Asian Nations Member States.	R&D, design, manufacturing, distribution, marketing, branding	The profit margins of its R&D-based products are 10%–20% higher than those of non-R&D products.
Saijo Denki is a local air-conditioner manufacturer founded in 1987 as an original equipment manufacturer. With R&D capabilities, it has transformed itself into an original brand manufacturer and can compete with foreign air-conditioner manufacturers in Thailand. It exports its products to many countries.	R&D, design, manufacturing, distribution, marketing, branding	Its own-brand products have profit margins 24% higher than original equipment manufacturers.
Silicon Craft was established in 2002 by Silicon Valley veterans who had returned to Thailand. It is Thailand's first and only integrated circuit design company. It designs customised and standard microchips for radio frequency identification applications and delivers products with high-value-added features. Its products are exported to Australia, Canada, China, Europe, the Republic of Korea, New Zealand, and the United States.	R&D, design	Its radio frequency identification products can compete with those of Texas Instruments.
Siam Bioscience was founded in 2009 by CPB Equity, an investment arm of the Crown Property Bureau that manages royal assets. It is Thailand's first and only producer of biosimilar drugs, which are almost identical to original biologic drugs for which patents have expired. An example is biosimilar erythropoietin, which controls red blood cell production for patients with kidney problems.	R&D, design, manufacturing, distribution, marketing, branding	Market entry of the company helped reduce the price of erythropoietin significantly.
PCS is a leading local auto parts manufacturer, specialising in high-accuracy machine parts, i.e. engine, common rails, and transmission parts. It supplies leading Japanese car assemblers in Thailand.	R&D, design, manufacturing	Its common rail parts are competitive in the global market.
Cho Thavee specialises in designing and manufacturing commercial automotive vehicles, such as trucks, trailers, buses, catering trucks, fire rescue vehicles, armoured vehicles, troop carriers, and battle ships.	R&D, design, manufacturing	The company has the largest market share of catering high loader trucks for Airbus 380 worldwide.

Source: Authors' interviews.

8.3 | Innovation Governance and Policies in Thailand

In this section, we begin by briefly analysing the governance structure of the current innovation system. We then discuss the targets set by the government and the policy measures used to achieve them, and evaluate their effectiveness.

8.3.1 Governance structure of the innovation system

The institutional structure in which the Thai R&D and innovation policy system operates is fragmented and fraught with governance issues. The review team of the United Nations Conference on Trade and Development (UNCTAD) identified six major governance issues (UNCTAD, 2016):

- (i) **The absence of a strategic driver of policy.** The lack of a strategic policy driver was partly due to the ineffective functioning of the NSTI Policy Committee and the National Research Council – the twin policymaking bodies. By law, both were chaired by the prime minister. However, since the prime minister rarely chaired the meetings, they were chaired by a deputy prime minister or a junior minister, which undermined the sense of ownership among other ministers. This was highly undesirable given the cross-departmental nature of R&D and innovation policies.
- (ii) **Several bodies responsible for funding and management.** More problematic from a governance perspective was that some agencies, such as the National Research Council, combined functions of policy guidance and funding of research. This leads to potential conflicts of interest.
- (iii) **Insufficient monitoring and evaluation.** The process of budget allocations lacked sufficient monitoring, control, and programme evaluation.
- (iv) **Lack of prioritisation.** There was a tendency to elaborate plans consisting of extensive lists of actions, without prioritising them.
- (v) **Little private sector involvement.** The private sector was not sufficiently involved or consulted in the policy elaboration process or in making strategic decisions.
- (vi) **A confusing system.** A proliferation of government bodies and entry points in the innovation system created confusion, opacity, and misunderstanding among stakeholders. This made it hard for the private sector, particularly small and medium-sized enterprises with limited resources, to understand and navigate the system.

To solve the first two problems, the government reformed the structure of the innovation system in late 2016 by setting up the National Research and Innovation Policy Council as the sole policymaking body. The new body is chaired by the prime minister and served by

the joint secretariats of the NSTI Policy Office and the National Research Council Office.⁸ Also, under this new structure, the National Research Council no longer functions as a funding agency, resolving its potential conflicts of interest. The remaining problems are to be addressed by the newly formed National Research and Innovation Policy Council.

8.3.2 R&D targets and policy measures

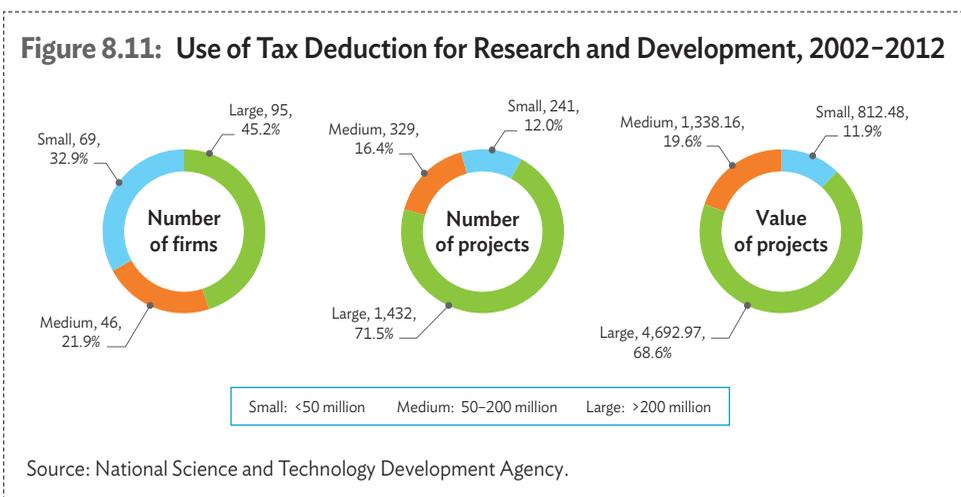
Under the 12th National Economic and Social Development Plan, the Government of Thailand targets economic growth of at least 5% per year during 2017–2021 to increase the country's GDP per capita to US\$9,325 (National Economic and Social Development Board, 2017). Annual productivity growth must exceed 2.5% to achieve these targets. The government realises that R&D is important to future growth and has set a target to increase total R&D investment to 2% of the country's GDP and increase the share of private R&D investment to 70% by 2021. It also targets having at least 2,500 R&D personnel per million population by 2021 – almost double the number in 2015.

The government employs several policy measures to achieve the R&D investment target. To increase public investment, higher R&D budgets have been allocated to agencies in the line ministries, public universities, research-granting agencies, and government research institutes. The government has also ordered state-owned enterprises to invest at least 1% of their revenue in R&D. It also grants tax incentives to encourage private R&D investment. There are some policy instruments that are rarely used. For example, until very recently, government procurement had never been used to promote technology development, even though it was widely believed to be an effective means for technology transfer in mega-infrastructure projects, such as railways.

Tax incentives have often been used by the government to increase private R&D investment. This is because, unlike direct budget allocation, tax incentives are invisible government spending. An important tax incentive scheme administered by the Ministry of Science and Technology (MOST) allowed a 200% tax deduction for private R&D investment expenditure. The rate was adjusted to 300% after the corporate income tax rate was reduced from 30% to 20% in 2015 to keep the government's subsidy constant at 60%. Previously, the Revenue Department, whose main mission is to collect tax, was responsible for approving R&D investment projects applying for tax deductions. The role was transferred to the NSTDA to facilitate more objective assessment and approval.

⁸ This is done by the National Council for Peace and Order's Order 62/2559, which has a binding power similar to a legislative act.

The R&D tax incentive appeared to have limited effects on promoting private R&D investment. During 2002–2012 – the latest period for which data are available – the total R&D investment approved for tax deduction was estimated to be B6.85 billion (Figure 8.11). Up to 210 companies were approved for tax deduction in any given year, most of them large. Tax revenue foregone was estimated to be B1.7 billion (US\$50 million) during the 11-year period. This is a very small sum compared to tax revenue foregone in other government schemes. For example, the investment tax incentives granted by the Board of Investment (BOI) incurred B278 billion in foregone tax revenue in 2012 alone. It was also small compared to the B92 billion of excise tax revenue foregone incurred by the ‘First Car Scheme’, which promoted private car ownership during 2012–2013.



The R&D tax incentive scheme also has many drawbacks. First, it has a 9–12 month approval process. Second, it unintentionally favours larger companies over smaller ones because they can better tolerate the high fixed costs of the application process. In addition, they do not suffer from liquidity problems during the long approval period. Third, the definition of R&D investment is too narrow. In particular, costs related to design and development for commercial uses are ineligible for tax deduction. Moreover, certain expenditures, such as administrative costs, including those related to managing intellectual property, are not deductible under the scheme.

Another important tax incentive scheme to promote R&D and investment in innovation is administered by the BOI. Previously, the BOI focused on attracting large foreign investment projects and paid little attention to technology development.

However, given the need for Thailand to transform itself into a more technologically advanced country, the agency has introduced several new promotional schemes.

First, the BOI revamped its basic investment promotion scheme in 2015. Previously, the level of incentive depended on the sector and location of the investing companies. The new scheme not only revises the list of promoted sectors but also favours activities that generate high value-added. For example, it grants the maximum of eight years of corporate income tax exemption to projects with creative and engineering design, R&D, embedded software development, or cloud services provision.

Second, the new scheme introduces merit-based incentives on top of the basic incentives to stimulate investment activities that benefit the country or the industry at large. Activities eligible for merit-based incentives include R&D carried out in Thailand or jointly with overseas institutes, donation to the Technology and Human Resource Development Fund or approved institutes, acquisition of intellectual property, advanced technology training, development of local Thai suppliers, and product and packaging design. Projects with such activities are entitled to up to three more years of additional tax exemption.⁹ For companies that conduct R&D and other innovative activities, the new scheme is far more generous than the previous one. However, it still has the inherent weakness of favouring larger companies over smaller ones due to the reasons specified above. As the BOI has not disclosed data on applications and approvals under the new investment promotion scheme, its adoption, effectiveness, and impacts cannot be evaluated.

To achieve the R&D personnel target, the government is focusing on increasing the number of science, technology, engineering, and mathematics (STEM) postgraduates. Government scholarships are granted to talented students on the condition that they work in the public sector after graduation. At least five government agencies are involved in granting STEM scholarships: the Thailand Research Fund, the MOST, the Institute for the Promotion of Teaching Science and Technology, the Office of the Higher Education Commission, and the Office of the Civil Service Commission. Box 8.2 provides details of some of their programmes.

The UNCTAD review team observed that the Government of Thailand provides only a limited number of scholarships in relation to the size of its student population – fewer than 700 scholarships per year for more than 1.8 million students enrolled

⁹ For more details, see Thailand Board of Investment. Merit-Based Incentives. http://www.boi.go.th/index.php?page=Merit-based_Incentives.

in undergraduate, master's, or doctorate programmes (UNCTAD, 2016). However, the Thailand Development Research Institute (2016) found that many scholarship programmes were poorly planned or managed. As a result, there were many dropouts, late graduates, and graduates who could not find public agencies to affiliate with. There were also large mismatches between the expertise of the graduates and the demand of the affiliated agencies, and little coordination among the agencies involved, resulting in overlapping missions and rivalry. Therefore, government scholarship programmes should be expanded only when they are properly managed.

BOX 8.2

SELECTED SCHOLARSHIP SCHEMES PROVIDED BY THAI GOVERNMENT AGENCIES

Development and Promotion of Science and Technology Talents Project. The programme is managed by the Institute for the Promotion of Teaching Science and Technology. It has provided scholarships to talented students in science and technology since 1984. The institute collaborates with 10 schools, pairing each one with a mentor university. Each year, the programme offers 100 scholarships at the secondary-education level and 180 at higher levels. During 1984–2013, it granted 4,488 scholarships.

Ministry of Science and Technology Scholarship Program. The programme has granted scholarships to students (high school level to doctorate), civil servants, and university faculty members since 1990. During 1990–2015, it granted 3,712 scholarships for studying abroad and 469 scholarships for studying in Thailand. By 2015, 2,803 persons had graduated from the programme and more than 95% were working in universities and government agencies.

Royal Golden Jubilee PhD Programme. The programme, an initiative of the Thailand Research Fund, provides 300 fellowships annually for doctoral students to conduct research, including one year of study abroad with foreign co-advisers. During 1998–2008, it granted 4,208 scholarships to Thai students and 2,686 PhD students graduated from the programme. The programme has involved more than 1,400 Thai advisers and more than 2,300 international co-advisers in 40 different countries. Its new International Research Network supports researchers and networks formed around research topics of interest to Thailand.

Sources: United Nations Conference on Trade and Development (2016); Thailand Development Research Institute (2016).

Recognising the gap between the demand and supply of research personnel in the public and the private sectors, the MOST launched a programme called 'Talent Mobility' in 2015. The programme aims to encourage the use of new technologies in the private sector by facilitating the mobility of researchers from universities and government research institutes to the private sector. The NSTI Policy Office, which administers the programme, set a target to mobilise at least 200 researchers per year from 15 institutions

to spend 20% of their time in the private sector for up to two years. However, the mobility rate is limited as universities and government research institutes have no incentive to participate in the programme (UNCTAD, 2016).

One R&D and innovation personnel policy area that has been overlooked by the Government of Thailand is that of importing foreign human resources. According to the Ministry of Labour, there were about 2.98 million registered migrant workers in Thailand in 2015. However, 95% of them are low-skilled workers from neighbouring countries. Only 5% are high-skilled personnel that work as managers, professionals, technicians, or other skilled workers, either under the cumbersome temporary work permits or under approval by the BOI in promoted companies. This is because, under the Thai labour and immigration law, foreign skilled workers are only permitted to work in a Thai company if it employs four Thai nationals for every employed foreigner and pays a B2 million registration fee for each foreign worker.

8.3.3 Other schemes to promote innovation activities

Many Thai government agencies also operate various schemes to promote innovation activities, in addition to R&D support. Table 8.7 gives some examples of active schemes.

**Table 8.7: Schemes to Promote Innovation Activities
Other than Research and Development**

Organisation	Schemes to Promote Innovation Activities
National Innovation Agency	The National Innovation Agency provides grants to support the development and commercialisation of new products and processes. It also operates the Innovation Coupon Program, which gives potential innovators vouchers for research and technological services to be performed by universities and government laboratories.
National Science and Technology Development Agency (NSTDA)	The NSTDA operates the Industrial Technology Assistance Program to assist companies in technology development projects by connecting them to technology sources, including those from overseas. The programme also supports research and development (R&D), organises training, and funds projects on a 50:50 matching basis. The NSTDA also operates the Thailand Science Park, which hosts its four national research centres specialising in biotechnology, electronics, material sciences, and nanotechnology. Some tenant companies conduct R&D activities in fields related to the activities of the NSTDA's research centres.
Board of Investment	The Board of Investment offers foreign and domestic industrial investors tax incentives to encourage investment in training, R&D, and university–industry collaboration in promoted sectors.

Source: Authors, from various sources.

8.4 | Future Directions for Innovation Policies in Thailand

To increase its growth rate, Thailand must raise its investment in R&D, produce more R&D personnel, and, most importantly, manage its R&D system better to achieve greater efficiency. We suggest that the government implements the following policies.

8.4.1 Increase public investment in R&D

To catch up with other East Asian countries, Thailand must invest significantly more in R&D. However, simply increasing its R&D investment will not guarantee greater innovation capability. Thailand must also invest wisely by allocating its limited public funds efficiently and using them to encourage private investment with the aim of creating a more demand-driven system. To achieve this, it will need to take the following actions.

- Increase the budget for basic research at least at the same rate as the nominal GDP growth rate while increasing the budget for applied R&D at a faster rate. The aim is to increase public investment in R&D to the 2% of GDP target in 2021 and to conduct relatively more applied R&D.
- Allocate most of the R&D budget through research-granting agencies that have good management records, rather than through agencies in line ministries that do not have research management capabilities. The aim is to increase the efficiency of public investment in R&D.
- Instruct granting agencies to allocate all basic research grants to universities through competitive funding. The only portion that should be exempted from competition is core funding for their basic functioning.
- Direct granting agencies to allocate funding for applied R&D towards matching funds from the private sector. For example, one baht of public money can be matched with one baht in funding from the private sector. The aim is to make universities and research institutes more responsive to the needs of the private sector and to encourage the private sector to invest more in R&D.

8.4.2 Create accountability in publicly funded research

Without an appropriate accountability mechanism, publicly funded research would not generate sufficient economic return. We suggest that the government hold publicly funded research accountable by setting clear targets:

- Set clear targets for research-granting agencies commensurate with the size of their funding. These agencies should be regularly evaluated by independent assessors to measure their impacts based on cost and benefit analyses. The results should be reported to cabinet, the parliament, and the public.
- Set clear targets for government research institutes that receive direct funding from the government commensurate with the size of their funding. They should also be evaluated similarly to the research-granting agencies mentioned above.

8.4.3 Create a specialised government research institute

We also suggest that the government create a specialised government research institute with the sole mission of conducting R&D for commercialisation. The institute can be modelled after the Industrial Technology Research Institute of Taiwan, A*Star of Singapore, the Fraunhofer Society of Germany, or other institutions with solid records. The new institute can be created either by spinning off the industrial technology unit of the NSTDA into an autonomous agency or by setting up a new entity from scratch. To ensure that the institute responds to market demands, its board of directors should be composed mainly of representatives from the private sector. In addition, it should be financed by matching funds between the public and private sectors in the manner mentioned above.

8.4.4 Improve human resources policies

A shortage of R&D human resources is a major bottleneck inhibiting the private sector from undertaking more R&D and innovation activities. To solve this problem, we suggest that the government improve its R&D human resources policies by:

- reforming the current government scholarship systems to be more demand driven by allowing private companies to contribute to scholarships in exchange for the right to hire scholarship recipients after graduation;
- allowing and encouraging R&D professionals in public universities and government research institutes to work in the private sector by expanding the Talent Mobility programme; and
- allowing foreign R&D personnel and highly skilled professionals to work in Thailand by abolishing the foreign national employment quotas and expediting immigration procedures.

8.5 | Conclusion and Summary of Policy Recommendations

Thailand's remarkable growth from the 1960s to the mid-1990s demonstrated its ability to transform itself from a traditional economy into a modern one based on manufacturing and services. The country has also shown it can diversify its exports, both in terms of products and market destinations. However, despite its past accomplishments, it has experienced lower growth rates since the 1997 Asian financial crisis. If it does not upgrade its R&D and innovation capabilities, the country risks falling into the middle-income trap. To achieve higher growth rates, Thailand needs to increase its investment in R&D, produce more R&D personnel, and, most importantly, manage its R&D system better to achieve greater efficiency. We suggest that the government improves the Thai R&D system by:

- increasing public investment in R&D and using public money to encourage private investment in R&D;
- creating accountability in publicly funded research by setting clear targets for research-granting agencies and government research institutes commensurate with the size of their funding, and evaluating these agencies regularly to measure their impacts;
- creating a specialised government research institute with the sole mission of conducting R&D for commercialisation and ensuring that it responds to market demands by designing appropriate governance and funding structures;
- improving R&D human resources policies by reforming the current government scholarship systems to be more demand driven, expanding the current Talent Mobility programme, and making it easier to employ foreign R&D personnel and highly skilled professionals; and
- making technology transfer an explicit objective of government procurement for the government's megaprojects, such as railway and water-management projects.

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Innovation Policy in Viet Nam

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9.1 | Introduction

After more than 30 years of implementing the Doi Moi (renovation) policy, Viet Nam has gradually shifted from a centrally planned system towards a socialist-oriented market economy. Comprehensive reforms have been implemented in three main pillars: (i) improvement of institutions for the market economy, (ii) macroeconomic stabilisation, and (iii) proactive economic integration into the regional and global economies. Such reforms have strengthened Viet Nam's microeconomic foundations and led the country to periods of high economic growth. Viet Nam's economic growth rates of 7.6% per annum during 1991–2000 and 6.8% per annum during 2001–2010 were among the highest in the world.

Since 2011, however, Viet Nam's economy has been facing sluggish growth and modest improvement in the quality of growth and labour productivity. Economic growth decelerated to 5.8% per annum on average during 2011–2015. This slowdown could be attributed in part to the deterioration of labour productivity growth and suggests the need to seek a new driving force for Viet Nam's economic growth. This, in turn, will require Viet Nam to make additional efforts to promote innovation, at least to augment labour productivity.

Since the start of the Doi Moi policy in 1986, Viet Nam's policy orientations and regulatory framework for innovation have improved significantly to cover all innovation-related issues at both the micro and macro levels. Pro-innovation policies, such as human resources development and investment targeted to the information technology

and hi-tech industries, have been formulated and implemented. However, they have been insufficient for sustaining economic and labour productivity growth. Thus, Viet Nam must review its innovation policy to identify the necessary amendments.

The paper is structured as follows. Section 9.2 summarises the key definitions and milestones of innovation policy in Viet Nam. Section 9.3 discusses the major outputs and progress of innovation policy in the country. Section 9.4 elaborates on the major issues that Viet Nam faces in promoting innovation, and Section 9.5 concludes with some recommendations.

9.2 | Evolution of Innovation Policy in Viet Nam

9.2.1 Definition of innovation

Definitions of innovation are diverse. From a broad perspective, innovation is associated with structural reforms to promote efficiency and productivity in competition policy, corporate and public sector governance, and regulatory reform. Economies at different stages of development face different challenges in developing the right mix of structural reform policies to support innovation-based economic growth (Table 9.1).

Innovation is multifaceted and extends beyond research and development (R&D) to intangible organisational capacities. However, this paper focuses on innovation in the narrow sense. In the narrow sense, the understanding of innovation is heavily influenced by Schumpeter's theory of innovation, which emphasises the changes in and commercial application of new methods, new technology, new materials, and new sources of energy (Śledzik, 2013). Based on Schumpeter's view, the Organisation for Economic Co-operation and Development (OECD) defines innovation as 'the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organization or external relations' (OECD, 2005). In this sense, innovation is a step beyond invention and requires the implementation of invention to lead to positive changes or outcomes. As such, innovation may take various forms, including products, processes, designs, marketing, and organisational approaches. Government policies may influence the innovation level of each economy by affecting variables such as risks, market opportunities, and the availability of, and access to, funding. Thus, they must adequately identify appropriate policies to mitigate the impediments to innovation at both the firm and national levels.

Table 9.1: Common Aspects of Structural Reforms and Innovation at Different Levels of Economic Development

	Developing (learning – factor driven)	Middle (catching-up – efficiency driven)	Advanced (frontier – innovation driven)
Regulatory reform	Developing institutions to support robust regulatory policy development and implementation	Implementing frameworks to identify and manage the impacts of regulatory reform; working to ensure that regulation does not inhibit firm innovation	Implementing advanced tools to support transparency and robust regulatory policy; using regulation to promote innovation and the adoption of new technologies
Public sector governance	Implementing governance frameworks to support the rule of law and remove corruption and administrative abuse	Administrative simplification, improving coordination between government agencies	Sophisticated governance arrangements to incentivise efficient and effective public spending, taxation, and ownership (where applicable)
Competition policy	Establish competition authority to enforce competitive markets	Establish comprehensive competition policy framework	Sophisticated competition framework to encourage long-term dynamic efficiency
Corporate governance	Providing basic legal infrastructure to support the birth, life, and death of firms	Refining corporate governance systems to enable increased capital mobilisation and more complex corporate structures	Sophisticated and flexible legal infrastructure to support firm governance and risk-taking, incentivise growth, and enable the mobilisation of capital

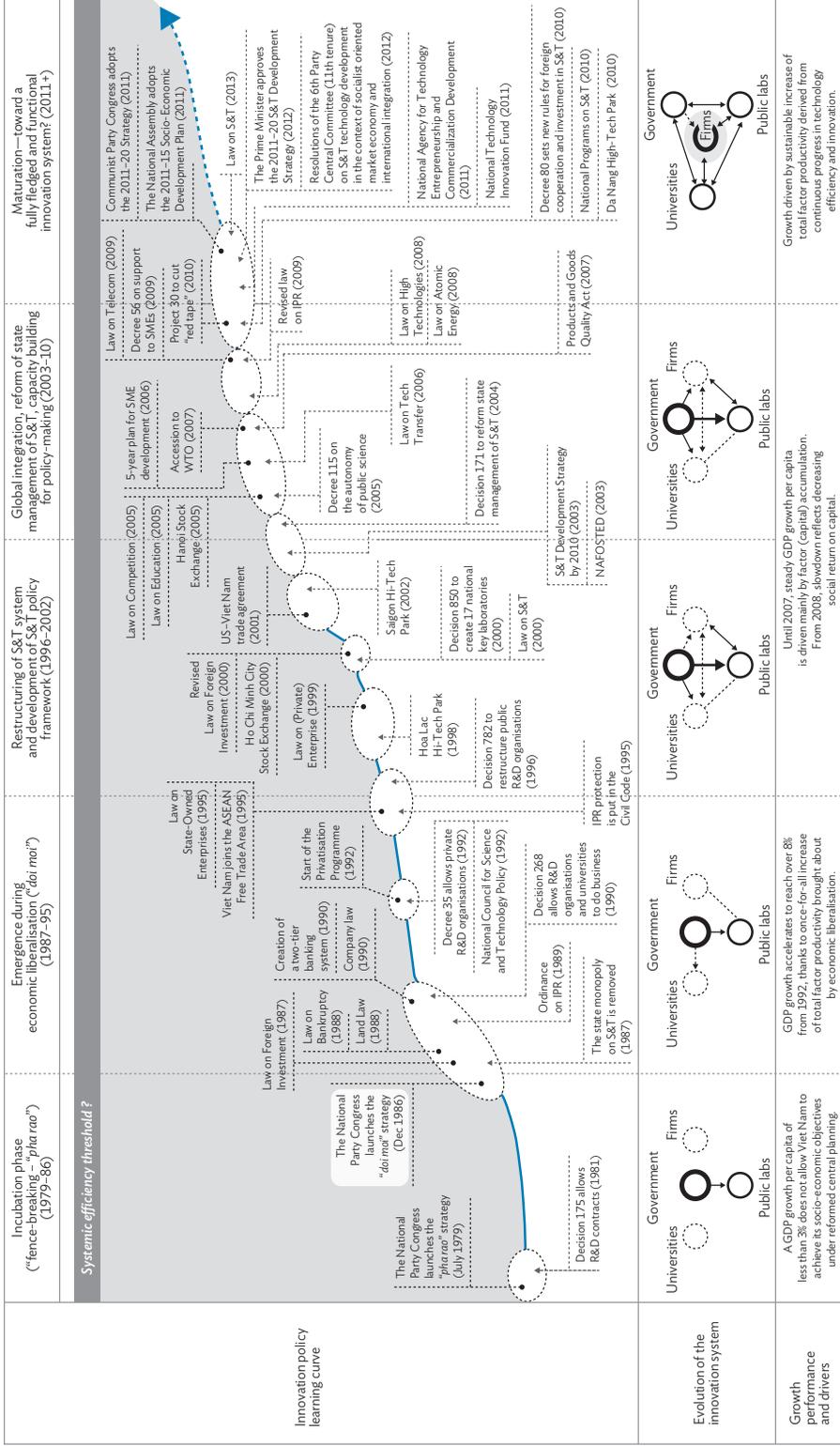
Source: Asia-Pacific Economic Cooperation (2015), *APEC Economic Policy Report 2015: Structural Reform and Innovation*. Singapore: Asia-Pacific Economic Cooperation Secretariat.

9.2.2 The evolution of innovation policy in Viet Nam

The pro-innovation policy framework in Viet Nam has evolved extensively since the implementation of the Doi Moi policy (Figure 9.1). During 1987–1995, Viet Nam witnessed the creation of a new legal framework for science and technology (S&T)-based development. The state monopoly on S&T activities was gradually removed, R&D organisations were allowed to enter into contractual relationships with individuals and non-state actors, and basic regulations on technology transfer were implemented.¹

¹ Decision No. 268-CT dated 30 July 1990 by the President of the Council of Ministers on the registration and operations of economic organisations established by administrative agencies and organisations; Decree No. 35-HDBT dated 28 January 1992 by the Council of Ministers on the state management of S&T activities.

Figure 9.1: Viet Nam's Innovation Policy: Institutional Reform and Learning Curve



ASEAN = Association of Southeast Asian Nations, GDP = gross domestic product, IPR = intellectual property rights, R&D = research and development, S&T = science and technology, SME = small and medium-sized enterprise, WTO = World Trade Organization.

Source: Organisation for Economic Co-operation and Development (2014, p. 23).

The legal basis for intellectual property rights (IPR) protection was introduced during this period with the issuance of Ordinance 13-LCT/HDNN8 on industrial IPR in 1989² and the incorporation of IPR regulations in the Civil Code in 1995. In 1993, the National Centre for Natural Sciences and Technology was given the broader mission of conducting both fundamental and applied research. However, public funding of S&T continued to go exclusively to government S&T organisations, and S&T priorities and evaluation mechanisms remained unchanged. Viet Nam's accession to the Association of Southeast Asian Nations (ASEAN) and the ASEAN Free Trade Agreement in 1995 also set out the country's commitments on S&T promotion, technology transfer, and human resources development, partly reflecting Viet Nam's first attempts to conform its S&T standards and activities to regional and international levels.

During 1996–2010, the S&T system was restructured and the state management of S&T was overhauled. Research centres were established under corporations, in accordance with Decision 782/QD-TTg in 1996,³ to strengthen links between S&T and production. Relations between public research organisations and industries began to take shape in 2004 and 2005,⁴ and new innovation infrastructure was initiated (e.g. the Hoa Lac Hi-tech Park and, later, the Saigon Hi-tech Park). The Law on Science and Technology (in 2003), the Law on Technology Transfer (in 2006), and the Law on High Technology (in 2008) helped strengthen the legal framework for the involvement of foreign investors and hi-tech activities ranging from manufacturing and production to education and training. In line with this direction, the Law on Standards and Technical Regulation was approved in 2007 with the aim of aligning national norms with international standards. The Intellectual Property Law was revised in 2005 and 2009, creating a sound basis for Viet Nam's integration into the international innovation system.

Viet Nam's engagement in the Viet Nam–United States Bilateral Trade Agreement, with its high-quality commitments on IPR, also reinforced the country's commitment to IPR – a critical concern for foreign investors in Viet Nam. The government's institutional capability was strengthened by the creation of the National Council for Science and Technology Policy (in 1997),⁵ which directly advises the prime minister

² Ordinance No. 13-LCT/HDNN8 of the State Council dated 28 January 1989.

³ Decision No. 782/QD-TTg dated 24 October 1996 of the prime minister on the organisation of R&D agencies in S&T.

⁴ Decision No. 171/2004/QD-TTg dated 28 September 2004; Decree No. 115/2005/ND-CP dated 5 September 2005 by the government on the autonomy of public science organisations.

⁵ Decision No. 1077/1997/QD-TTg dated 12 December 1997.

on national S&T development policy; the State Agency for Technology Innovation (in 2007); the Viet Nam Science and Technology Evaluation Centre (in 2006); and the National Agency for Technology Entrepreneurship and Commercialization (in 2011). In parallel, new legal frameworks and public support mechanisms were introduced, notably the National Foundation for Science and Technology Development, which began operation in 2008.

During 2011–2016, S&T development and innovation were specified as among the highest priorities under the Socio-economic Development Strategy, 2011–2020 and the Socio-economic Development Plan, 2016–2020. In 2015, the Minister of Science and Technology identified five key measures for S&T: (i) significantly and consistently upgrading the organisational structure, management mechanism, and operations of S&T activities; (ii) mobilising resources to implement S&T development orientations; (iii) continuously strengthening national S&T potential; (iv) developing the S&T market, S&T entrepreneurs, and S&T-related services; and (v) promoting international integration in S&T.

The amendment of the Law on Science and Technology in 2013 incorporated significant improvements, such as expanding the rights of S&T organisations to do business; promoting the development of the S&T market; reserving incentives for S&T enterprises in hi-tech fields;⁶ stipulating expenditures to be counted as reasonable expenses; and introducing clear provisions on tax, credit, and funds for S&T activities.

In summary, Viet Nam's innovation policy has undergone drastic changes, including in the scope, facilitation of entry and operation in S&T, and types of support. These changes were driven by (i) the need to enhance competitiveness at the firm and product levels as Viet Nam has integrated more deeply into the world and regional economies; (ii) the narrowing of space to support business entities in Viet Nam due to economic integration, which has made S&T one of the few targets for legitimate support; and (iii) the internalisation of international rules and practices related to innovation management and promotion.

⁶ Incentives included the exemption and reduction of corporate income tax for enterprises investing in hi-tech zones; preferential access to land and infrastructure in industrial zones, export-processing zones, economic zones, and hi-tech zones; interest rate support or lending guarantees; and financial support to invest in scientific and technological projects or to cover part of the technological transfer.

9.2.3 Intellectual property rights protection in Viet Nam

The Ordinance on IPR in 1989 marked the initial basis for the legal framework of IPR in Viet Nam. Subsequently, the Law on Intellectual Property was promulgated in 2005 and amended in 2009, and its guiding implementation legislation, such as decrees and circulars, were issued. Other laws relevant to IPR include the Competition Law, the Civil Code, the Criminal Code, and the Law on Customs.

In line with integration into the regional and international economy, IPR is an important chapter in the Viet Nam–United States Bilateral Trade Agreement, signed in 2000. As Viet Nam prepared for accession to the World Trade Organization in the early 2000s, the Agreement on Trade-related Aspects of Intellectual Property Rights (TRIPS) became the framework for its international commitments on IPR. The new-generation free trade agreements (FTAs) since 2015, such as the European Union (EU)–Viet Nam FTA and the Trans-Pacific Partnership (TPP), pushed for even deeper commitments on IPR. TPP commitments on IPR are evaluated as TRIPS+, which reflects a higher level of IPR protection in relation to TRIPS and other conventions on IPR. The TPP covers such IPR-related areas as issues of pharmaceutical exception (relating to public health), and trademark and industrial design protection. Meanwhile, the EU–Viet Nam FTA’s commitments on IPR focus more on geographical indication, which is not mentioned in the TPP.

Viet Nam also joined other international agreements on intellectual property (IP), including the Berne Convention for the Protection of Literary and Artistic Works; the Madrid Agreement Concerning the International Registration of Marks; the Paris Convention for the Protection of Industrial Property; the International Convention for the Protection of New Varieties of Plants; the ASEAN Framework Agreement on Intellectual Property Cooperation; the Convention for the Protection of Producers of Phonograms Against Unauthorized Duplication of their Phonograms; and the Rome Convention for the Protection of Performers, Producers of Phonograms and Broadcasting Organizations. Consequently, the design of Viet Nam’s legislation and its level of protection of IP follows the protection standards under TRIPS and other related conventions of which Viet Nam is a member.

Currently, the mandate for state management of IPR protection is assigned to three agencies: the National Office of Intellectual Property under the Ministry of Science and Technology (MOST); the Copyright Office of Vietnam under the Ministry of Culture, Sports and Tourism (MCST); and the New Plant Variety Protection Office

under the Ministry of Agriculture and Rural Development (MARD). Of the three, MOST, in coordination with the MCST and MARD, takes prime responsibility for the state management of IPR and industrial property rights. The MCST, within the ambit of its tasks and powers, performs the state management of copyright and related rights, while MARD performs the state management of rights to plant varieties.

9.3 | Innovation Performance in Viet Nam

9.3.1 Innovation competitiveness

The Global Competitiveness Report, 2016–2017 ranked Viet Nam 60th out of 138 countries on overall competitiveness, with a score of 4.3 out of 7. Notably, of three sub-indices, the sub-index of innovation and sophistication factors had the lowest score of 3.5 and a rank of 84th. The score has shown no significant improvement over the years (Table 9.2). Thus, although Viet Nam has adapted its laws and regulations in line with its World Trade Organization accession, these efforts have been insufficient to improve the country's relative innovation competitiveness.

Table 9.2: Viet Nam's Global Competitiveness Index

Item	2007–2008	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014	2014–2015	2015–2016	2016–2017
Rank	68/131	70/134	75/133	59/139	65/142	75/144	70/148	68/144	56/140	60/138
Score (1–7)	4.04	4.10	4.03	4.27	4.24	4.11	4.18	4.2	4.3	4.3
A. Basic requirements	77	79	92	74	76	91	86	79	72	73
B. Efficiency enhancers	71	73	61	57	66	71	74	74	70	65
C. Innovation and sophistication factors	76	71	55	53	75	90	85	98	88	84
11. Business sophistication	83	84	70	64	87	100	98	106	100	96
12. Innovation	64	57	44	49	66	81	76	87	73	73

Source: World Economic Forum, Global Competitiveness Index database, various years.

Examining the 12th pillar of innovation in more detail, Viet Nam ranked well on government procurement of advanced technological products (27/138) and company spending on R&D (49/138) (Table 9.3). Capacity for innovation achieved the highest score (4.0/7). The availability of scientists and engineers, and government procurement of advanced technological products have been relatively highly ranked, although their scores have trended downwards in recent years.

Table 9.3: Innovation Sub-index of Viet Nam in the Global Competitiveness Index, 2008–2017

Item	2007–2008	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013	2013–2014	2014–2015	2015–2016	2016–2017
Ranking out of	131	134	133	139	142	144	148	144	140	138
Twelfth pillar: innovation	64	57	44	49	66	81	76	87	73	73
Availability of scientists and engineers	55	51	62	66	66	70	88	87	75	84
Capacity for innovation	41	41	33	32	58	78	86	95	81	79
Company spending on R&D	57	42	27	33	52	75	59	63	57	49
Government procurement of advanced tech products	36	21	11	18	41	39	30	34	28	27
PCT patents, applications per million population						97	92	93	91	95
Quality of scientific research institutions	94	85	64	63	74	87	89	96	95	98
University–industry collaboration in R&D	78	70	59	62	82	97	87	92	92	79
Score (1–7), unless indicated otherwise										
Twelfth pillar: innovation	3.2	3.3	3.5	3.4	3.2	3.1	3.1	3.1	3.2	3.3
Availability of scientists and engineers	4.5	4.5	4.2	4.1	4.1	4.0	3.8	3.8	3.9	3.8
Capacity for innovation	3.7	3.5	3.7	3.6	3.2	3.0	3.4	3.5	3.8	4.0
Company spending on R&D	3.3	3.6	3.8	3.6	3.2	3.1	3.2	3.2	3.3	3.5
Government procurement of advanced tech products	4.0	4.2	4.5	4.4	4.0	3.9	4.0	3.9	3.9	3.8
PCT patents, applications per million population						0.1	0.1	0.2	0.2	0.2
Quality of scientific research institutions	3.4	3.6	3.7	3.8	3.5	3.4	3.4	3.3	3.3	3.4
University–industry collaboration in R&D	2.9	3.1	3.5	3.7	3.4	3.2	3.3	3.3	3.3	3.3

PCT = Patent Cooperation Treaty, R&D = research and development.

Source: World Economic Forum, Global Competitiveness Index database, various years.

9.3.2 Science and technology actors

In accordance with the 2013 Law on S&T, S&T organisations are classified into three groups: technological R&D institutes; universities, academies, and colleges; and S&T services organisations. A 2014 survey by MOST found that Viet Nam had 1,055 S&T organisations, of which R&D institutes accounted for the largest share (48%); universities, academies, and colleges made up 32%; and S&T services organisations accounted for 20%. Most S&T organisations were in the technical and technological science area (Table 9.4). Most R&D institutes are small with an average of only 55 people. The government has established international R&D institutes, such as the Viet Nam–Korea Science and Technology Institute (in 2017) and the Viet Nam Institute for Advanced Studies in Mathematics (in 2010), with the aim of achieving breakthrough results.

Table 9.4: Viet Nam’s Science and Technology Organisations, 2014

Type	R&D Institutes		Universities, Academies, Colleges		S&T Services Organisations	
	No.	Share (%)	No.	Share (%)	No.	Share (%)
Natural science	60	11.9	26	7.7	26	12.3
Technical and technological science	178	35.2	105	31.0	136	64.2
Health-medicine science	27	5.4	32	9.4	3	1.4
Agricultural science	104	20.6	18	5.3	12	5.7
Social science	105	28.8	143	42.2	32	15.1
Human science	31	6.1	15	4.4	3	1.4
Total	505	100.0	339	100.0	212	100.0

No. = number, R&D = research and development, S&T = science and technology.

Source: Ministry of Science and Technology (2016), *Survey on S&T Capacity of S&T Organizations in Vietnam in 2014*.

By 2015, Viet Nam had 204 S&T enterprises, most of which were operating in priority fields in line with the S&T development strategy, 2011–2020, including information and communication technology, biotechnology, new materials, mechanics and automation, and the environment. Viet Nam had more than 400 hi-tech firms located in hi-tech parks and zones, 34 hi-tech firms located outside industrial zones, and more than 1,400 software enterprises (MOST, 2016).

9.3.3 Science and technology human resources

According to MOST (2016), in 2013, Viet Nam had 164,744 people working in R&D related-activities, of which 128,997 were direct R&D personnel (i.e. researchers and scientists, on a headcount basis). Almost half of the R&D personnel (49.2%) worked for universities, 23.1% for R&D institutes and centres, and 14.4% for enterprises.

By educational level, most R&D personnel held bachelor or master's degrees (86.8%), while personnel with doctorates accounted for 9.5% of the total (Table 9.5).

Table 9.5: Viet Nam's Research and Development Human Resources by Organisational Status and Educational Level, 2013

Organisational Status	Number of Employees by Educational Level				Total
	Doctorate	Master's	University	College	
R&D institutes/centres	3,367	8,815	16,635	1,002	29,820
Universities	7,959	31,582	22,819	1,075	63,435
Administrative agencies	229	1,795	6,135	300	8,460
Public service agencies	252	1,616	5,268	359	7,495
Enterprises	185	1,154	15,175	2,038	18,553
Non-profit organisations	269	260	652	53	1,234
Total	12,261	45,224	66,684	4,827	128,997
Organisational Status	Share of Employees by Educational Level (%)				Total
	Doctorate	Master's	University	College	
R&D institutes/centres	11.29	29.56	55.78	3.36	100.00
Universities	12.55	49.79	35.97	1.69	100.00
Administrative agencies	2.71	21.22	72.52	3.55	100.00
Public service agencies	3.36	21.56	70.29	4.79	100.00
Enterprises	1.00	6.22	81.79	10.98	100.00
Non-profit organisations	21.80	21.07	52.84	4.29	100.00
Total	9.50	35.06	51.69	3.74	100.00

R&D = research and development.

Source: Ministry of Science and Technology (2016), compiled from the 2014 Survey on R&D and 2014 Enterprise Survey.

In 2013, Viet Nam had 14.3 R&D personnel per 10,000 population, equivalent to one-fifth that of Japan (70.2/10,000) and Singapore (74.8/10,000) and one-sixth that of the Republic of Korea (82.0/10,000). Using the full-time equivalent method,⁷ the number of R&D personnel in Viet Nam was 61,663 (6.8/10,000) – higher than Indonesia and the Philippines but much lower than Malaysia and other advanced Asian countries (Table 9.6).

Table 9.6: Full-time Equivalent Research and Development Personnel of Viet Nam and Selected Economies

Economy	Full-time Equivalent R&D Personnel (number per 10,000 population)
Singapore (2013)	66.7
Republic of Korea (2013)	64.2
Japan (2013)	52.0
United States (2012)	40.3
EU28 (2013)	34.1
Russia (2013)	30.8
Malaysia (2012)	17.9
China (2012)	11.0
Viet Nam (2013)	6.8
Thailand (2011)	5.4
Indonesia (2009)	2.1
Philippines (2007)	0.7

EU = European Union, R&D = research and development.

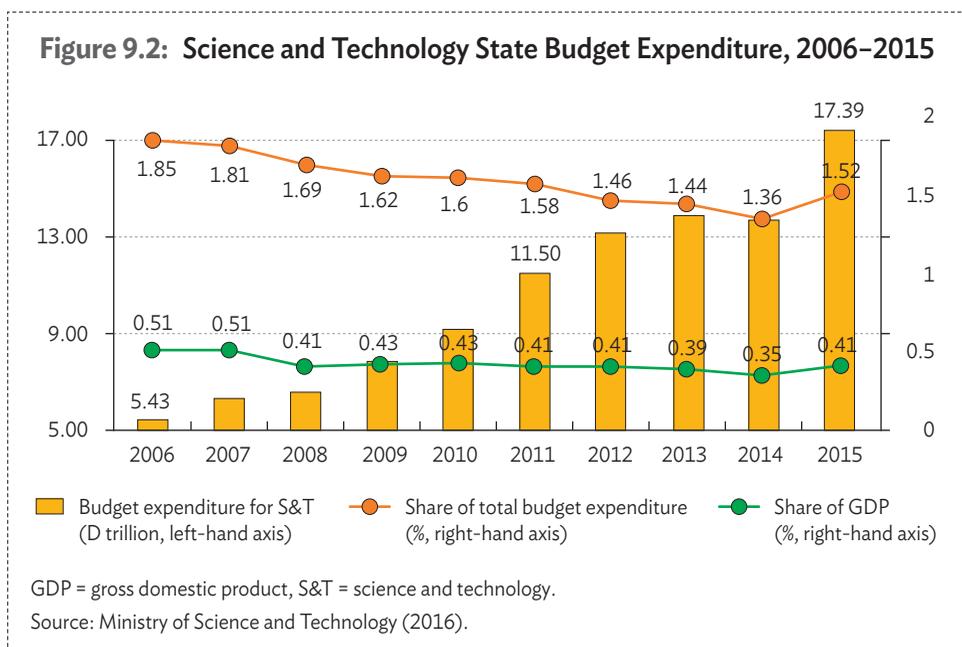
Source: Ministry of Science and Technology (2016).

9.3.4 Science and technology finance

Most S&T activities are financed by the state budget. During 2006–2015, total expenditure on S&T ranged from 1.36% to 1.85% of the state budget expenditure (Figure 9.2). In 2015, S&T accounted for 1.52% of the total budget expenditure

⁷ As defined by the OECD, full-time equivalent employment is the number of total hours worked divided by the average annual hours actually worked in full-time jobs. In international practices, full-time equivalent R&D personnel are personnel who work in R&D activities on a full-time basis within a year. On an annual basis, full-time equivalent is considered to be 2,080 hours, which is calculated as 8 hours per day x 5 working days per week x 52 weeks per year.

(equivalent to D17.39 trillion), which represented an average increase in absolute terms of 13.8% during 2011–2015 but a decrease compared with the 2006–2010 average in terms of share. The share of S&T investment in total gross domestic product (GDP) also decreased from 0.51% to 0.41% during 2006–2015.



Viet Nam’s gross expenditure on R&D (GERD)⁸ was 0.37% in 2013 (Table 9.7). As such, the country was considerably less R&D-intensive than Malaysia and slightly less so than Thailand. By source, the state budget contributed the largest share of GERD (56.7%), followed by enterprises (41.8%) and foreign loans (1.5%).

9.3.5 Science and technology infrastructure

Viet Nam has made important progress in S&T infrastructure in recent years. In line with Decision 850/QĐ-TTg, it established 16 national key laboratories in 2000 to serve seven fields of basic science: biotechnology (5 laboratories), information technology (3), material technology (2), mechanics-automation (2), petro-chemistry (1), energy (1), and infrastructure (2). The laboratories are based in 13 research institutes and 3 universities under the management of 8 ministries

⁸ GERD is the ratio of total R&D expenditure to GDP.

and line agencies. In addition, three national hi-tech parks were founded in three regions: Hoa Lac Hi-Tech Park in the north, Ho Chi Minh Hi-Tech Park in the south, and Da Nang Hi-Tech Park in the central region. A total of 140 projects have invested more than US\$7.1 trillion in these hi-tech parks. There are 8 software parks concentrated in major cities (such as Ha Noi, Ho Chi Minh City, Da Nang, and Hai Phong), and 13 hi-tech agricultural zones (such as in Thai Nguyen, Son La, Hanoi, Lam Dong, and Hau Giang).

Table 9.7: Gross Expenditure on Research and Development in Viet Nam and Selected Economies (%)

Economy	GERD
Republic of Korea (2015)	4.23
Japan (2015)	3.28
United States (2015)	2.79
Singapore (2015)	2.20
China (2015)	2.07
EU28 (2015)	1.96
Malaysia (2015)	1.30
Russia (2015)	1.13
Thailand (2015)	0.63
Viet Nam (2013)	0.37
Philippines (2013)	0.14
Indonesia (2013)	0.08

EU = European Union, GERD = gross expenditure on research and development.

Sources: Ministry of Science and Technology (2016); World Bank, World Development Indicators (2017).

9.3.6 Science and technology products

Hi-tech products have accounted for a rising share of Viet Nam's trade value, especially since 2011 (Table 9.8). The share of hi-tech products rose to over 27% in 2013–2014 from less than 6% during 2000–2008. The growth rate of total imports of hi-tech products ranged from 9.7% to 13.7% during 2000–2010 and jumped to 24.2% in 2013 and 22.9% in 2014. Though the hi-tech share in total imports and exports remains modest in relation to that of low- and medium-tech products, the improvement partly reflects Viet Nam's efforts to promote S&T and innovation activities, which in turn have resulted in the positive change in the trade structure of the country.

Table 9.8: Share of Viet Nam's Exports and Imports by Technological Level, 2000–2014 (%)

Level	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Exports											
Hi-tech	5.6	5.5	5.7	5.4	6.6	8.4	10.6	14.5	22.0	27.7	27.2
Low-tech	24.6	31.7	31.4	33.6	33.4	36.2	38.0	34.1	30.1	30.3	31.7
Medium	4.3	5.6	6.4	8.1	7.9	7.2	8.0	8.3	9.0	8.6	9.0
Other	65.5	57.3	56.5	53.0	52.1	48.2	43.4	43.1	38.9	33.4	32.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Imports											
Hi-tech	12.0	9.7	9.8	12.0	10.9	13.7	13.0	14.4	20.8	24.2	22.9
Low-tech	18.3	19.7	18.4	18.7	17.5	18.6	19.6	18.3	17.8	18.0	18.4
Medium	31.6	28.1	26.0	27.9	27.7	29.0	27.1	24.8	23.1	22.6	23.5
Other	38.0	42.4	45.8	41.4	43.9	38.7	40.4	42.5	38.3	35.2	35.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: United Nations Comtrade Database, various years.

According to calculations by MOST, technological innovation growth⁹ in Viet Nam reached 10.7% per annum during 2011–2015, achieving the 10%–15% target set in the S&T development plan for the period. The results also revealed that rapid technological innovation occurred in such industries as information and communication technology, petrol, aviation, and finance and banking. Nevertheless, most firms were using technologies two or three generations behind the world average. Less than 20% of manufacturing firms (one-third of enterprises in Viet Nam) applied advanced technology, and most of these received foreign investment.

⁹ MOST's calculations of Viet Nam's technological innovation growth covered 13 groups of input and output indicators of technological innovation activities, including (i) budget expenditure for S&T (% of GDP); (ii) R&D human resources (head count per 10,000 people); (iii) the ratio of university graduated and higher-level over the total human resources of enterprises (%); (iv) the number of international S&T publications per 1 million people; (v) the ratio of total applications of technological property rights to GDP (D1,000 billion); (vi) expenditure on R&D and technological innovation by enterprises (% of GDP); (vii) the number of grants of technological property rights to GDP (D1,000 billion); (viii) imports of machinery and equipment (% of GDP); (ix) the ratio of transferred technological property rights to total grants of technological property rights; (x) purchases of machinery and equipment by enterprises (% of GDP); (xi) the ratio of enterprises with quality management certificates to the total number of enterprises (%); (xii) the ratio of exports of hi- and medium-tech products to gross exports (%); and (xiii) exports of machinery and equipment over gross exports (%).

Table 9.9: International Applications by Viet Nam via World Intellectual Property Organization-administered Treaties

Year	PCT System	Madrid System	Hague System
2001–2005	11	103	0
2006–2010	37	212	0
2011–2015	77	355	2
2011	18	65	n.a.
2012	13	80	n.a.
2013	18	70	1
2014	7	77	1
2015	21	63	

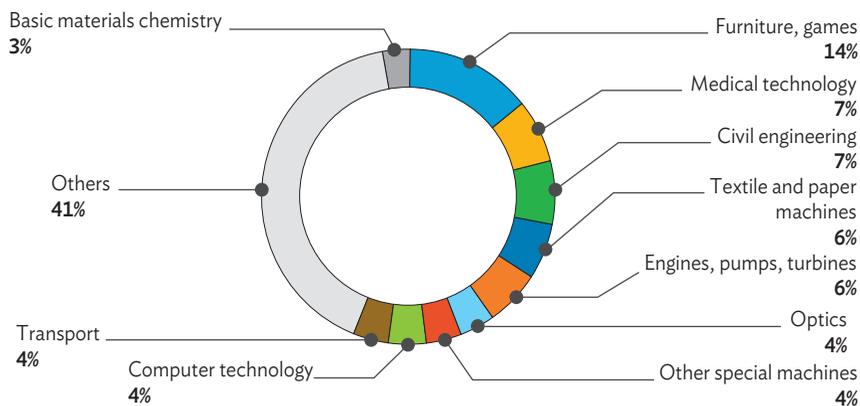
PCT = Patent Cooperation Treaty.

Source: World Intellectual Property Office.

International applications of new-to-the-world technological innovations in Viet Nam are low. This is reflected in Viet Nam's performance in treaties administered by the World Intellectual Property Organization, including patent applications through the Patent Cooperation Treaty, the Madrid System, and the Hague System (Table 9.9). Viet Nam made 434 international applications via these three systems during 2011–2015. This was much higher than the total for Indonesia (79 applications) and the Philippines (268), similar to Thailand's (429), but much lower than Malaysia's (1,473) (World Intellectual Property Office, 2016). The technological field with the largest share of patent applications (14%) was furniture and games. Other fields with significant shares of patent applications included medical technology (7%) and civil engineering (7%) (Figure 9.3).

In 2011–2015, there were 21,296 intellectual property applications for inventions and 1,759 for utility solutions in Viet Nam, compared with 14,697 and 1,292, respectively, during 2006–2010 (Table 9.10). Domestic applications grew rapidly, with the annual number increasing from 52 in 2001 to 301 in 2011 and 538 in 2015 (National Office of Intellectual Property, 2016). The overwhelming majority of invention applications were filed by foreign residents; during 2011–2015, 2,196 invention applications were filed by Vietnamese, and 19,100 were filed by foreigners (90%) (National Office of Intellectual Property, 2016). Viet Nam witnessed a steep rise in both resident and non-resident trademark registrations during 2011–2015. The figure jumped from 134,481 in 2006–2010 to 159,346 in 2011–2015, of which applications filed by Vietnamese accounted for the majority (74% and 80%, respectively). This indicates that awareness of the importance of IP protection has gradually improved.

Figure 9.3: Patent Applications in Viet Nam by Technological Field, 2001–2015 (%)



Source: World Intellectual Property Organization.

Table 9.10: Origin of Viet Nam’s Intellectual Property-related Applications, 2006–2015

Period	Origin	Invention	Utility Solution	Industrial Design	Trademark	Geographical Indication	Total
2006–2010	Total	14,697	1,292	8,865	134,481	30	159,365
	Vietnamese	1,183	744	6,168	100,137	27	108,259
	Foreigners	13,514	548	2,697	34,344	3	51,106
2011–2015	Total	21,296	1,759	10,692	159,346	25	193,118
	Vietnamese	2,196	1,174	7,116	126,959	20	137,465
	Foreigners	19,100	585	3,576	32,387	5	55,653

Source: National Office of Intellectual Property (2016), *Annual Report 2015*.

9.4 | Major Issues

9.4.1 Inadequate pro-innovation policy environment

Overlapping and inconsistency of intellectual property policy design and implementation

The National Assembly and the government oversee the setting of national legal regulations and decide on the broad socio-economic development policies, including S&T policy. At the lower level, many institutions are involved in detailed policy design

and the implementation of S&T and innovation, especially the line ministries and, to a lesser extent, the provincial governments. The Ministry of Science and Technology undertakes cross-sectoral policy coordination with regard to the innovation framework and initiatives; the Ministry of Planning and Investment develops socio-economic development plans and investment plans; and the Ministry of Finance allocates and disburses the budgetary resources for public initiatives. However, the duplication of priorities in legal documents on S&T is common, and the list of sector targets remains inconsistent. Some strategies, plans, and targets are too ambitious and lack adequate resources for implementation, which leaves room for inaction or a lack of coordination by implementing bodies.

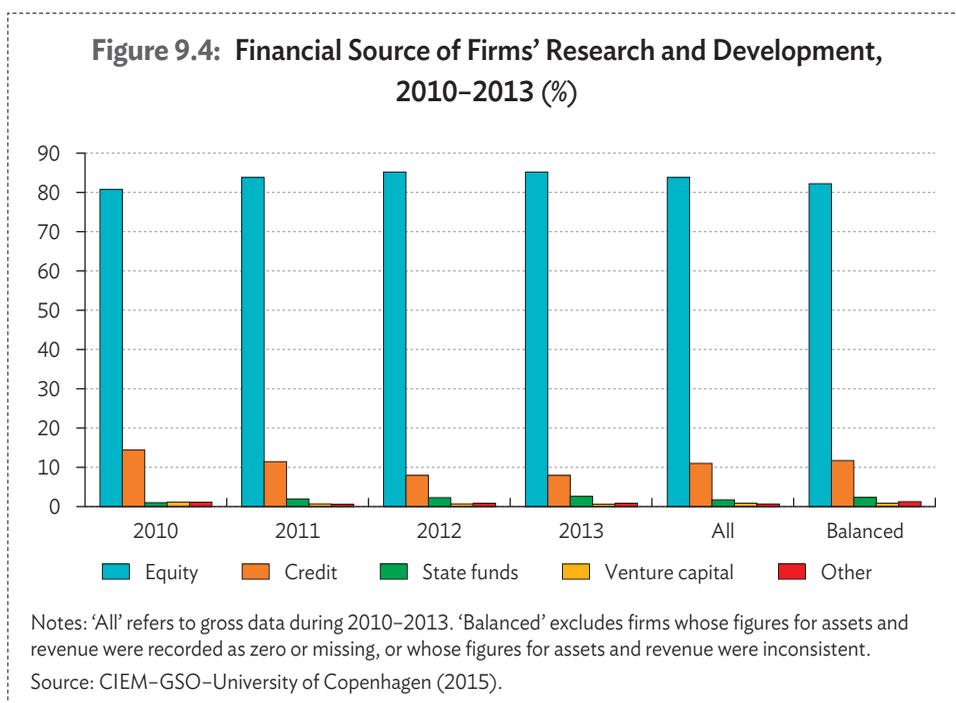
Several associations, such as the Viet Nam Union of Science and Technology Associations and the Viet Nam Intellectual Property Association, provide advice and proposals to government authorities. Through their financial and/or technical support programmes, multilateral and bilateral organisations (such as the United Nations Development Programme, the World Bank, the Asian Development Bank, the Korea International Cooperation Agency, and the Japan International Cooperation Agency) play an important advisory role in S&T and innovation policy in Viet Nam. However, the participation of nongovernment organisations remains inadequate, despite their valuable contributions to the design and implementation of S&T and innovation-related policies.

Insufficient and ineffective financing for science and technology

Financing for S&T and innovation activities in Viet Nam still depends heavily on budget support. State expenditure for R&D accounted for 56.7% of GERD in 2013. Limited budgets and fragmented, dispersed investment explain the small average size of project grants.¹⁰ To add to the problem, most public expenditure on S&T is distributed through ministries and entails significant management costs, especially in relation to administrative processes or 'red tape', despite significant improvements due to recent efforts. Consequently, most beneficiaries of the budget expenditure for S&T activities are public research organisations. Only 4% of public expenditure on S&T goes to universities (Tran and Vo, 2011). This represents about 15% of universities' investment in R&D, most of which is financed by international donors (50%) and enterprises (30%). The results of a survey by the CIEM, the General Statistics Office (GSO), and the University of Copenhagen were consistent with this finding, showing

¹⁰ Government funding for a ministerial research project can be as low as D100 million (about US\$4,800) a year.

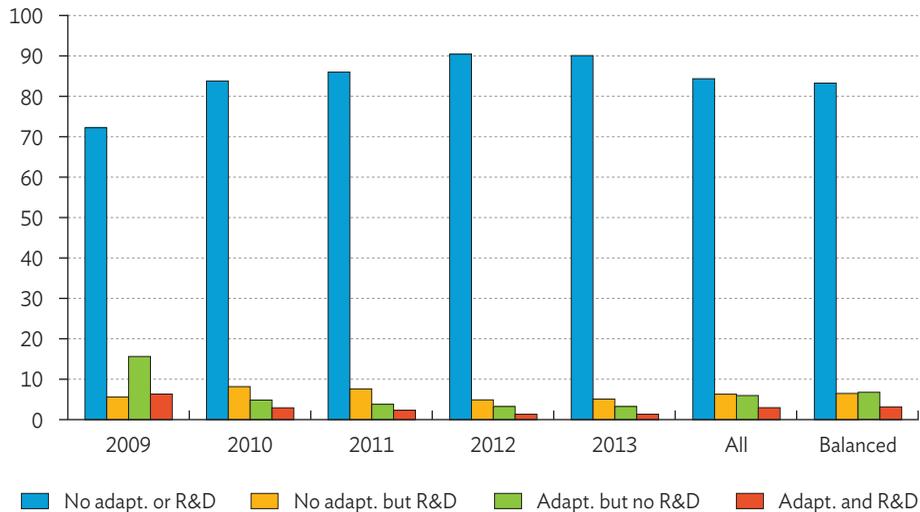
that most firms' R&D expenditure is financed by equity (84%) or credit (12%), while state budgetary assistance for R&D is very modest (2%) (CIEM–GSO–University of Copenhagen, 2015) (Figure 9.4).



Inadequate investment by firms in S&T and innovation in general and R&D in particular poses another concern. The CIEM–GSO–University of Copenhagen (2015) survey of more than 700 firms each year from 2009 to 2013 revealed that most surveyed firms did not engage in any technology adaptation or R&D activities (Figure 9.5). About 7% of firms pursued either R&D or adaptation, while 3% of firms pursued both R&D and adaptation. Adaptation and R&D activities declined over the survey period. Of the firms surveyed, 83% did not have an adaptation or R&D strategy. As adaptation appears to be more cost-effective in the short run (in terms of technological sophistication), greater policy support for adaptation is the preferred choice. Findings from other surveys are similar, including those by the GSO (2014) and the National Economics University (2016).¹¹

¹¹ According to the GSO survey (2014), of 7,450 surveyed firms, only 6.2% participated in R&D activities. Firms' expenditure on innovation accounted for only 0.2%–0.5% of total revenues. Meanwhile, the survey conducted by the National Economics University (2016) showed that of the 300 surveyed industrial enterprises in Hung Yen Province, 58.5% did not engage in any R&D activities; 14.2% spent less than 0.5% of their total revenue on R&D, while 16.2% allocated 1.5%–2.0% of total revenue for R&D (Le, 2017).

Figure 9.5: Share of Firms in Viet Nam Doing Technology Adaptation and/or Research and Development, 2009–2013 (%)



Adapt. = adaptation, R&D = research and development.

Notes: 'All' refers to gross data during 2009–2013. 'Balanced' excludes firms whose figures for assets and revenue were recorded as zero or missing, or whose figures for assets and revenue were inconsistent.

Source: CIEM–GSO–University of Copenhagen (2015).

Insufficient quality and the relevance of the science and technology workforce

The quality of Viet Nam's workforce suffers from the structural deficiencies in Viet Nam's tertiary educational system. As illustrated in Table 9.11, during 2006–2014, secondary and tertiary education accounted for a very modest share of budget expenditure for education and training, with universities and colleges receiving 12.4%, vocational schools 9.7%, and professional secondary schools 3.5%. This indicates that the majority of state resources have been invested in universal basic education rather than higher education, though the latter is arguably more crucial to the development of S&T and innovation.

At the same time, higher education has significant systematic weaknesses in terms of governance (information and incentives) and financing, which constrain its capacity to produce the human resources and skills needed for the labour market. Higher education institutions may be unable to provide the skills the labour market needs because they lack information on demand. Instruments to provide institutions (and students) with labour market information and mechanisms to channel inputs from firms into curriculum and programme design and implementation are limited in Viet Nam.

Table 9.11: Structure of Budget Expenditure by Educational Level, 2006–2014 (%)

Educational Level	2006	2008	2009	2010	2011	2012	2013	2014
Preschool	7.5	7.5	7.9	7.9	8.2	8.2	8.2	8.2
Primary education	31.2	29.9	29.1	28.5	28.2	28.3	28.3	28.3
Lower secondary education	21.6	22.0	22.6	21.5	21.4	21.6	21.6	21.6
Upper secondary education	10.3	11.0	11.3	11.8	11.2	11.1	10.9	11.1
Total of preschool and basic education	70.6	70.5	70.9	69.7	69.0	69.2	69.0	69.2
Vocational	6.7	10.0	9.8	9.7	9.9	9.7	9.7	9.7
Professional secondary schools	2.6	3.3	3.2	3.4	3.6	3.5	3.5	3.5
Colleges, universities	8.9	12.0	11.7	11.7	12.0	12.4	12.4	12.4
Continuing education	1.2	1.2	1.5	1.8	1.7	1.6	1.8	1.6
Others	10.0	3.0	2.9	3.7	3.8	3.6	3.6	3.6
Total of vocational and higher education	29.4	29.5	29.1	30.3	31.0	30.8	31.0	30.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Ministry of Education and Training (2015).

University–industry links in curriculum design are weak, with the result that curricula and training programmes for workers are outdated and lack relevance. According to the OECD and the World Bank (2014), only 9% of firms responding to the 2011 Viet Nam Employer Skill and Innovation Survey were involved in curriculum design.

Even when sufficient information exists, the lack of incentives for public institutions to produce the skills needed by the labour market may ultimately hamper all attempts to improve the relevance of education. The highly qualified faculty members of public institutions often do not deliver because they are not held adequately accountable to parents and students. On the other hand, relatively low salaries and, most importantly, limited opportunities for advancement make it hard to attract high-quality academic staff. Meanwhile, cumbersome promotion procedures do not sufficiently reward academic achievement on the basis of merit.

Viet Nam's public institutions are still protected by financing policies that give them a competitive advantage. Limited autonomy in academic and administrative areas also generates disincentives to tailor programmes to the needs of the local community and to hire and reward the faculty required to deliver these programmes and undertake relevant research. The lower level of development of private higher education is another factor that restricts the capacity to produce higher education graduates and the relevant skills for the economy in S&T fields.

9.4.2 Narrower policy space for supporting science and technology development and innovation

The current policy framework for S&T and innovation in Viet Nam focuses on a wide range of policy support, including tax reduction and exemption, administrative simplification and modernisation, preferential access to credit, trade promotion, education and training, information support, market development, and R&D. However, Viet Nam's increasing integration into the regional and international economies through diversified international commitments, such as FTAs and bilateral investment treaties, presents some potential issues with the remaining policy space.

First, the policy space for tariffs has been significantly narrowed in accordance with tariff reduction commitments. This benefits medium- and high-tech industries that depend heavily on imported inputs. However, the use of tariffs as an instrument to protect domestic production, especially in the case of newly developed products, is no longer feasible in the new context. This also has implications for any high-value-added innovative industries that Viet Nam may wish to develop in the future. Second, the policy space for non-tariff measures is also smaller because measures such as import quotas and the temporary prohibition of imports and/or exports cannot be applied to trade in hi-tech products and their spare parts. Meanwhile, the use of technical standards to prevent inflows of foreign goods and services becomes less possible due to the requirement of justification and/or transparency. Third, credit assistance for industrial production is somewhat restricted. Export subsidies or production subsidies for industrial products, including hi-tech ones, are prohibited. Finally, under current and pending FTAs (such as the TPP), measures such as export ratio and local content requirements are no longer permitted. Foreign investors sometimes even enjoy more preferential treatment than their domestic counterparts.¹² This preferential

¹² Circular No. 20/TT-BKH&CN (2014) on standards of imported used machines was suspended before taking effect (1 September 2014). This suspension was attributed to pressure from foreign direct investment enterprises that wanted to relocate their factories from other countries to Viet Nam.

treatment is not specific to foreign direct investment, but eligibility criteria in terms of capital scale and technology level mean that it is unlikely to be accessible to most domestic enterprises.

Meanwhile, there is still significant space for the government to take other measures to support the development of innovative industries. The education and training of labour and R&D have been mentioned in many policies related to human resources development and technical assistance for hi-tech enterprises. These can be implemented, in principle, through measures such as preferential financial support from the state budget for education and training programmes, part payment of technological transfer expenses, and tariff exemptions or reductions when importing production inputs for hi-tech projects or supporting industries. Hi-tech products are also eligible for trade promotion and market development campaigns.

As reflected by the current legal framework for S&T and innovation development and integration regulations, such policy space has been employed, at least in principle. However, the policy space itself may be restricted by a lack of available funds in the state budget – which sometimes makes it impossible to promote the development of S&T and innovation – and the limited effectiveness of existing policies and/or regulations.

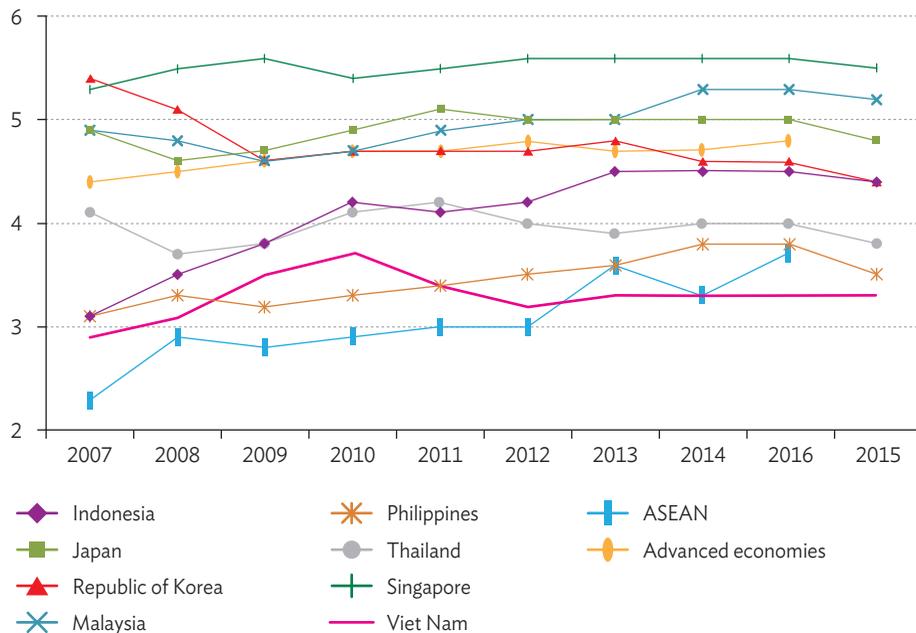
Viet Nam's stage of economic development still requires suitable policy space to protect and/or facilitate the development of S&T and an innovation-based economy. Protection measures remain important for achieving this. Nevertheless, Viet Nam's new-generation FTAs (such as the EU–Viet Nam FTA and the TPP), which incorporate higher standards of intellectual property protection, may be beneficial to the design and enforcement of S&T policy.

9.4.3 Inadequate innovation linkages

Limited university–industry collaboration

The available evidence, while partial and fragmented, points to the existence of very weak links between science and industry in Viet Nam. Figure 9.6 depicts university–industry collaboration in R&D in Asian countries during 2007–2016. Viet Nam's score improved little during this period. After 2010, the figure even trended downwards and Viet Nam was overtaken by the ASEAN average since 2013 and the Philippines since 2012. Compared with the scores of other ASEAN Member States, such as Malaysia, Singapore, and Thailand, or advanced countries, Viet Nam's performance was the lowest.

Figure 9.6: University–Industry Collaboration in Research and Development, 2007–2016



ASEAN = Association of Southeast Asian Nations.

Note: The score ranges from 1 to 7, where 7 is the best.

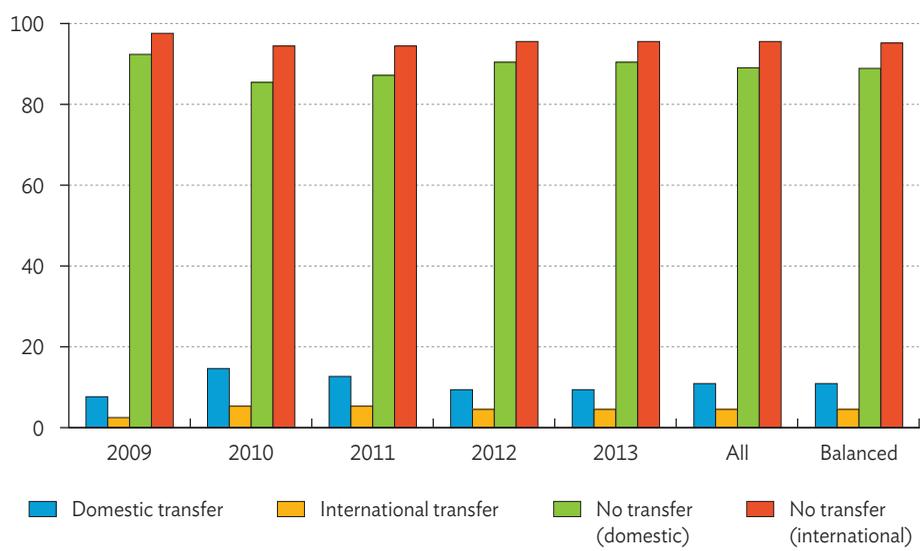
Source: World Economic Forum (2017), Global Competitiveness Index database.

The situation is partly attributable to pronounced resource constraints, which may limit opportunities for collaboration. Many institutes have yet to look for the appropriate S&T market segments, and focus on research using their currently available resources without aligning with the needs of enterprises. Furthermore, the lack of intermediary institutions and agencies, and of consultancies, evaluation, valuation, and the provision of technology-related information is also a constraint on interactions between the public research sector and businesses. CIEM and the World Bank's 2012 Employers Skill Survey involving 352 firms (330 firms in formal sectors and 22 firms in informal sectors) found that only 6% of firms had engaged in innovation-related cooperation with an outside partner, and only 1% had collaborated with research institutes and universities. Another survey by the Hanoi National University (2013) of 583 enterprises showed consistent results. The share of respondents that had collaborated with a research organisation or a university was only 16% and 17%, respectively (Phung and Le, 2013).

Insufficient technology transfer: Backward and forward linkages and horizontal spillovers

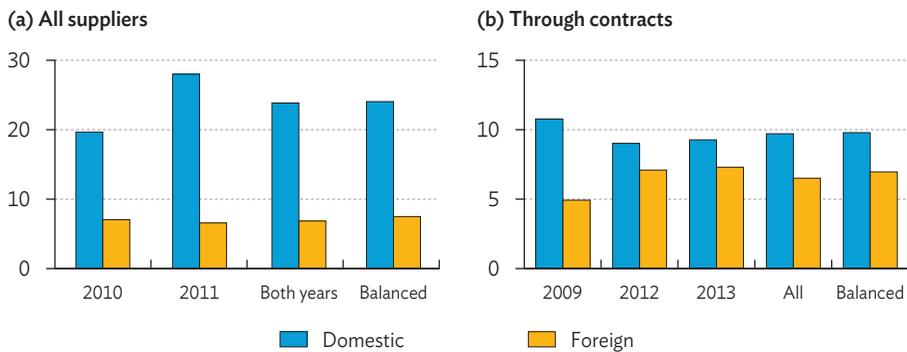
CIEM–GSO–University of Copenhagen (2015) found modest levels of backward linkages (technology transfer from customers) and forward linkages (technology transfer from suppliers) between domestic and foreign firms in Viet Nam. Firms that reportedly received technology transfers from domestic customers accounted for 11% of cases, while the share for technology transfers from international customers was only 4.5% (Figure 9.7). This indicates that, contrary to expectations, the main route for technology transfers was through trading relationships with domestic firms and not with foreign firms who operate either in Viet Nam or abroad. Most positive spillovers through backward linkages were formally specified in contracts (more than 70%), while the indirect benefits from interacting with foreign firms in the same sector or region were scarce. Only about 7% of respondents reported technology transfers through forward linkages with international suppliers, both for all suppliers and for transfers through contracts; the equivalent figure for forward linkages with domestic suppliers was 24% – more than triple (Figure 9.8). Thus, as in the case of backward linkages, the evidence shows that technology transfers through forward linkages are more likely to occur from contact with domestic rather than international firms.

Figure 9.7: Backward Linkages: Technology Transfer from Customers (%)



Note: ‘All’ refers to gross data during 2009–2013. ‘Balanced’ excludes firms whose figures for assets and revenue were recorded as zero or missing, or whose figures for assets and revenue were inconsistent.

Source: CIEM–GSO–University of Copenhagen (2015).

Figure 9.8: Forward Linkages: Technology Transfer from Suppliers (%)

Note: 'All' refers to gross data during 2009–2013. 'Balanced' excludes firms whose figures for assets and revenue were recorded as zero or missing, or whose figures for assets and revenue were inconsistent.

Source: CIEM–GSO–University of Copenhagen (2015).

9.5 | Conclusion and Recommendations

9.5.1 Conclusion

Together with its economic reforms and integration, Viet Nam's innovation policy has been gradually expanded and amended. S&T achievements have contributed to economic development in Viet Nam through their impacts on labour productivity and economic structure. The fourth industrial revolution will offer more opportunities for developing countries such as Viet Nam to speed up their technology catch-up process, creating a sound foundation for more sustainable economic growth.

However, there are obstacles to more effective S&T innovation-led growth in Viet Nam. The country's S&T and innovation capacity – the national innovation system – is inadequately developed, and R&D activity is insufficient, in both the business and public sectors. This can be attributed to shortcomings and weaknesses, including in institutions, human resources development, investment and financing for S&T and innovation development, and collaboration and linkages among relevant bodies (both in terms of management and implementation).

For more sustainable economic development, Viet Nam should (i) address the bottlenecks for S&T and innovation development and utilisation; and (ii) pay adequate attention to the constraints of scarce resources and the existing and available policy

space in the context of deeper integration in regional and international value chains and production networks. In the process, the government should continue its leading role in providing a long-term orientation on S&T and innovation priorities, and it should also encourage deeper private sector engagement in innovation.

9.5.2 Recommendations

For a more effective innovation policy, Viet Nam should consider the following five sets of recommendations.

- (i) Recommendations for improving the institutional and policy framework for S&T and innovation
 - Improve coordination among the bodies responsible for state management and policy formulation and the implementation of S&T and innovation policy. The aim is to foster consistency among strategic visions and priorities. Greater development and use of existing strategic intelligence units and the enhancement of regular and effective communication and networking among policymakers will play a vital role. Foster the accumulation of experience in specialised government departments and agencies to improve the ability of S&T managers to translate high-level policy orientations into achievable objectives.
 - Increase the resources for policy evaluation in government agencies and departments to enhance public accountability. Accordingly, the analytical evaluation base for S&T and innovation policy formulation should be strengthened by including internationally comparable S&T statistics and evaluation practices. Encourage the generation, distribution, and analysis of information in more public organisations. Setting realistic and well-defined goals is important.
 - Improve the policy formulation and enforcement of IPR. Reinforce efforts to address regulatory obstacles to doing business (such as administrative burden and lack of transparency) to create a favourable business investment environment for innovation.
- (ii) Recommendations for strengthening human resources for innovation
 - Allocate sufficient funding for vocational training and upper secondary and tertiary education to promote both the quality and the quantity of the human resources base for technical and research personnel.

- Provide more opportunities to enhance the skills of the S&T labour force through short-term training programmes and part-time tertiary education. Pay more attention to entrepreneurship and soft skills, such as creativity, leadership, and teamwork.
- Use public–private partnerships to encourage businesses to play a greater role in the national effort to develop human resources. Firms, especially state-owned and multinational enterprises, should be encouraged to increase their training investments, fund demand-tailored aspects of formal education, and become involved in decisions about curricula and teaching programme design.
- Improve the quality of management. Competitive and merit-based selection of managers in the business and research sectors is necessary to promote firms' participation in S&T and innovation.

(iii) Recommendations for strengthening the role of the business sector

- Expand public support for enterprises' R&D and innovation to strengthen both R&D capacity and linkages with public research organisations. Improve in-house innovation capabilities, which require skills to engage in design, engineering, marketing, information technology, and R&D at the firm level.
- Nurture the development of the enterprise sector by promoting state-owned enterprise reforms that strengthen the overall business investment environment in terms of competition, access to finance, and administrative requirements. A suitably adapted public–private partnership pilot programme for R&D and innovation could help focus and leverage resources, and improve cooperation between public research and business actors, including foreign firms.
- Encourage enterprises of all types of ownership to invest in S&T, especially in hi-tech and creative industries and their supporting industries. Ensure that Viet Nam retains the policy space to use a range of tax incentives and disincentives to steer investment capital, from both domestic and foreign sources, into these priority areas.

(iv) Recommendations for enhancing the contribution of public research organisations

- Reform the mandates and operations of public research organisations towards a market-oriented approach instead of a mission-oriented one. Restructure ineffective organisations (for instance, through mergers or by dissolving them) to enhance the viability and alignment of research work. During this process, the role of MOST is vital for strategy and policy supervision.

- Strengthen the capacity of public research organisations to attract and retain high-quality personnel. This, in turn, relates to aspects such as payment mechanisms, working conditions, and the availability of research equipment.
 - Facilitate the process of institutional autonomy and the self-responsibility of public research organisations. The performance-based allocation of funding may help strengthen research–industry links and the transformation to organisational autonomy.
- (v) Recommendations for strengthening S&T and innovation linkages
- Develop and enforce appropriate mechanisms, including incentives to encourage greater collaboration between research organisations and industry and integration with national and international S&T networks, to promote high-tech transfers from foreign firms to domestic ones, especially small and medium-sized enterprises. A major concern is the ability of domestic firms in Viet Nam to acquire such technology from foreign investors. Historical records indicate that without such mechanisms, foreign investors are less likely to transfer technology. The added costs of accessing foreign technologies due to tighter and expanded IPR enforcement in many FTAs and bilateral investment treaties are also of special concern in this regard.
 - Encourage the establishment of training partnerships between vocational education providers, universities, foreign-invested enterprises, and domestic firms to bridge the large productivity and quality gaps between foreign-invested and domestic private enterprises. State-owned enterprises could act as intermediaries in such partnerships.

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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.

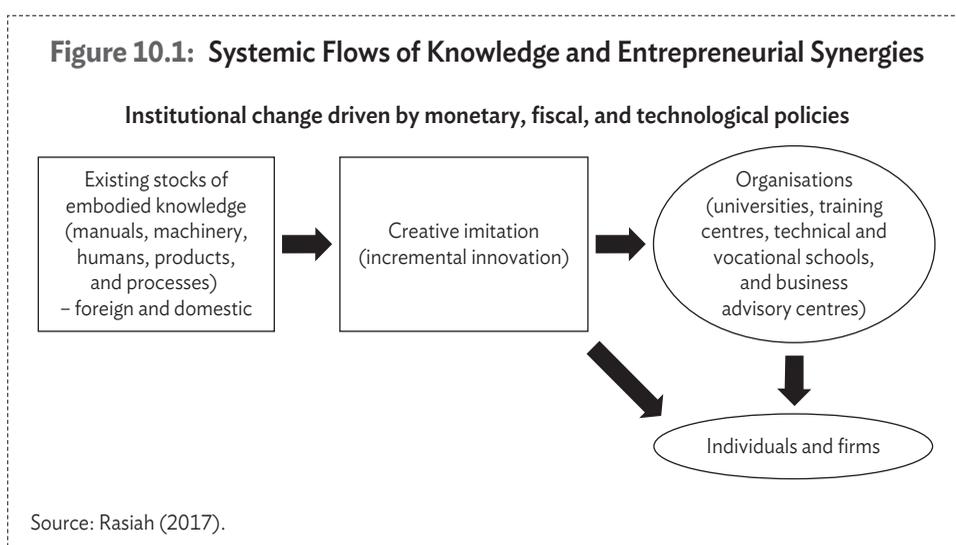
10.2 | Theoretical Considerations

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).



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

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.

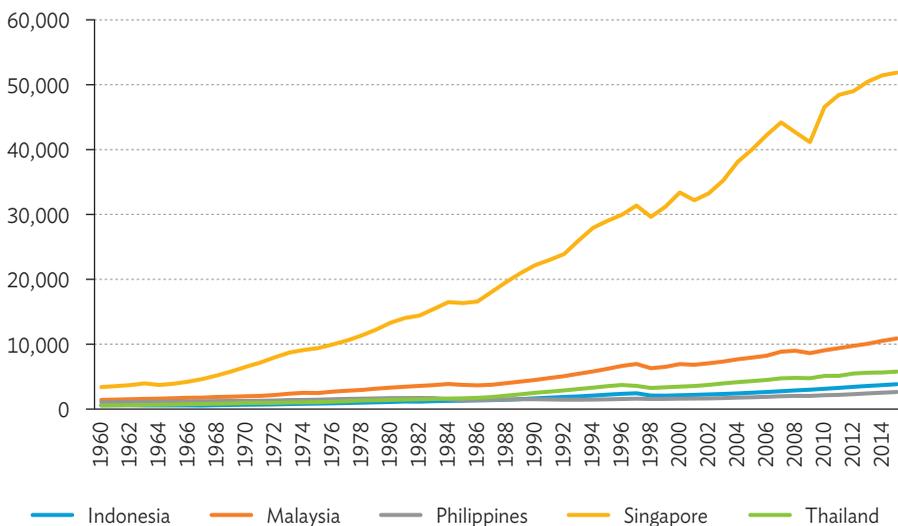
10.4 | Innovation Policies and Infrastructure

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.

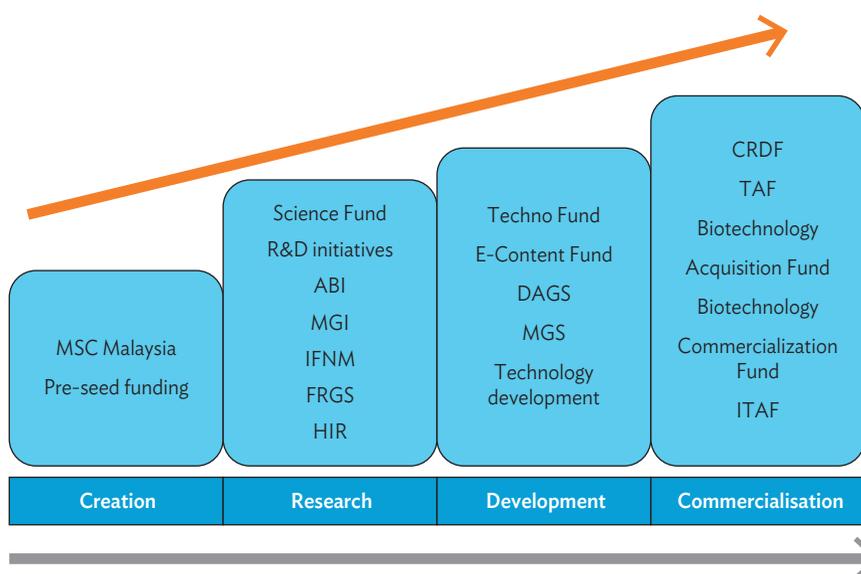
Links between foreign electronics firms and national firms have appeared promising since the 1980s, when demand for proximate sourcing increased (Rasiah, 1988, 1989). Indeed, significant supplies of precision tools, semi-automated machinery, and fabrication opportunities were established between multinational 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


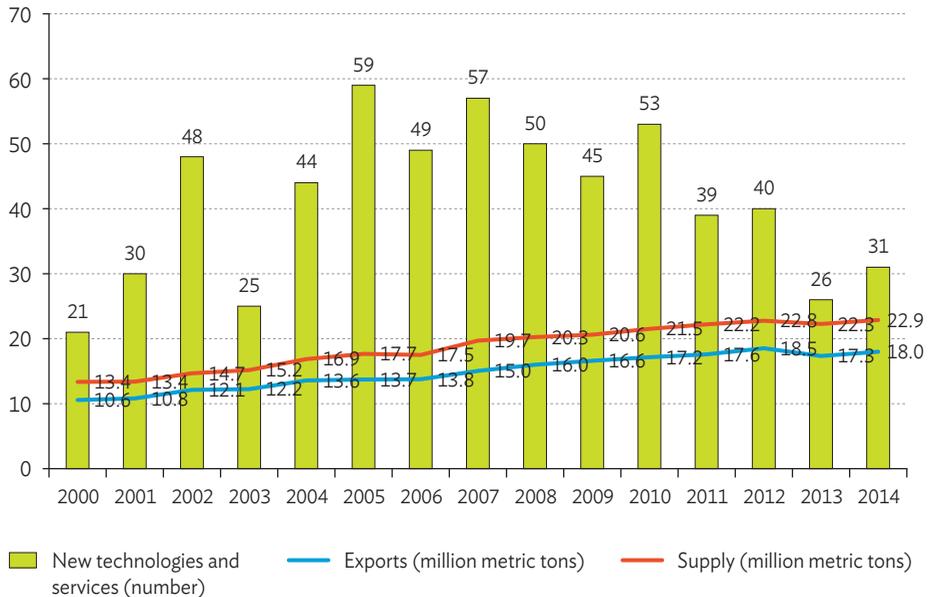
ABI = Agro-Biotechnology R&D Initiative, CRDF = Commercialisation of R&D Fund, DAGS = Demonstrator Application Grant Scheme, FRGS = Fundamental Research Grant Scheme, HIR = High Impact Research, IFNM = Pharmaceutical and Nutraceutical R&D Initiative, ITAF = Industrial Technical Assistance Fund, LRGS = 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 disaster-

simulation 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.

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 (Durongkaverroj, 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.

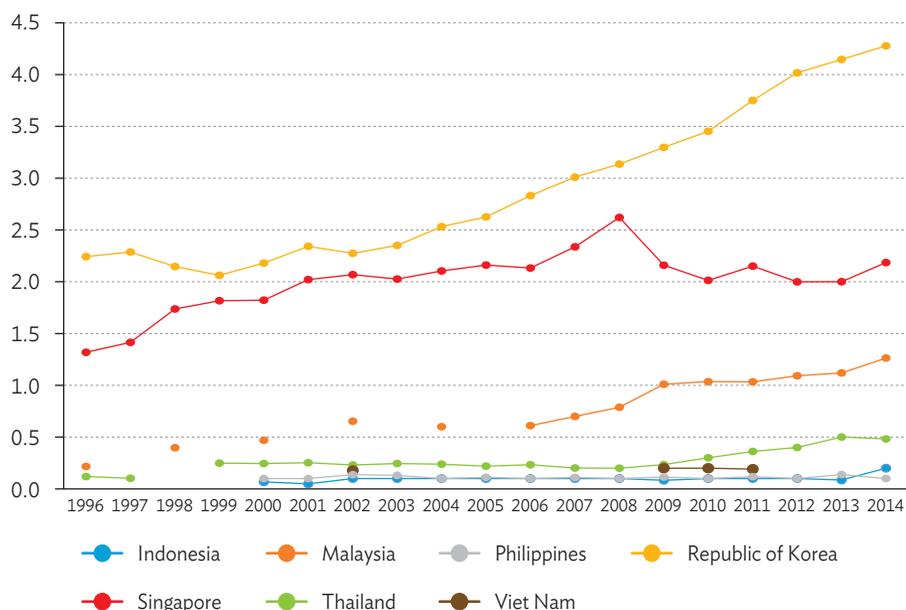
10.5 | Innovation Inputs

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 (%)

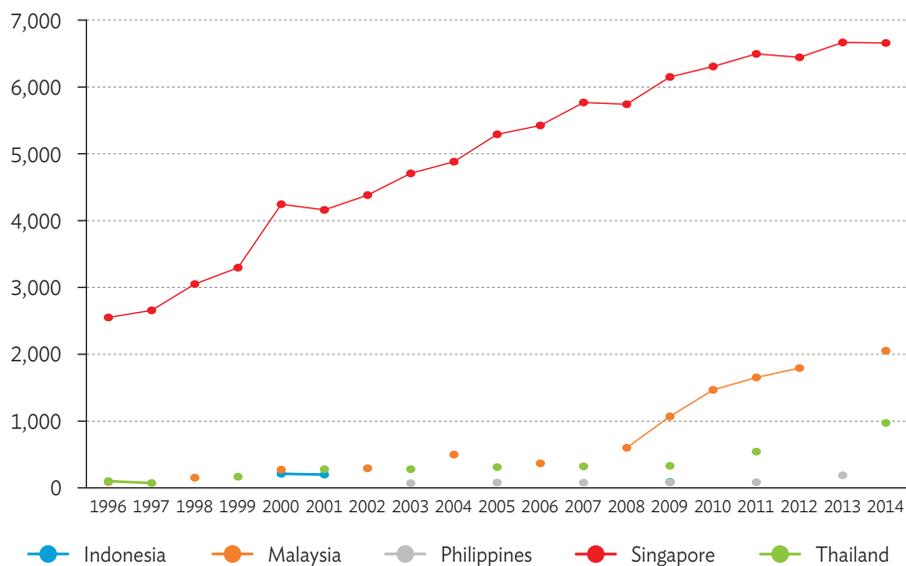


Source: World Bank (2016).

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.

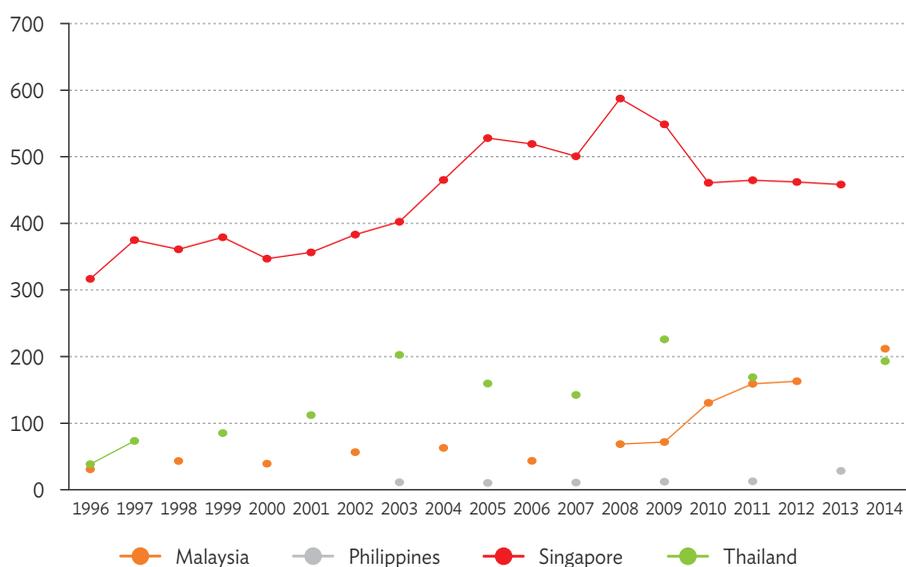
R&D technicians. Singapore also led in the share of R&D technicians per million people among the five countries (Figure 10.8). However, after rising from 317 in 1996 to 588 in 2008, the figure fell to 458 in 2014. Although Malaysia ranked second in 2014 with 212 R&D technicians per million people compared 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).

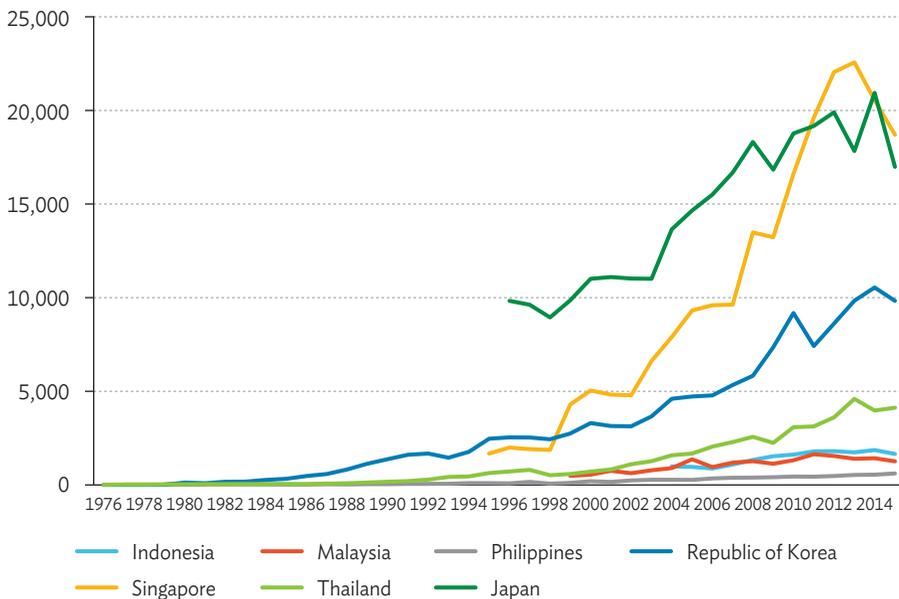
Figure 10.8: Research and Development Technicians in the Populations of Selected Economies, 1996–2014 (number per million people)



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.

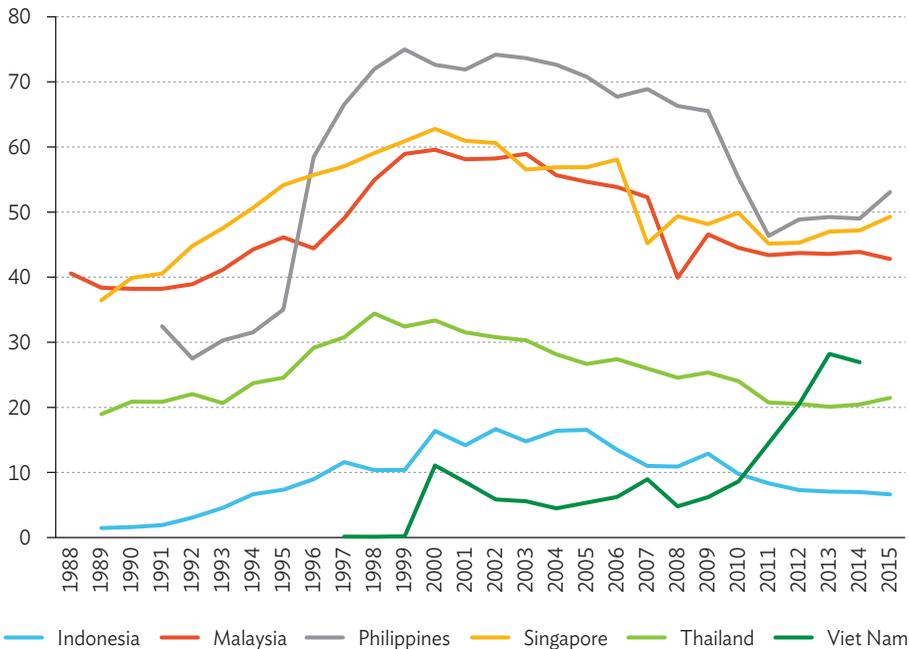
10.6.1 High-tech exports in manufacturing

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).

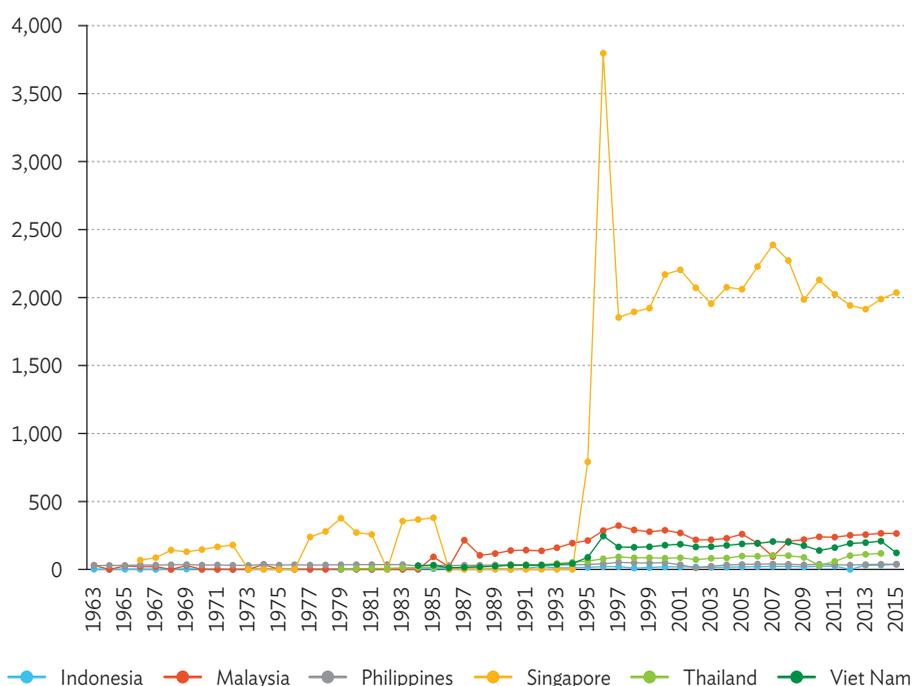
10.6.2 Patents

Although not comparable with the achievements of Korea and Taiwan, patent applications⁵ 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)



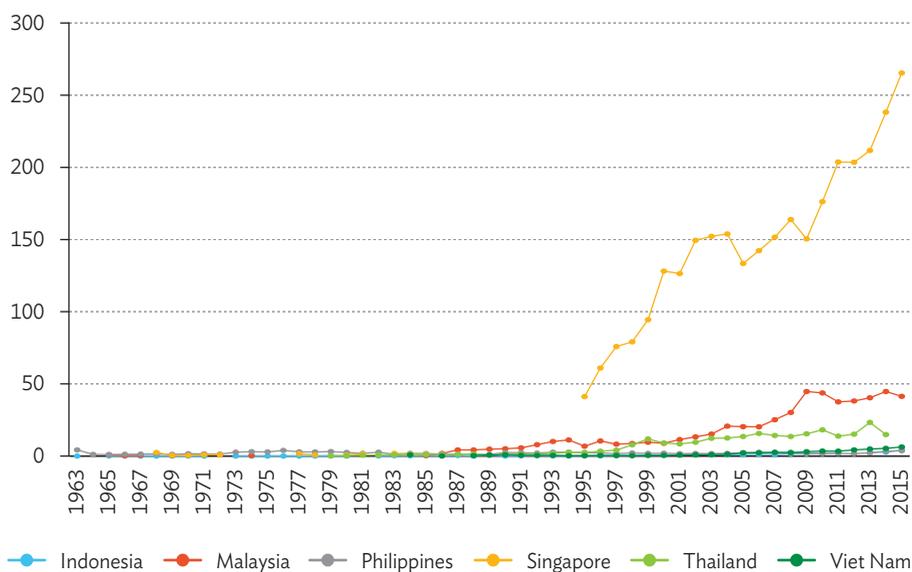
ASEAN = Association of Southeast Asian Nations.

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)



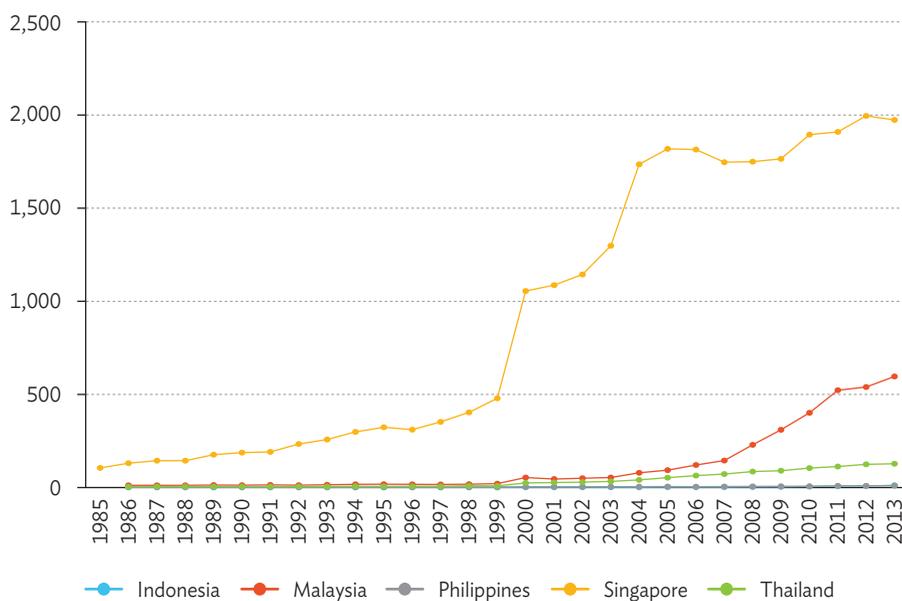
ASEAN = Association of Southeast Asian Nations.

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.

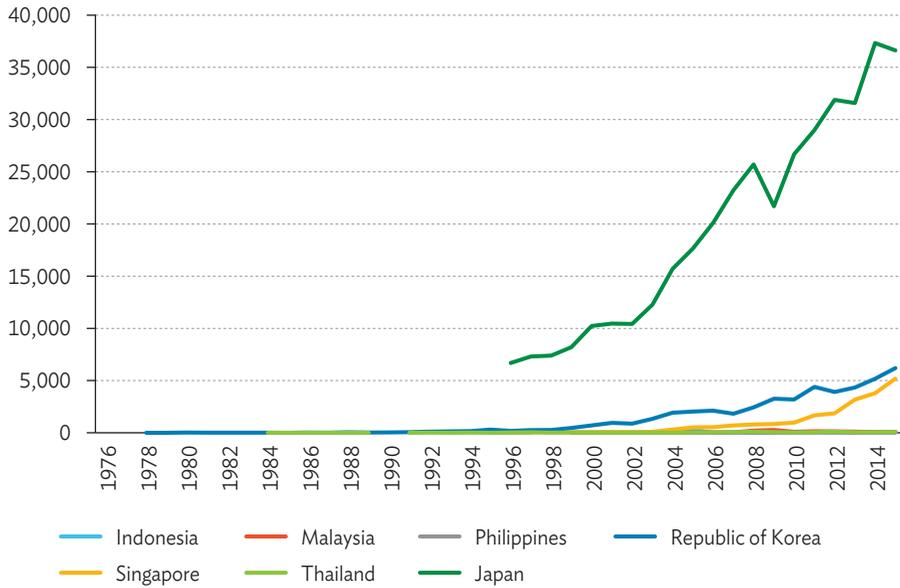
Source: World Bank (2016).

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.

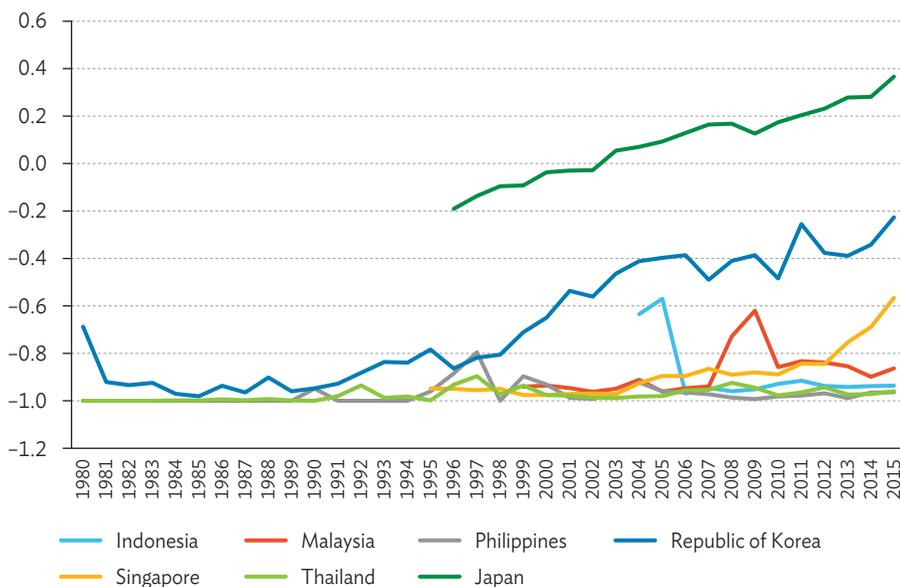
We used the formula: $(\text{exports} - \text{imports}) / (\text{exports} + \text{imports})$, to measure intellectual property dependence on foreign sources. Japan has enjoyed a massive surplus in its net intellectual property trade balance since 2003 (Figure 10.15). In 2014, Japan enjoyed an intellectual 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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Conclusion and Policy Recommendations

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This book, *Innovation Policy in ASEAN*, has addressed the fundamental question as to what kinds of innovation policies should be introduced in the Association of Southeast Asian Nations (ASEAN) and how ASEAN Member States (AMS) can promote innovation to achieve sustainable economic development.

The theoretical framework presented in Chapter 2 gives us a useful benchmark to design concrete innovation policies to provide possible solutions and prescriptions for such problems. First, it is emphasised that innovation policies need to make knowledge spillovers work smoothly and seamlessly among public institutes, universities, and private firms within a country. Knowledge spillovers should be appropriately integrated into the framework of sectoral, regional, and national innovation systems, taking into account both technological appropriability (i.e. private ownership) and opportunities (i.e. public access). Thus, the policy implication derived from innovation theory is that AMS should build a whole-of-government approach to help knowledge spillovers and innovation diffusion occur across various bodies by involving mediators, such as innovation intermediaries.

Based on this theoretical framework concept, Chapters 3–9 analyse past and current innovation policies implemented in China, Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam. These countries face the difficult problem of nurturing their innovation capability to help them advance from developing to developed country status in the mid-to-long term. These chapters conduct interesting analyses and present insightful recommendations on the innovation policies of individual countries according to their particular circumstances and development stages.

This concluding chapter attempts to summarise the key policy recommendations that can be applied more generally to all AMS that aspire to achieve innovation.

The key message is for AMS not only to increase investment in research and development (R&D) and innovative activities but also to enhance innovation capability and improve the environment in which innovation occurs.

First of all, the successful examples of China and Singapore, which have achieved economic development since the 1960s and the 1980s, respectively, serve as a useful reference for innovation policy in ASEAN. The common strategy taken by these two countries has been to attract foreign direct investment (FDI) by encouraging multinational companies (MNCs) headquartered in developed countries, such as the United States, members of the European Union, and Japan, to locate in domestic industrial zones (usually special economic zones) in the hope of receiving significant technology transfers from them. By tapping FDI with the aid of industrial policies, such as the formation of industrial clusters, a strong export orientation, and education biased towards science and technology, China and Singapore have steadily moved up the technology ladder and enhanced their innovation capabilities. FDI linked to new technology has been a foundation for the current innovative activities of these two countries.

More importantly, innovation policies based on technology transfers from FDI are even more effective for AMS now than they were in the past. As Baldwin (2016) illustrates, production networks embodied by the 'second unbundling', which disperses the processes and tasks of factories across borders using dramatically advanced information and communication technologies, have accelerated the offshoring of production activities from developed to developing countries since the 1990s. In addition to physically relocating production processes to developing countries, this active offshoring of MNCs has brought technology and knowledge of production skills, marketing, and management to local firms.

Hence, thanks to the globalisation of FDI led by the second unbundling, most developing countries, including AMS, can formulate new industrial development strategies to enhance their industrial competitiveness and innovation capability by integrating low-wage domestic workers with the advanced technologies of MNCs. Although further examination is required as to whether 'radical innovation' beyond such simplistic 'process innovation' is realised through technology transfer from MNCs, this is likely to channel much know-how, as well as the innovation base, to them. Moreover, industrial policies relying on FDI in the epoch of the second unbundling do not require countries to arrange all the production processes and tasks in one country. Rather, only part of the fragmented production processes and tasks in a particular industry can

be located there. This implies that governments' efforts to promote innovation can be reduced from a 'big push' to a 'small nudge' because the critical mass of technological development and innovation is relatively small (Baldwin, 2016).

In this respect, the FDI strategy adopted by ASEAN, which is symbolically represented as 'a single market and production base' and 'an integrated and highly cohesive economy' in the 2015 and 2025 ASEAN Economic Blueprints, respectively, is well-aligned with innovation creation. ASEAN and developing East Asia's production networks, particularly in the automobile and machinery industries deployed by MNCs, are among the most advanced in the world. As ERIA (2015) stresses, individual AMS can move up the development steps with the help of FDI by taking maximum advantage of this new international division of labour. Innovation policy in ASEAN should therefore be consistent with this newly proposed industrial development strategy in the hope that local firms receive knowledge spillovers from MNCs by participating in production networks in the region. In addition to continuously attracting FDI as an intermediary of technology, it is important for ASEAN to strengthen economic integration to realise efficient and effective production networks through, for example, infrastructure enhancement, the removal of non-tariff barriers, and economic partnership agreements, such as the ASEAN-plus-one free trade agreements.

Some AMS, such as Malaysia and Thailand, are very concerned about falling into the middle-income trap. If they do not significantly upgrade their industrial structures and competitiveness in the global market through their own innovation achievements, their economic growth may stagnate and labour wages may rise while they remain as middle-income economies. To avoid this scenario and progress to developed-country status, in the long run, these countries must implement forward-looking innovation policies in addition to attracting FDI for the purposes of technology transfer and knowledge spillovers. The necessity of valid innovation policies in ASEAN seems obvious given that progress in innovation has largely been less than satisfactory. For this reason, this chapter proposes three policy recommendations that individual AMS are encouraged to consider.

First, the biggest problem most AMS face is the absence or functional failure of a government organisation to control and coordinate the innovation policies that are formulated and implemented across various departments in a country. Simply put, systemic and systematic national innovation systems (NIS) have not yet been fully established. As an essential impetus for a workable innovation policy in ASEAN, Chapter 1 emphasises the importance of an NIS, which can be defined as a continuous

process by a government where institutions, learning processes, and networks play a central role in generating technological change and innovation via intentional, systemic interactions between the various components. The key point is that a government can be an endogenous positive actor that works for institutional systems where there are well-organised interactions among many agents, including public institutes, universities, and private firms, including both local companies and MNCs.

In ASEAN, Singapore is an exception for having succeeded in institutionalising its NIS. As Chapters 7 and 10 demonstrate, the Economic Development Board (EDB) of the Government of Singapore has systematically advanced technological development, world-class infrastructure, efficient public services, and the provision of incentives and grants for FDI. Effective control and coordination by the EDB, in collaboration with the Agency for Science, Technology and Research (A*STAR), resulted in the formation of the biomedical sciences cluster. Foreign pharmaceutical firms and talents were attracted; physical infrastructure was developed; public research institutes were located in the cluster; biomedical local firms, start-ups, and venture capital were promoted; and R&D links between universities and the healthcare services sector were encouraged. Most innovations that have been produced in Singapore to date are regarded as incremental and not comparable with those of Western countries or Japan and the Republic of Korea (hereafter, Korea). However, Singapore is steadily preparing the capability to create radical innovation under the auspices of the EDB and A*STAR, which constitute a formal, integrated, and well-functioning NIS.

Another useful reference can be found in Japan's NIS. In 2001, the government set up the Council for Science, Technology and Innovation (CSTI), with greater responsibility for setting and evaluating science, technology, and innovation (STI) policy, under the Cabinet Office to strengthen the coordination function within the government. The CSTI is attended by relevant ministers and professionals from academia and the private sector and chaired by the prime minister, vesting the CSTI with strong authority to determine the future direction of Japanese STI policy and prioritise the STI fields to which resources should be intensively devoted. While ministries still enjoy a degree of autonomy for their innovation policies, the CSTI has greatly contributed to improving coordination among them.

The first policy recommendation for AMS is therefore to vest responsibility for the establishment and/or reinforcement of their NIS framework in a government organisation, preferably a single body. This government body should hold unified authority with strong leadership under government control to lead and coordinate

innovation policies developed across various departments from a holistic viewpoint. Some AMS have already established initiatives or organisations to promote domestic innovation. Examples include the National Research Council in Indonesia; the Global Science and Innovation Advisory Council and the National Science Council in Malaysia; and the National Science, Technology and Innovation Policy Committee and the National Research Council in Thailand. But, as the chapter authors show, despite good intentions, weak coordination and implementation prevent most of these bodies from functioning as they should.

By employing such government organisations for the control and coordination functions, AMS governments can strategically drive and implement harmonised innovation policies; set priorities for measures, plans, and programmes to maximise the use of limited resources; and evaluate and monitor their effectiveness. By doing so, AMS should more rapidly tackle issues such as building science and technology infrastructure (including physical and human resources); enhancing intellectual property rights; and establishing favourable regulation climates for knowledge spillovers, technology diffusion, and innovation.

Second, governments need to do more to encourage the private sector (including both domestic and foreign firms), with appropriate monetary incentives to invest more in R&D to stimulate technological development and innovation. It remains essential for AMS governments to spend a larger share of their budgets on R&D and innovative activities since R&D intensity (as a percentage of gross domestic product), patent applications, and the number of R&D researchers have stagnated at very low levels in most AMS (except Singapore) compared with China, Japan, and Korea. There also seems to be scope for AMS to increase the research budgets allocated to public research institutes and universities, which currently have more research potential than private sector research institutes in terms of professional human resources. However, merely increasing government spending is unlikely to reverse the stagnation of R&D, innovative activities, and the resultant innovation achievements in AMS. This is because a permanent government spending increase can never be sustainable in the long run with limited budgets, and an approach that is too government-centric often fails due to government failure. Worse still, it unintentionally undermines the incentive of the private sector to innovate.

It is, therefore, recommended that the innovation policies of AMS be orientated more towards encouraging the innovative activities of the private sector to focus on areas that are always subject to the market mechanism, where resources are in principle

allocated efficiently. The government can then confine its responsibility to addressing market failures to achieving innovation, i.e. where the private rate of return to innovative activities is smaller than the social one. Possible inducements governments can provide to avoid under-investment by the profit-seeking private sector include subsidies and tax credits for R&D and human resources development, grants for targeted innovative activities, and patent grants. As Chapter 2 illustrates in the whole-of-government approach, other factors critical to mitigating market failure and promoting private sector innovation include sound competition and deregulation; indirect research support, such as information provision; and education.

One conspicuous area of market failure is the commercialisation of innovation achievements. Realising innovation from genuine interest is not necessarily the ultimate goal; providing commercialised products to the market to enhance consumer welfare is much more critical in most cases. In an extreme situation, the value of innovation, especially innovation created from applied research, might be null unless it is appropriately commercialised. It is, therefore, critical that AMS governments help private firms and public research institutes commercialise their innovation achievements.

To help achieve this goal, governments should create specialised public research institutes whose primary mission is to conduct R&D and technical support related to commercialising various types of innovation achievements. This policy recommendation is raised in Chapter 8 in relation to Thailand, but it is equally applicable to all AMS since they frequently encounter obstacles at the commercialisation stage due to a lack of adequate know-how. Such public research institutes can be modelled after existing similar institutes, such as A*STAR in Singapore and Fraunhofer-Gesellschaft in Germany. For example, Singapore's Exploit Technologies Pte Limited is a commercialisation arm of A*STAR. The company is strongly orientated towards driving the country's innovation and commercialising its research outcomes by translating them into marketable products, processes, and services. Other AMS should be able to create similar institutes to facilitate commercialisation in an effective manner, whether as a spinoff from the government department in charge of industrial technology or an entirely new body.

Third, AMS must further develop a conducive 'innovation ecosystem' in their NIS involving universities, public research institutes, and private sectors. The government-led approach mentioned above underscores the important role of the government as an endogenous, proactive controller and coordinator of its NIS. However, this approach will necessarily fail if other innovation bodies are left behind. University-industry

collaboration (UIC) is an integral part of innovation ecosystems that are conducive to technology diffusion and knowledge spillovers, and it occupies a central position in the NIS of many developed countries. UIC occurs when universities, while engaging in research and education activities, provide consulting services and license their technologies to industries, conduct joint research projects with them, and create academic entrepreneurship, such as spin-offs and start-ups in return for receiving specific research funds from them. It is worth noting that UIC can contribute to local-government-led regional development initiatives, as Chapter 5 highlights in the case of Bandung City in Indonesia.

Accordingly, AMS must nurture UIC as an effective instrument not only to enhance university-launched innovations but also to disseminate and commercialise them for private industry through close interactions in the region. To capitalise on the opportunities, policies and measures to expedite UIC must be formulated, similar to the Basic Law for Science and Technology in Japan and the Technology Licensing Organization Law and Bayh-Dole Act in the United States. Through such legal and institutional enhancements, AMS should further expand UIC best practices, such as those used in Bandung City, which have so far been observed in only a few regions.

To establish an innovation ecosystem, AMS could also aim to create public institutes or programmes similar to the local public technology centres (*kosetsushi*) in Japan. As innovation intermediaries, *kosetsushi* successfully foster the development of local manufacturing industries, particularly small and medium-sized enterprises (SMEs) (Fukugawa and Goto, 2016). Administered by local governments, they help clients, primarily private firms and individuals, innovate. In general, the main roles of the intermediaries are to (i) diffuse technological knowledge through testing, technical consultation, joint research, and seminars for engineering education; (ii) license patents, mainly to local SMEs; and (iii) act as network mediators connecting SMEs with external sources of knowledge. Although some developed countries have introduced such programmes drawing on Japan's experience, developing countries, including AMS, have yet to organise full-fledged public institutes or programmes to support regional innovation in manufacturing. Nevertheless, the lessons learned by frontrunners in forming their NIS can be a useful resource from which AMS can learn.

So far, this chapter has discussed innovation policies necessary for individual AMS. However, it is also important to examine region-wide innovation policies in the framework of ASEAN that can make the region as a whole more attractive as an innovation hub. To achieve this, three proposals are presented.

First, given ASEAN's collaborative efforts to engage in innovation policy at the ASEAN Committee on Science and Technology, it needs to formulate initiatives to promote innovation that entail more cross-regional synergies and positive feedback across AMS. Put simply, ASEAN-wide collaboration should be the desirable policy direction. As Chapter 10 indicates, possible initiatives include (i) innovation surveys or censuses for use in the planning, monitoring, and evaluation of innovation infrastructure; (ii) databases and platforms on R&D findings and innovation for the collaborative sharing of knowledge and convenient access to the knowledge pool; and (iii) optimised coordination of R&D grants and subsidies, technical and vocational training, and higher education programmes across AMS. In particular, it is worth considering a comparison of AMS innovation policies by instituting a peer review system to assess countries' innovation stages and the speed at which their innovation capabilities are advancing. Such a system is likely to motivate each AMS to accelerate the establishment of an NIS. It will also allow AMS to learn from the best practices of other countries.

Second, it is important to further promote goods, investment, and service trade liberalisation and deregulation. Trade liberalisation, such as reducing both the tariffs and non-tariff barriers of goods, exposes local firms to market competition. According to a study by Aghion et al. (2009), although import competition may generally discourage innovation by reducing profits, top firms close to the technological frontier tend to increase their investments in R&D. In addition, investment and service trade liberalisation and deregulation within ASEAN has the significant potential to spur innovation in the region. Since service industries account for the majority (around 50%) of GDP in most AMS, and manufacturing industries currently take on the characteristics of services (so-called 'servitization'), innovation leading to productivity improvements in service industries may enhance economic performance as a whole. Unlike goods trade liberalisation and deregulation, service trade liberalisation faces many challenges in ASEAN despite its considerable potential. Hence, ASEAN is urged to consider further eliminating service trade restrictions in the ASEAN Framework Agreement on Services and the ASEAN Trade in Services Agreement.

Third, policies to facilitate the free movement of natural persons are recommended to encourage greater innovation. Freer movement is usually desirable because innovation is often promoted through person-to-person contact among people with diverse backgrounds. Knowledge spillovers are also brought about by people, especially scientists, who contribute to R&D investments. Highly skilled immigrants are more likely to have positive economic impacts on developing countries since, in most cases, immigrants and domestic workers complement each other. The freer movement

of engineering service providers, assured in the mutual recognition agreements, is particularly important given that the engineering workforce is a foundation for STI. Further improvements in domestic laws and regulations on engineering services are, therefore, needed to make it easier for certified engineers to work overseas. Moreover, since human capital with higher education qualifications is an essential component of operationalising the innovation ecosystem, ASEAN must strengthen collaboration among ASEAN universities through harmonising their curricula and degrees to spur new university-based innovation that transcends national boundaries. ASEAN must also ensure the interaction and exchange of students and researchers with outside universities.

This chapter concludes by raising two remaining issues to be explicitly addressed by future studies. One is the impact of the latest technologies, such as the Internet of Things, automation, artificial intelligence, and machine learning, which may change the face of innovation in the future. By leveraging such innovations, AMS may be able to achieve leapfrogging rather than step-by-step development.

The other is the gap stemming from the differences in innovation capability among AMS, as seen in the gulf between countries with high innovation capability, such as Singapore, and those where it is insufficiently developed, such as Cambodia, Lao PDR, and Myanmar. While AMS at a more advanced stage of innovation will enjoy more dividends from the innovations they achieve, those at a lower stage will fall further behind. The ASEAN Committee on Science and Technology may be able to play a major role in narrowing the innovation gaps among AMS.

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SUMMARY OF POLICY RECOMMENDATIONS

The following policy recommendations aim to provide possible directions for the innovation policies of ASEAN Member States and ASEAN to promote their own innovation creation.

I. Innovation Policy for Individual ASEAN Member States

Fundamental strategy: Continuously attract foreign direct investment from multinational companies and receive the benefits of knowledge spillovers from them to promote process innovation, particularly in the use of production networks or the ‘second unbundling’.

Strengthen economic integration to realise efficient and effective production networks (e.g. infrastructure enhancement, the removal of non-tariff barriers, and economic partnership agreements, such as the ASEAN-plus-one free trade agreements).

1. **Strategically drive and implement harmonised innovation policies; set priorities over measures, plans, and programmes; and monitor and evaluate them.**
 - Establish or reinforce a government organisation responsible for holding unified authority with strong leadership under government control to lead and coordinate innovation policies across various departments.
2. **Encourage the private sector, including both domestic and foreign firms, to invest more in research and development (R&D) and innovative activities.**
 - Provide subsidy and tax credits for R&D and human resources development, grants for targeted innovative activities, and patent grants.
 - Create specialised public research institutes with the primary mission of conducting R&D and providing technical support related to the commercialisation of innovation achievements modelled after other countries (e.g. Exploit Technologies Pte Limited of A*STARS in Singapore).
3. **Elaborate on a conducive innovation ecosystem for the national innovation system.**
 - Nurture university–industry collaboration to enhance university–launched innovations and to disseminate and commercialise them for private industrial sectors (e.g. by introducing laws analogous to the ‘Basic Act on Science and Technology’ in Japan and the ‘Technology License Organization Law’ and ‘Bayh–Dole Act’ in the United States).
 - Organise public institutes or programmes, such as local public technology centres, as innovation intermediaries to help private manufacturing firms, particularly small and medium-sized enterprises, innovate.

II. Innovation Policy for ASEAN as a Whole

1. **Formulate initiatives for promoting innovation with more cross-regional synergies and positive feedback across ASEAN Member States.**
 - Innovation surveys and censuses for innovation infrastructures; databases and platforms for R&D findings and innovation for collaborative knowledge; and optimised coordination of R&D grants and subsidies, and education programmes.
 - Compare ASEAN Member States’ innovation policies by introducing peer reviews.
2. **Accelerate goods, investment, and services trade liberalisation.**
 - Consider, in particular, further eliminating services trade restrictions in the ASEAN Framework Agreement on Services and the ASEAN Trade in Services Agreement.
3. **Promote the freer movement of natural persons, especially of highly skilled immigrants.**
 - Enhance the free movement of engineering service providers and make it easier for certified engineers in the mutual recognition agreement to work overseas.
 - Strengthen collaboration among ASEAN universities through harmonising their curricula and degrees to create new, university-based innovation.

INNOVATION POLICY IN ASEAN

Innovation Policy in ASEAN is a first attempt at a comprehensive innovation study of ASEAN. The book includes not only an overall theoretical framework for ASEAN, but also individual country analyses based on detailed data, empirics, case studies including both those of success and of failure, and concrete policy recommendations ranging from national to ASEAN-wide regional innovation policies. For ASEAN it is important not only to increase investment in R&D and innovative activities, but also to enhance innovation capability's physical and intangible characteristics, and improve the environment where innovation tends to take place. In the face of this significant challenge, achieving innovation can help each ASEAN Member State sophisticate its economies and industrial structures in the years to come. The book aims to provide insights for all stakeholders wishing to examine innovation policies in the region.



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