OECD Reviews of Innovation Policy

Innovation in Southeast Asia

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BETTER POLICIES FOR BETTER LIVES

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Foreword

This review draws on the experience of the OECD country reviews of innovation policy which, over the past years, have covered both advanced countries recognised as global leaders in innovation as well as emerging economies with fast-evolving capabilities in S&T and innovation.* It also complements the existing country reviews by providing a first mapping of science, technology and innovation in a major world region. Specifically, the review provides:

- A cross-country, regional synthesis that highlights recent economic developments with special reference to innovation and provides a quantitative and qualitative mapping and assessment of current capacity and dynamics in S&T and innovation in Southeast Asia, including intra- and extra-regional knowledge flows.
- A set of country profiles describing the state and dynamics of national innovation systems of Southeast Asian countries. These profiles draw on the OECD country innovation policy review approach; they cover the performance and institutional profile of national innovation systems and take into account the economic environment and framework conditions for innovation.

This review benefited from, and would not have been possible without, the active support of Southeast Asian countries. It aims at:

- Obtaining a more comprehensive understanding of the key elements, relationships and dynamics of innovation systems in Southeast Asia and the opportunities to enhance them.
- Providing a platform and starting point for launching in-depth reviews of innovation policy of individual Southeast Asian countries. A first in-depth review of this kind, the joint OECD-World Bank science, technology and innovation review of Viet Nam, is currently under way.
- By carrying out and disseminating the results of the review, facilitating mutual learning and helping enhance mutually beneficial S&T and innovation co-operation between Southeast Asian and OECD countries.

The review is intended to be relevant to a wide range of stakeholders in and outside the Southeast Asian region and the OECD, including government officials, entrepreneurs and researchers as well as the general public. It also contributes to the role of the OECD as a communication platform by providing an accessible and comprehensive presentation of innovation in Southeast Asia to a global audience.

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* www.oecd.org/sti/innovation/reviews

This review was initiated by Christoph Elineau, Coordinator of the EU-funded SEA-EU-Net Science Partners Project, with the support of Gerold Heinrichs of the International Bureau of the German Federal Ministry of Education and Research (BMBF), who proposed to the OECD's Directorate for Science and Technology (DSTI) a regional review of innovation in Southeast Asia drawing on the experience of the OECD country reviews of innovation policy. This initiative was subsequently taken up by the BMBF, Germany, and the Japan Science and Technology Agency (JST), which, along with the SEA-EU-Net project, jointly supported the review financially, and the Korean Science and Technology Institute (STEPI) which supported it in kind. Importantly, the initiative was endorsed by the ASEAN Committee on Science and Technology (ASEAN COST) which actively supported the project.

The review was led by Jean Guinet (formerly Country Review and Outlook Division [CSO], DSTI, OECD) until December 2010 and by Gernot Hutschenreiter (CSO, DSTI, OECD) since then. Gang Zhang (CSO, DSTI, OECD) played an instrumental role in its initiation and design as well as in project co-ordination, in particular for external relations.

Fact-finding missions were carried out in seven countries by two teams. One team, led by Gernot Hutschenreiter, consisted of Atsushi Sunami, Associate Professor (in Indonesia), National Graduate Institute for Policy Studies, Japan; Taeyoung Shin, Senior Fellow, Science and Technology Institute, Korea; Ulrike Tagscherer, Researcher, Fraunhofer Institute for Systems and Innovation Research, Germany, and Associate Professor, Chinese Academy of Sciences; and Masahito Yano, Senior Project Co-ordinator at the Singapore Office, JST, Japan. This team carried out interviews in Indonesia, Cambodia (joined by Junko Chapman, Fellow, Centre for R&D Strategy, JST, Japan, and Alexander Degelsegger, Centre for Social Innovation, Austria) and Viet Nam (joined and led by Jean Guinet). A second team, led by Gang Zhang, consisted of Michael Keenan (CSO, DSTI, OECD), Fujio Niwa, Emeritus Professor, National Graduate Institute for Policy Studies, Japan, Takeshi Usami, Chief, Department of International Affairs, JST, Japan, and Atsuya Yamashita, Director of Singapore Office, JST, Japan. This team carried out interviews in Thailand, Malaysia and Singapore. Several members of the two teams (joined by Emi Kaneko Ueda, Chief, Department of International Affairs, JST, Japan) also conducted interviews in Laos.

Numerous experts and stakeholders contributed their insights and time in interviews conducted during the fact-finding missions. Special thanks are due to all those who helped to co-ordinate and facilitate the interviews of the fact-finding missions, and in particular: Makara Khov, Institute of Technology in Cambodia; Franz Gelbke, Advisor at the Ministry of Research and Technology (RISTEK), in Indonesia; Sengchanh Phasayaseng, National Authority of Science and Technology, De partment of Science and Technology, Prime Minister's Office, in Laos; Academician Dato' Ir. Lee Yee Cheong, Chairman of the Governing Board, International Science and Technology and Innovation Centre for South-South Co-operation under the Auspices of UNESCO, and Nik Ahmad Faizul Abd Malek, Malaysian Industry-Government Group for High Technology, in Malaysia; Walter Lee, CEO, E-Cop, in Singapore; Simon Grimley, National Science and Technology Development Agency (NSTDA), Ketmanee Ausadamongkol, Thailand Productivity Institute, Nares Damrongchai and Kanchana Wanichkorn, National Science Technology and Innovation Policy Office, in Thailand; and Le Xuan Dinh, of National Agency for Science and Technology Information (NASATI), in Viet Nam.

Supported by national delegates to the ASEAN COST, background reports were prepared by national experts as follows. The background report on Cambodia was provided by Makara Khov, Institute of Technology of Cambodia; on Indonesia by Yanuar Nugroho (lead author), Manchester Institute of Innovation Research, University of Manchester, United Kingdom, and Irsan A. Pawennei and Mirta Amalia, both Centre for Innovation Policy and Governance, Indonesia; on Laos by Sengchanh Phasayaseng; on Malaysia by K. Thiruchelvam, Ng Boon Kwee, and Wong Chan Yuan, University of Malaya, and V.G.R. Chandran of Universiti Teknologi Mara, Malaysia; on Singapore by Poh-Kam Wong and Annette Singh, of National University of Singapore, Singapore; on Thailand by Patarapong Intarakumnerd of College of Innovation, Thammasat University, Thailand; and on Viet Nam by Le Xuan Dinh, NASATI, Viet Nam. Taeyoung Shin contributed a background report based on the findings of the fact-finding missions in Indonesia, Cambodia, Viet Nam and Laos, while Ulrike Tagscherer contributed a background report on science and industry relations in Indonesia and Viet Nam.

Annex A on China-ASEAN relations from a Chinese perspective was drafted by Jianglin Zhao, Institute for Asia and Pacific Studies, Chinese Academy of Social Sciences.

The review report was prepared for publication by Michael Keenan under the overall responsibility of Gernot Hutschenreiter and with contributions and support from Dimitrios Pontikakis (all CSO, DSTI, OECD). Valuable contributions in various forms and at different stages were received from Koen de Backer and Andrea Beltramello with support from Laurent Moussiegt (Structural Policy Division [SPD], DSTI, OECD) on trade and global value chains, Daniel Kupka (CSO, DSTI, OECD), Emanuel Hassan (consultant to the OECD), and Margot Schüller, Senior Fellow, German Institute of Global and Area Studies, Germany. Candice Stevens (consultant to the OECD), Ken Guy (Science and Technology Policy Division [STP], DSTI, OECD, and consultant at the time of contributing) supported by Richard Scott (STP, DSTI, OECD) made important contributions that brought the country profiles to their final form.

Research assistance and other valuable input at various stages of the preparation of the review were provided by Francesca Caselli, Natalie Cooke, Shujin Kim, Richard Scott, Kazuyuki Tanji, Shiguang Zhu and Yingchun Zhu, all at the OECD at the time of their contribution. Éric Archambault, President and CEO of Science-Metrix Inc, and Grégoire Côté (Montreal, Canada) supported the review by providing key bibliometric statistics. The Asian Productivity Organisation, located in Tokyo, Japan, provided support by generously allowing the OECD to use its rich database.

Valuable feedback was also received at presentations at various events organised by the SEA-EU-NET project, the regular sessions of the OECD Committee of Scientific and Technological Policy (CSTP) and its Working Party for Technology and Innovation Policy (TIP) and other OECD forums.

Joseph Loux and Julia Gregory of the OECD Secretariat provided general editorial support for the publication.

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Executive summary

Southeast Asia is one of the world's most dynamic regions. Southeast Asian economies are undergoing rapid changes and becoming ever more closely integrated into fast-evolving regional and global production and knowledge networks. Extending and deepening their capacities in science, technology (S&T) and innovation provides an opportunity for Southeast Asian countries to maximise the benefits of these changes by moving up the value chain, differentiating their economies and contributing to advances in science and technology in order to tackle societal grand challenges. A better understanding of existing capabilities and their dynamics is essential for their future development.

This review is in two parts. The first part provides a cross-country, regional synthesis that highlights recent economic developments with special reference to innovation and provides a quantitative and qualitative mapping and assessment of current capacity and dynamics in S&T and innovation in Southeast Asia. Most Southeast Asian countries look back at a successful history of rapid catch-up with advanced economies over the last decades. Nevertheless, there is great diversity across the region – for example, between high-income countries like Singapore and low-income countries that have entered a process of catching up much more recently. Differences in GDP per capita of Southeast Asian economies can be largely attributed to differences in labour productivity, which in turn is influenced by capital investment and total factor productivity (TFP). Over time, the contributions of these two inputs have shifted, with TFP growing in importance. This is consistent with the region's transition from a low income, capital-deficient region to an increasingly middle income, more capital-abundant region. Under these circumstances, technological change and more sophisticated and more demanding forms of innovation are likely to become more prominent.

Industrialisation in the region has been largely export-led and dependent on foreign direct investment (FDI). Southeast Asian countries are increasingly part of global value chains (GVCs), which have influenced the region's trade structures and strengthened comparative advantages in certain industries through the country-specific location of tasks. At the same time, the rise of China has an immediate impact on the economies of Southeast Asia via increasing bilateral trade and investment flows and cross-border flows of various forms of knowledge. It also has an impact through competition in third markets. To date, the economies of Southeast Asia have gained from China's increasing demand for a broad range of exports from this region. However, the improvement of China's manufacturing capabilities and the pace at which it moves up the value chain may raise competitive pressure on, and to some extent replace, imports of components that are currently manufactured in Southeast Asian countries. The competition for FDI is also likely to heat up further and Southeast Asian countries will need to develop new comparative advantages to compete.

Southeast Asian countries' R&D intensity broadly aligns with their income levels, with Singapore's level of expenditure around the OECD average of more than 2%; in most countries, however, it ranges between 0.05-0.2%. As in many OECD countries, the business sector is the dominant performer of R&D in Singapore, Malaysia and the

Philippines; the public sector is more prominent in other parts of the region. Growth in scientific output in the form of publications has outstripped worldwide growth rates and appears to have increased in quality, too, as measured by citation rates. These improvements have been driven by an expansion in R&D spending, but also by some re-organisation and changes in the governance of public institutes performing R&D, particularly in Singapore and Malaysia. In other Southeast Asian countries, such reforms remain overdue.

Levels of international patenting also broadly align with countries' income levels and, while showing strong growth, remain generally low. In many countries in the region, utility models are the preferred form of IP protection, which have lower novelty requirements than patents and are well-suited to more incremental types of innovation. In fact, much innovation in the region does not rely upon R&D inputs and is instead driven by technology adoption and incremental modifications to products and processes. Where R&D is performed in the business sector, it tends to be done largely in MNEs, even in the more economically advanced countries, like Singapore. But most FDI in the region is "efficiency-seeking" and aims to take advantage of different factor endowments offered by different locations. This means relatively little formal R&D is carried out by most MNEs in the region. At the same time, large domestic firms, many of which occupy monopoly positions, perform relatively little R&D for their size and, with a few notable exceptions, are not particularly innovative. Like their foreign-owned counterparts, they tend to provide too few opportunities for advanced technological knowledge spillovers into the wider economy.

Pro-innovation government policy in the region also differs by countries' income levels and reflects the key challenges they face. For instance, in Singapore, there is much policy emphasis on supporting indigenous high-tech entrepreneurship; this can be compared to less developed countries, where the focus is more on improving business framework conditions, particularly to attract FDI. In fact, the goal of attracting FDI continues to be a central pillar of industrial policy across all Southeast Asian countries and has a strong influence on innovation policy, where the aim is to reap knowledge spillovers as a means for upgrading domestic technological capabilities. Among other things, this requires major investments in developing human resources to absorb and assimilate new technologies and knowledge. Given current types of catch-up innovation activities in Southeast Asia, the necessary skill sets are often more likely to be acquired through vocational technical education and training programmes, as well as through in-firm training, than through academic university degree programmes. Yet, only Singapore has really excelled in promoting industrially-relevant workforce development. Similarly targeted initiatives in Malaysia and Thailand have had less impact and remain under-developed in other parts of the region. Inward mobility of skilled workers has been an important channel for Singapore to upgrade its competences, though this tends to contribute to an outward mobility of talent from certain other parts of the region.

To conclude, the future position of Southeast Asian countries in the world will greatly depend on their ability to further upgrade innovation capabilities. While important manufacturing capabilities have been acquired by a number of Southeast Asian countries, many have been less successful in developing their own domestic capabilities to innovate and to diversify into new areas. Strengthening these capacities will be necessary for Southeast Asian economies to maintain and strengthen their competitiveness, and will be critical for turning future competition, notably with China, into a positive-sum game. This calls for customised and forward-looking national innovation strategies that are well adapted to countries' specific initial conditions and that help build the capabilities required to seize the opportunities ahead.

The second part of the review consists of a set of country profiles describing the state and dynamics of national innovation systems six countries covering the whole range of income levels found in the region:

Cambodia is a low income country where agriculture and garment manufacture play an important role in the economy. There is little technological sophistication and innovation has yet to play a major part in economic development. Improvements in economic and innovation performance require improvements in a number of key aspects of the country's infrastructure – the information and telecommunications infrastructure is still at an early stage of development – and its legal and financial institutions, which are insufficiently geared towards supporting innovative entrepreneurial activity. Current policies focus on trade expansion and efforts to increase FDI. While there has been little explicit focus on science or innovation policy so far, general improvements to the business environment are likely to improve the framework conditions for innovation.

Indonesia is the largest and most populous country in the region, and a lower middle income country. Indonesia's economic growth performance has been strong and has shown resilience during the global financial and economic crisis. It relies to a considerable extent on exports of natural resources and imports of high-technology products outweigh exports. Levels of FDI have been modest relative to the size of the economy. It has not moved towards a technology-intensive industry structure. The development of more technology-intensive activities will require significant improvements in a number of areas, including in the information and communications technology (ICT) infrastructure, the business environment, including lower barriers to entrepreneurship and business risk, the investment framework, and human resources.

Malaysia, one of the region's upper middle income countries, has made important progress in developing STI capabilities. Like Singapore, it has developed an industrial sector based on the manufacture and export of the technology-based products of MNEs – electronics, particularly semiconductors, account for 40% of exports, followed by automobiles and parts. Substantial investments have been made in telecommunications infrastructure such as the Multimedia Super Corridor (MSC). Malaysia has been less successful in attracting increasingly advanced technological operations of MNEs, many of which have confined themselves to manufacturing and assembly activities. Knowledge spillovers, for example, through backward linkages to domestic firms, have also been limited. Furthermore, Malaysia continues to suffer from a continuing shortage of skilled labour, which has not been helped by the outward mobility of talent to other countries.

Singapore, a high income country, faces similar innovation policy challenges as many OECD countries. It has made significant progress in developing its STI capabilities, a process that was initially based on attracting and leveraging global MNEs to transfer increasingly advanced technological operations to Singapore, and developing infrastructure and human resources to absorb and exploit new technologies rapidly. In recent years, greater emphasis has been placed on enhancing indigenous R&D and innovation capabilities, with major investments in research infrastructures and entrepreneurial support schemes. While the government has played a significant "developmental state" role in guiding this development process, the emergence of a more vibrant technological entrepreneurial community is likely to be critical to Singapore's continuing transition from technology adopter to innovator.

Thailand, an upper middle income country, has become a key production base for automotive and electronics MNEs but has been less successful than Singapore and Malaysia in deriving technological capabilities from such activities. Transferred technology tends to be embodied in equipment while spillovers to domestic firms have been relatively weak. Levels of R&D spending, S&T workers and patents are below those of Thailand's principal competitors. Like other upper middle income countries, Thailand recognises the risk of being caught in a "middle-income trap". On the one hand, these countries are under competitive pressure from lower-cost emerging economies such as Viet Nam and dynamically evolving economies such as China and India; on the other, they continue to lag behind the more technological, learning-intensive economies of the original four Asian Tigers (Singapore; Korea; Hong Kong, China; and Chinese Taipei). This challenge can only be overcome by a stronger emphasis on innovation as a driver of economic growth.

Viet Nam is a lower middle income country that has successfully pursued an export-led growth strategy based on more open markets and increased FDI. The country has succeeded in extending the range of its export products and increasing productivity. Priority sectors such as information and communications technology continue to develop well and Viet Nam is now attracting investments from MNEs in information technology. Nevertheless, technology-based exports still constitute a small share of exports, and the current model may not be able to sustain the rates of growth achieved in the past. Continued economic growth and ability to compete in global markets will depend on increased investments in education and production capabilities. Linkages between the public and private sectors, including with foreign firms, also need to be strengthened. The government has started to pay attention to the role of innovation for future growth and has engaged in collaboration with international organisations, including OECD.

Part I

INNOVATION IN SOUTHEAST ASIA: AN OVERVIEW

Chapter 1

Economic development and performance

This chapter first provides a broad comparative overview of Southeast Asia as one of the world's most dynamic regions. It describes the emergence of Asian Tiger economies and their structural transformation into industrialised countries that export to world markets. It next focuses on the levels of economic performance – in terms of gross domestic product and labour productivity – that result from this change and shows the great diversity of Southeast Asia through a number of development indicators and reflects on this rich catch-up experience. Next, it outlines the trade performance of Southeast Asian countries and provides information on evolving patterns of trade from an innovation perspective. It highlights the factors underlying the changes observed, such as the increasing importance of global value chains (GVCs). Finally, it considers potential future drivers of economic change in the region, including GVCs and the rise of China as the region's centre of gravity. It highlights the role of innovation in seizing emerging opportunities and tackling the challenges presented by this new setting.

1.1. Modern Southeast Asian growth and development

1.1.1. Becoming one of the world's most dynamic regions

Southeast Asia is one of the world's most dynamic regions. A broad long-term perspective on economic performance across world regions (see Table 1.1 for the definition of regional groups)[1] shows that output in Southeast Asia overall has grown at a respectable average annual rate of 5.4% over some three decades. Southeast Asia's GDP growth is exceeded only by that of East Asia (8.6%) – where the unprecedented dynamism of the People's Republic of China and strong performance by countries such as Korea acted as major engines of growth – and, in recent years, of South Asia (6.1%). Southeast Asia has been much more dynamic in the long term than world regions such as Latin America, North America or Europe (Figure 1.1). Growth accelerated in particular in the first part of the 1990s, but the East Asian financial crisis of the late 1990s had a deep and, in some respects, lasting effect on the region. In the second half of the 2000s, growth fell behind that of a newly dynamic South Asia. Nonetheless, Southeast Asia's GDP is now five times its size in 1980 and is still increasing at a respectable rate.

Important, yet somewhat smaller, advances have also been made in terms of GDP per capita (Figure 1.2). Here again, Southeast Asia leads the world's developed regions and Latin America. In 2011 Southeast Asia's GDP per capita was 2.4 times higher than in 1980, while in South Asia and East Asia GDP per capita increased by 3.5 and 9 times, respectively. Since 1980 Southeast Asia's GDP per capita has grown annually by 2.9%. This is low in comparison to South Asia at 4.1% and East Asia at 7.4%.

Despite the dynamism of a number of emerging economies, which are reshaping the world economy (OECD, 2012), striking differences in per capita income persist both within and across world regions. In North America, the European Union, and developed Asian and Pacific countries, levels of output per capita have remained higher than those of the other Asian regions and Latin America. In 2011, GDP per capita in East Asia, Southeast Asia and South Asia amounted to USD 3 309, USD 1 858 and USD 809, respectively.

The example of pioneering East Asian countries has helped to trigger the subsequent dynamism of an increasing number of countries. Without denying the role of other factors, this evolution can be said to have started in the period following World War II when Japan, through its post-war reconstruction and unprecedented economic growth, provided inspiration and also raised the aspirations of many countries. In particular, Japan's experience served as an example for a number of smaller East Asian countries, which attempted to follow Japan's development strategy of the 1960s and 1970s while adapting it to their country-specific circumstances and needs (Yusuf and Nabeshima, 2009). The more recent success of Korea and China similarly inspires many lagging countries today.

The first pioneering cohort of newly industrialising countries/economies (NICs or NIEs) consisted of Chinese Taipei, Hong Kong (China), Korea and Singapore – the "Asian Tigers" as they came to be called. Their catching up began with industrialisation and the development of their manufacturing base. They experienced rapid industrialisation and economic growth from the 1960s, thereby initiating a spectacular process of convergence towards the industrialised world's standard of living. This was accompanied by profound socioeconomic and structural changes.

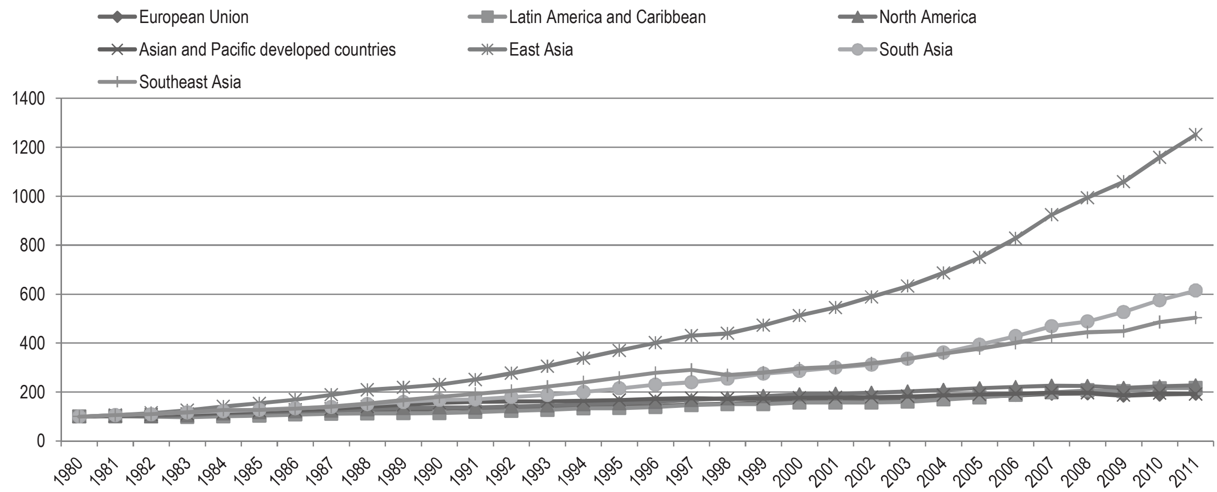
Table 1.1. Regional groups

European Union	Latin America and Caribbean	North America
Austria	Antigua and Barbuda	Bermuda
Belgium	Argentina	Canada
Bulgaria	Aruba	United States
Cyprus	Bahamas, The	
Czech Republic	Barbados	**Asian and Pacific developed countries**
Denmark	Belize	Australia
Estonia	Bolivia	Japan
Finland	Brazil	New Zealand
France	Cayman Islands	
Germany	Chile	**East Asia**
Greece	Colombia	China
Hungary	Costa Rica	Hong Kong, China
Ireland	Cuba	Korea
Italy	Dominica	Mongolia
Latvia	Dominican Republic	Chinese Taipei
Lithuania	Ecuador	
Luxembourg	El Salvador	**South Asia**
Malta	Grenada	Bangladesh
Netherlands	Guatemala	Bhutan
Poland	Guyana	India
Portugal	Haiti	Maldives
Romania	Honduras	Nepal
Slovak Republic	Jamaica	Sri Lanka
Slovenia	Mexico	
Spain	Netherlands Antilles	**Southeast Asia**
Sweden	Nicaragua	Brunei Darussalam
United Kingdom	Panama	Cambodia
	Paraguay	Indonesia
	Peru	Laos
	Puerto Rico	Malaysia
	St. Kitts and Nevis	Myanmar
	St. Lucia	Philippines
	St. Vincent and the Grenadines	Singapore
	Suriname	Thailand
	Trinidad and Tobago	Viet Nam
	Turks and Caicos Islands	
	Uruguay	
	Venezuela, RB	
	Virgin Islands (US)	

Note: Chinese Tapei and Malta are not included in the aggregates for all indicators. Groups for Asian regions correspond to those used by the Asian Development Bank.

Figure 1.1. Growth of GDP in seven world regions, 1980-2010

In constant 2000 US dollars

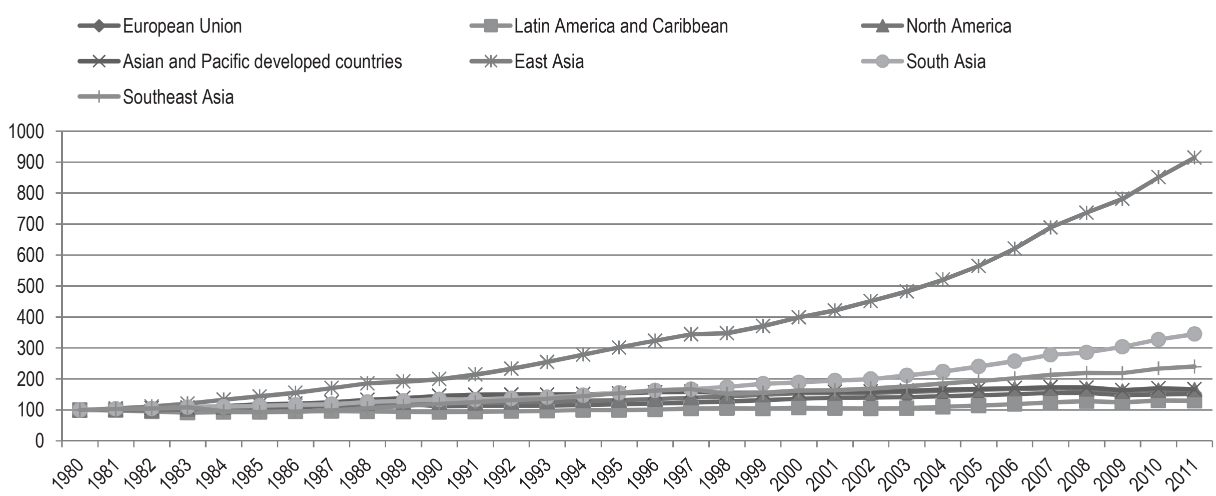


Note: Missing data are not estimated. Myanmar, the Cayman Islands, Turks and Caicos, the Virgin Islands are not included due to data availability.

Source: World Bank.

Figure 1.2. Growth of GDP per capita in seven world regions, 1980-2010

In constant 2000 US dollars



Note: Missing data are not estimated. Myanmar, the Cayman Islands, Turks and Caicos, and the Virgin Islands are not included due to data availability.

Source: World Bank.

A number of factors underpinned and supported the industrial development of this pioneering group of countries, among them high domestic savings and foreign demand for their export goods, notably from the undisputed engine of the world economy, the United States. These countries' strategies had similarities to but also differences from Japan's as they also relied on foreign direct investment (FDI) to support their early industrialisation phase and the transition from resource-based production to manufacturing. Like external demand, FDI came primarily from the United States. The NIEs' openness to FDI made it possible for multinational enterprises (MNEs) to obtain low labour costs as they extended their global assembly operations. During the take-off of the four Tigers, the economic potential of China and substantial parts of Southeast Asia was still dormant, and no one seriously expected China to become the world's second economy within a third of a century and perhaps the dominant economic power in the not so distant future (Subramanian, 2011). This meant, among other things, that competition on product markets but also for attracting FDI was limited. In sum, the geopolitical environment and institutional factors such as the international trade regime of the time worked in favour of the decidedly market-based NIEs.

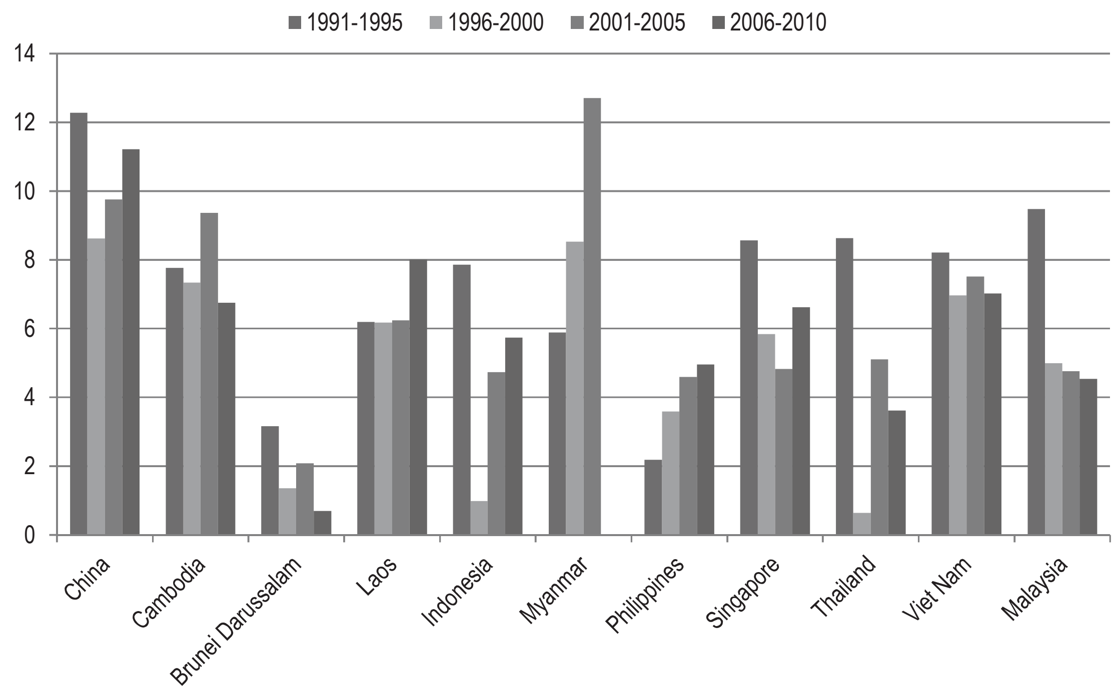
Naturally, the rapid and successful economic development of the Asian Tigers was closely observed and in some respects emulated by other countries across the region and beyond. In due course, four countries with populations much larger than those of the four pioneering NIEs emerged as a second generation of Asian Tigers: Indonesia, Malaysia, Thailand and, to a lesser degree, the Philippines. Unlike the four pioneering Tigers by and large, the second-generation Southeast Asian Tigers were heavily resource-based with little prior industrialisation. They adopted – in broad terms – the industrialisation and export-led growth model of their forerunners, with manufacturing as an engine of growth and development. More recently, as a result of their reforms, countries such as Viet Nam, Cambodia, Laos and Myanmar have become increasingly integrated in the regional and global economy. Some have grown at rates that put them ahead of the more mature Tigers. In terms of levels of income and productivity as well as skills, industrial capabilities and technology, they still have a long way to go to catch up with the region's more advanced middle-income economies.

The successful Tiger economies made considerable efforts to achieve structural change by developing their infrastructure and extending and improving their human resource base in order to upgrade their industrial activities and raise productivity. They also implemented to varying degrees more targeted forms of "industrial policy". The whole process – in itself a large-scale innovative experiment – of transition to an industrialised economy producing for export markets required and fostered the acquisition of substantial industrial capabilities, both technological and managerial.

Yet, innovation capabilities need to be increased very significantly to meet the challenges of a profoundly changed, and changing, environment. One important change is the rise of China, which has transformed – and keeps transforming – the region. While it offers important opportunities for the countries of Southeast Asia it also challenges them in different ways. Middle-income countries in Southeast Asia, for example, have to respond to more vigorous competitive pressure from China on the one hand, and from the region's low-wage countries on the other.

Moreover, the region as a whole, and notably the middle-income economies of the second generation of Asian Tigers such as Thailand, Malaysia and Indonesia, has not recovered the growth rates that preceded the East Asian financial crisis. Two large economies, Indonesia and Thailand, saw growth decelerate sharply in the wake of the crisis (Figure 1.3). While growth performance improved in most countries in the first half of the 2000s, many have not regained the levels of growth they enjoyed prior to the crisis. Low-income economies such as Myanmar, Cambodia and Viet Nam, which were less tightly integrated in the international economy and were not severely affected by the Asian crisis, grew strongly during this period. But growth for Southeast Asia as a whole has not yet fully recovered from the 1997-98 crisis. The average rate of growth in the second half of the 2000s, a period of turbulence in major parts of the world economy but which Southeast Asia weathered well, was 2 percentage points below that of the first half of the 1990s (APO, 2012).

Figure 1.3. Average annual growth rate of GDP, 1991-2010



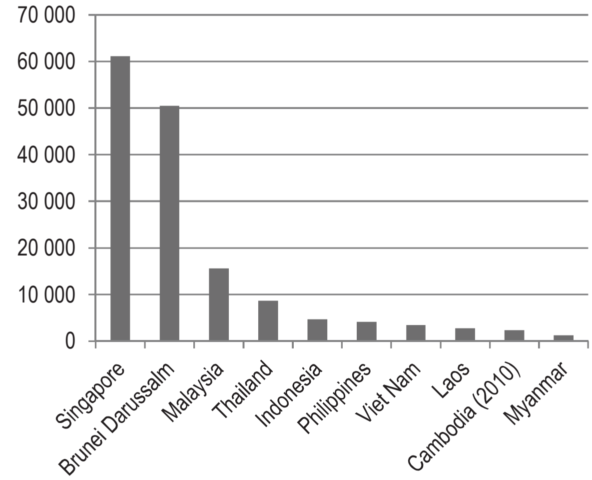
Source: World Bank Databank, 2012.

1.1.2. Current levels of economic performance

The rather diverse development trajectories of Southeast Asian economies and societies are reflected in large differences in gross national income (GNI) per capita. Singapore, the region's most important logistics hub, and oil-rich Brunei Darussalam are the two high-income countries (USD 12 256 or more). Among the higher-middle-income countries (USD 3 976-12 275), Malaysia is well ahead of Thailand. Indonesia, the Philippines, Viet Nam and Laos are in the lower-middle-income category (USD 1 006-3 999). Cambodia and Myanmar are low-income countries (USD 1 005 or less). In terms of gross national product (GDP) per capita, Singapore and Brunei Darussalam are well above the OECD average, and would have a place among the leaders (Figure 1.4). Malaysia follows well behind but is ahead of Thailand, which is followed by Indonesia, the Philippines and Viet Nam and Laos, Cambodia and Myanmar.

Figure 1.4. GDP per capita, 2011 or latest available year

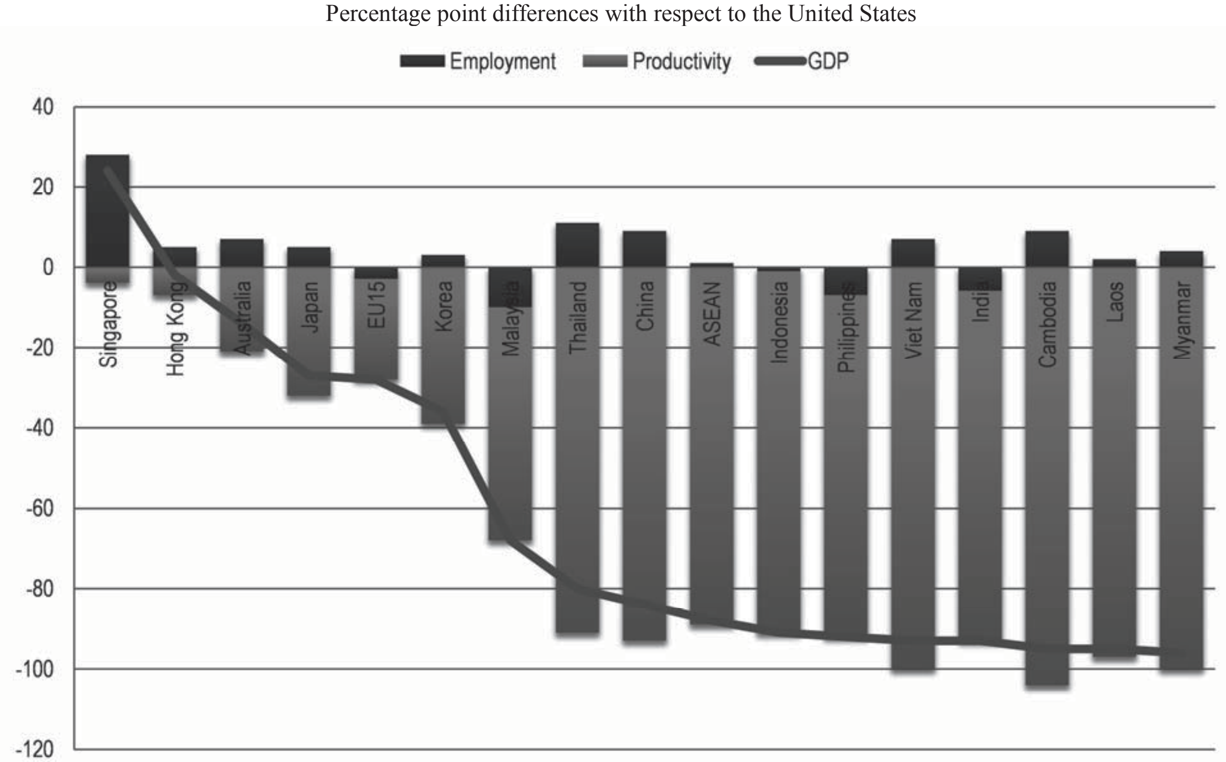
PPP, current international dollars



Note: Estimate for Myanmar.
Source: World Bank.

Figure 1.5. Labour productivity and employment gap relative to the United States, 2010

Percentage point differences with respect to the United States



Note: Breakdown of per capita GDP gap at constant market prices, using 2005 PPPs.

Source: APO (2012) based on official national accounts, including adjustments.

Box 1.1. Labour productivity

Labour productivity shows the profile over time of how productively labour is used to generate gross output. Changes in labour productivity reflect the joint influence of changes in capital and intermediate inputs, as well as technical and organisational changes and changes in efficiency within and between firms, the influence of economies of scale, varying degrees of capacity utilisation, and measurement errors. Labour productivity reflects how efficiently labour is combined with other factors of production, how many of these other inputs are available per worker and how rapidly embodied and disembodied technical change proceeds. According to the definitions of output and labour input, labour productivity can be measured in terms of GDP per working hour or per worker.

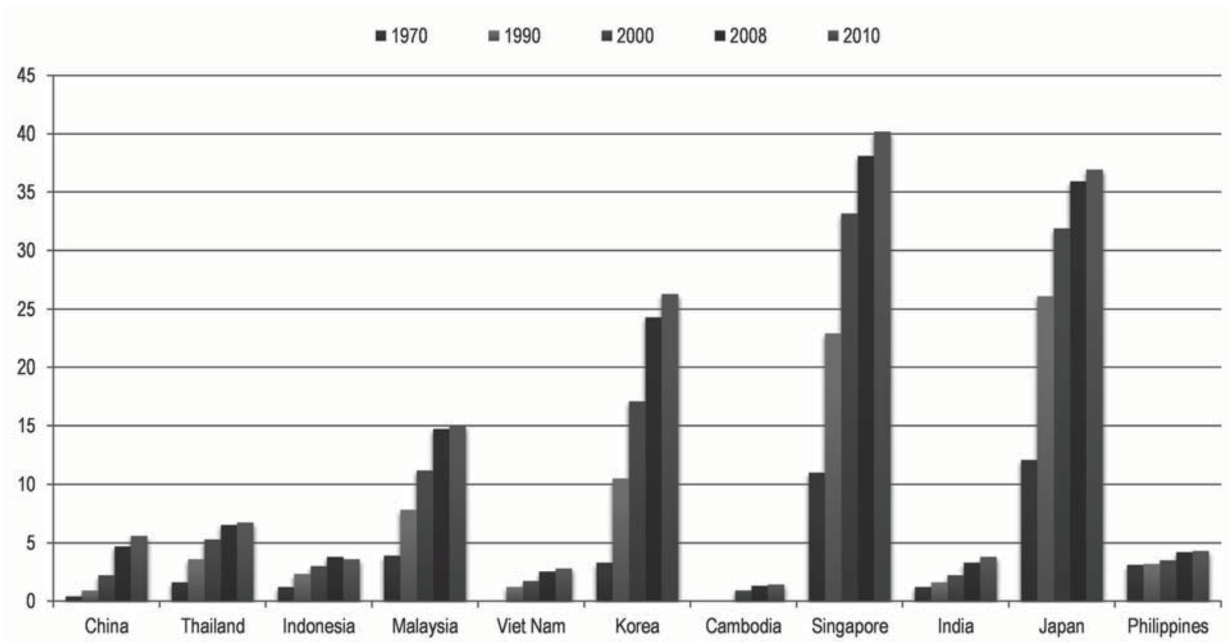
Source: OECD (2001).

It is worth taking a closer look at the income gap that separates the majority of Southeast Asian countries from the advanced economies. To do so it is standard practice to break down the difference in GDP per capita between two economies into the gap in labour productivity (for a definition see Box 1.1) and the gap in employment (or labour utilisation). The gap in GDP per capita of Southeast Asian economies compared to the United States can be attributed entirely to lagging labour productivity (Figure 1.5). The same holds true, though to a lesser extent, in comparison to Japan or the European Union. The labour productivity gap is also the main factor behind lagging GDP per capita in China and India and the much smaller gap that separates Korea from the United States. Among Southeast Asian countries Singapore is the great exception. Labour productivity in Malaysia, and to a lesser extent Thailand, compares favourably to the other Southeast Asian economies.

An increase in GDP per capita can be achieved by increasing the employment rate (labour utilisation) in various ways, *e.g.* by reducing unemployment, by increasing labour productivity or by a combination of the two. Once an economy achieves high levels of labour utilisation, the only way to increase GDP per capita is to boost labour productivity.[2] Changes in labour productivity may result from changes in capital intensity, labour quality or total factor productivity (TFP) (Hanel, 2008). In the short term they are also influenced by fluctuations in the level of economic activity. A powerful – and in the long term the most powerful – driver of labour productivity growth is innovation of various types, *e.g.* process or product innovations, technological innovations or non-technological innovations (often in combination).

As the above breakdown of per capita GDP gap suggests, levels of labour productivity are still modest in most Southeast Asian economies. Singapore is the outstanding exception; it has become a productivity leader among Asian nations, outperforming Japan and with an edge over the dynamic Korean economy (Figure 1.6). Malaysia has also made significant progress in the past decades; it holds a middling position between the regional leaders and the majority of Southeast Asian economies. Among the region’s larger economies, Thailand has also progressed but at a rather slow pace, while productivity levels in the Philippines, Indonesia, Viet Nam and Cambodia are still low in comparison.

Figure 1.6. Levels of labour productivity per hour, 1970-2010



Note: GDP at constant basic prices per hour, using 2005 PPPs, reference year 2010, USD.

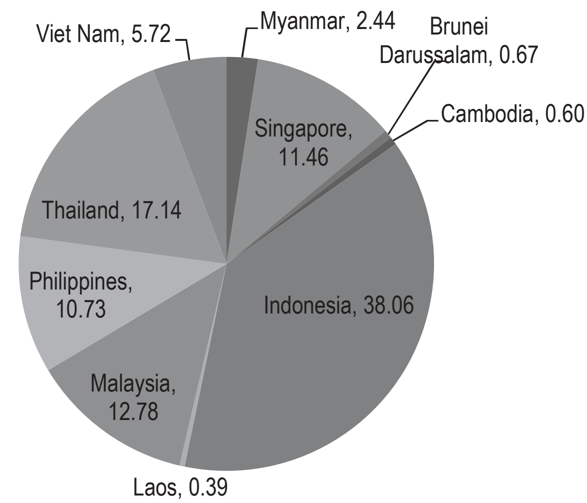
Source: APO (2012).

In a more dynamic perspective, labour productivity growth can be broken down into the effects of capital deepening (an increase in capital intensity, measured by capital input per hour worked) and TFP growth. Experience suggests that rapid capital deepening tends to be characteristic of the earlier phases of industrial development. Leading countries in the East Asian region such as Japan and Singapore recorded fast capital deepening in the 1970s and 1980s; more recently this has been the case in emerging economies such as Viet Nam. Over 1970-2010, capital deepening contributed some 50% or more to labour productivity growth, with considerable volatility across countries and over time. During 2000-10 TFP growth was the dominant factor in labour productivity growth in Singapore and Malaysia (APO, 2012, p. 91).

1.1.3. A diverse region

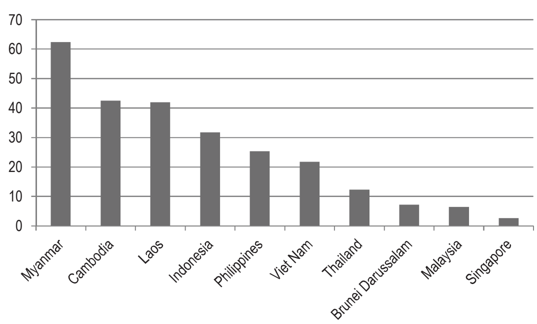
Southeast Asia presents not only an impressive dynamism but also a rich history and great diversity (*e.g.* Owen, 2005). One of the most obvious differentiators is the size of the country or the economy. The size of a national economy has implications for the scale and scope of the domestic market and may therefore condition a country's economic development through its effect on such economic variables as the size distribution of firms, their industrial specialisation and export orientation. The region consists of relatively small countries in terms of surface or population such as Singapore, Brunei Darussalam or Laos, but also larger ones such as Indonesia, Viet Nam and the Philippines. Indonesia has by far the region's largest economy and most populous country (with a share of 38.1% of ASEAN GDP, see Figure 1.7), followed by Thailand (17.1%), Malaysia (12.8%), Singapore (11.5%), the Philippines (10.7%) and Viet Nam (5.7%). Myanmar (2.4%). Cambodia, Laos and Brunei Darussalam have a combined share of 1.7%.

Figure 1.7. Percentage share in ASEAN GDP by country, 2010



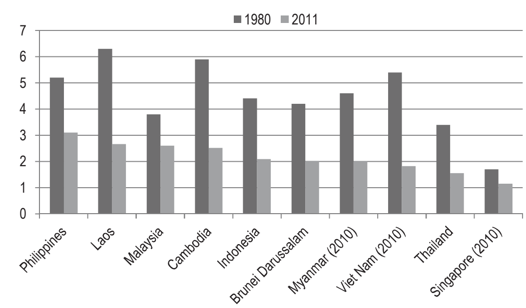
Source: World Bank and IMF.

Figure 1.8. Mortality rate (under 5 years) per 1 000 live births, 2011



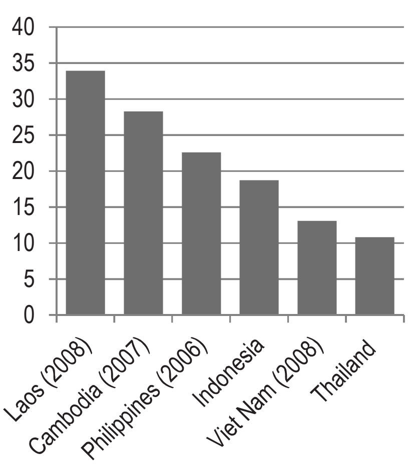
Source: World Bank.

Figure 1.9. Fertility rates, 1980 and 2011



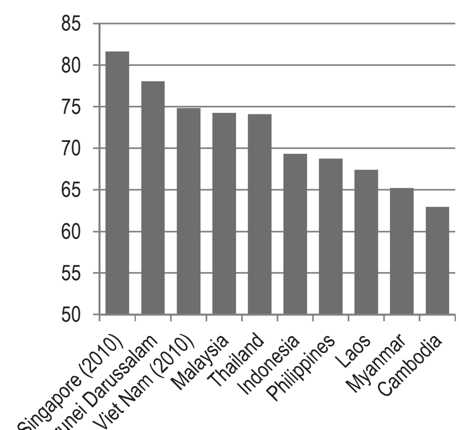
Source: World Bank.

Figure 1.10. Percentage of population below the income poverty line (PPP $1.25 per day), 2009 or latest available



Source: UNDP (2011).

Figure 1.11. Life expectancy at birth, total (years), 2011

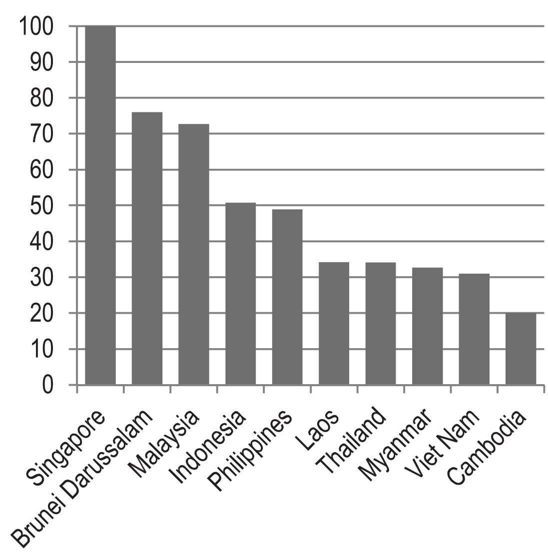


Source: World Bank.

Country-specific development challenges can significantly affect the scope of S&T policy. Headline economic measures such as GDP or GDP per capita sometimes fail to convey important aspects of a country's economic development. Foremost among an extended set of development indicators is the distribution of gains from income increases within countries as manifested in such measures as human health and poverty levels. In terms of health, Southeast Asia has made huge strides in recent decades, for the most part corresponding to increases in GDP per capita. Indeed, average life expectancy in the region has converged to levels close to those of developed countries and most countries in the region are relatively close to the average (Figure 1.8). There are however exceptions. For instance, Indonesia has a higher infant mortality rate than suggested by its GDP per capita (Figure 1.9). On the contrary, Viet Nam has a higher life expectancy than suggested by its GDP per capita (Figure 1.8). The percentage of the population below the income poverty line confirms this pattern. Viet Nam has a lower poverty level than wealthier countries such as the Philippines or even Indonesia (Figure 1.10).

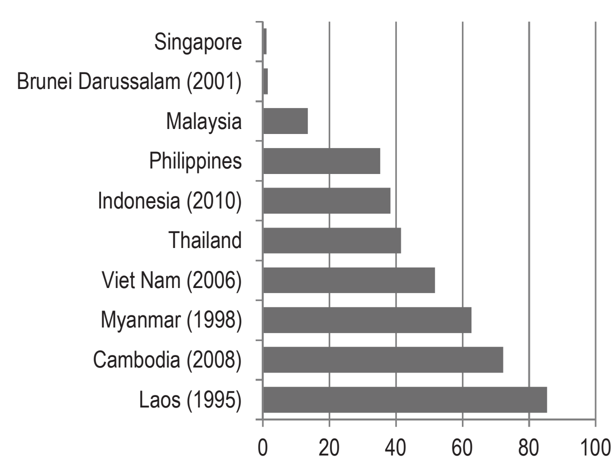
An economically sustainable rate of population growth is another development challenge. Fertility rates have important implications for a country's growth dynamics. High fertility rates imply a potentially larger workforce but only have a net positive economic impact if economic growth outstrips population growth. This presupposes productivity improvements which in turn depend on human capital investment and the pace of technological change. While fertility rates dropped sharply in most countries from 1980 to 2011 (Figure 1.11), they do not correspond neatly to contemporary GDP per capita. The Philippines, whose GDP per capita is around the regional median, has the highest fertility rate in the region.

Figure 1.12. Percentage of urban population, 2011



Source: World Bank.

Figure 1.13. Employment in agriculture (% of total employment), 2009 or nearest year



Source: World Bank.

Urbanisation is an important part of the development history of many countries, as it is generally associated with pronounced productivity improvements. However, urbanisation implies costs in terms of crowding and congestion and this can create challenges for development. On the whole, wealthier countries tend to be more urbanised (Figure 1.12). The only exception is Thailand which has a higher level of GDP per capita than would be expected from its (low) degree of urbanisation which is close to that of Viet Nam and Laos. Structural change parallels the trend towards urbanisation and is often summarily described as a transfer of the workforce from agriculture to manufacturing (and from rural to urban areas). In terms of the share of employment in agriculture (Figure 1.13) the pattern is again mostly consistent with variation in GDP per capita. The only notable exceptions are Thailand and Myanmar which have respectively a higher and lower share than suggested by their GDP per capita.

1.1.4. Catching up

As a result of their economic development, most Southeast Asian countries look back at a successful history of rapid catch-up with the United States and other advanced economies over the past decades. Only Brunei Darussalam, a high-income country, and the Philippines, which started from a much lower initial income per capita, fell behind. As noted earlier, the Asian crisis was a serious setback and effectively extended the time and effort required to close the gap to leading high-income countries. The speed of the catch-up differed across Southeast Asian countries. Overall, nations with lower initial income levels tended to have higher average annual growth rates (Table 1.2). Cambodia (from 1998) which initially had a GDP per capita of less than 5% of the US level, caught up to the United States by an annual 3%. However, Singapore, which started from a much higher base, recorded stronger gains than large countries such as the Philippines and Indonesia.

Table 1.2. Catch-up with the United States, 1970-2010

Level and average annual growth rate of GDP at constant market prices, using 2005 PPPs

Initial GDP level to the United States	Annual rate of catch-up to the United States (C1) > 3%	(C2) 1% < - < 3%	(C3) 0% < - < 1%	(C4) < 0%
(L1) 60% <			Japan, EU15	**Brunei-Darussalam,** Bahrain, Kuwait, Qatar, Saudi Arabia, UAE, Australia
(L2) 20% < - < 60%	**Singapore**	Hong Kong, China; Oman		Iran
(L3) 5% < - < 20%	Chinese Taipei, Korea	**Malaysia**, Sri Lanka, **Thailand**	Mongolia	Fiji, **Philippines**
(L4) < 5%	**Cambodia**, China	India, **Indonesia**, **Laos**, **Myanmar, Viet Nam**	Bangladesh, Nepal, Pakistan	

Note: The annual catch-up rates are based on the difference in the growth of per capita GDP at constant prices between each country and the United States during 1970-2010. The starting years for some countries differ owing to data availability: Cambodia (1987), Laos (1984) and Nepal (1974).

Source: APO (2012).

Sources of growth

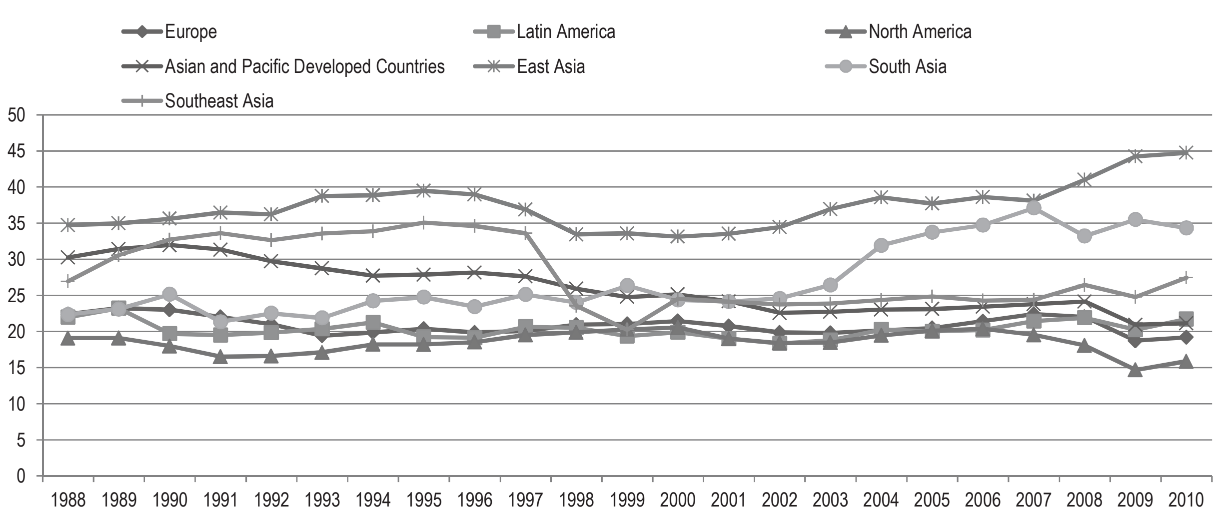
Economists have suggested different explanations for the rapid catch-up of Asian countries and in particular of East Asia's NIEs after the end of World War II (Page, 1994; Rodrik, 1995; Collins and Bosworth, 1996; Stiglitz, 1996; Nelson and Park, 1999). More recent studies have also covered Southeast Asian countries, India, and China (Bosworth and Collins, 2007; Park, 2010). Major sources of growth are the accumulation of physical – now often differentiated between IT and non-IT – capital and human capital (Krugman, 1994; Young, 1995; Senhadji, 2000; Lau and Park, 2003; Park, 2010); "multi-factor" or "total factor" productivity growth, which reflects to some degree technological change and innovation, also plays a significant role in certain periods and countries, as will be shown below.

Accumulation of physical and human capital

The share of gross capital formation in GDP has remained much higher in (fast-growing) East Asia than in North America and the European Union (Figure 1.14). It has also increased sharply in South Asia since the beginning of the 2000s, and in 2010 amounted to nearly 35%, compared to approximately 45% in East Asia. The pattern of gross capital formation as a percentage of GDP in Southeast Asia differs from that of all other regions under consideration. Its share increased rapidly from the mid-1980s, peaked in the mid-1990s at about 35%, decreased sharply in the wake of the Asian crisis and since 2001 has stabilised at a significantly lower level than that of the pre-crisis decade. There have been recent signs of recovery but at approximately 28% in 2010 Southeast Asia is still far from its high levels of gross capital formation. Developed countries in the Asian and Pacific region, Europe, and North America have lower ratios of capital formation to GDP and so does Latin America.

Figure 1.14. Gross capital formation in world regions, 1988-2010

As a percentage of GDP



Source: World Bank.

The growth of gross capital formation since 1981 has been especially strong in countries with a low initial level of output per capita such as China, Viet Nam and India. In contrast, the Philippines and Brazil have not succeeded in achieving high annual growth of gross capital formation, despite their relatively low initial level of output per capita. Their growth rates have nevertheless been higher than those of high-income countries such as Japan and Germany. Conversely, Singapore has continued to accumulate physical capital at a rapid pace despite relatively high initial output per capita. The trends in Southeast Asia indicate that as economies become richer and more capital-intensive it is more difficult to accumulate extra capital, partially owing to the need to replace obsolete capital. As discussed in more detail below, capital accumulation is an important factor in economic growth.

Education, and tertiary education in particular, is widely acknowledged as a key contributor to technological progress (Vandenbussche et al., 2006). Most countries with a low level of GDP per capita in 1981 appear to have increased the average years of tertiary schooling (Barro and Lee, 2010) faster than those with high standards of living at the beginning of the period. Among Southeast Asian countries for which data are available, this is the case of Viet Nam, Malaysia and Indonesia. Among the Southeast Asian countries with low per capita output at the beginning of the period, the Philippines and Laos have extended tertiary education at a slower pace than the others. In contrast, Singapore has extended tertiary education rapidly despite its relatively high initial level of output per capita. The rapid expansion of tertiary education in these countries could have a strong impact on the ability to innovate and the level of productivity attained. Higher levels of tertiary education are a prerequisite for conducting R&D, which is important for product innovation, acquisition of technologies, engineering and design. However, a broad range of skills at different levels is also required to feed innovation in catching-up economies, as well as in advanced economies.

Growth accounting: the contribution of capital, labour and total factor productivity

According to a growth accounting exercise (see Box 1.2 for a definition) focused on Asian economies (APO, 2012), economic growth of Southeast Asian countries over the past four decades (1970-2010) can be mainly attributed to capital accumulation (Figure 1.15 and 1.16). The contribution of capital services ranges from 72% in Malaysia to 45% in Viet Nam. Output growth has been mainly driven by investment in non-IT capital. The contribution of non-IT capital exceeded 40% in most countries; in Singapore and the Philippines it was in the range of 60%, and in Malaysia it reached 67%. In contrast, IT capital contributed 9% in Singapore and 6% in the Philippines, followed by Malaysia and Thailand with 5%, Viet Nam 4% (1986-2010) and just 2% in Indonesia. (By comparison, IT capital contributed 16% in the United States and 12% in Japan). Labour input growth played a very important role as well, contributing about 30% to economic growth in Southeast Asian countries and even 40% in the Philippines. In contrast, labour contributed only 12% in China, 15% in Korea and was negative in Japan at -2%. TFP growth also made a significant contribution to Southeast Asian output growth. During 1970–2010 TFP growth accounted for no less than 31% of economic growth in Thailand and for 26% in Viet Nam, 15% in Indonesia, 8% both in Singapore and Malaysia, but was negative in the Philippines. Although TFP growth is an important driver of economic growth in Southeast Asian countries, its contribution to output growth is much lower than in China (37%).

Box 1.2. Growth accounting and total factor productivity (TFP)

Growth accounting

From a growth accounting perspective, the growth of output can be broken down into changes in the amount of capital and labour and changes in TFP. In more recent growth accounting studies, capital is separated into IT capital and non-IT capital to reflect the increasing impact of IT – a "general purpose technology" permeating modern economies – on productivity in a wide range of sectors, including services. Labour input is another key production factor (important for estimates of TFP), which can be measured by actual hours worked or the number of workers.

Total factor productivity

TFP shows how productively combined inputs are used to generate gross output and measures the efficiency of inputs used in production. It is a broader measure of productivity efficiency than labour productivity since it takes all input categories into consideration. It is the part of growth that cannot be explained by the accumulation of the traditional inputs of physical capital and labour. TFP growth is measured by deducting from output growth the growth of labour and capital inputs. The growth rate of both inputs is weighted with their share in total costs.

TFP growth reflects the impact of technological progress and innovation more generally. It consists of two components, technological progress (TP) and technical efficiency change (TEC). TP is due to technological innovation, technology diffusion and technology introduction. TEC derives from improvements in the management of production processes and resource allocation, organisational change and scale efficiency. For example, better management enables a firm to be more productive with the same level of inputs and technology, and more flexible labour markets result in a more efficient allocation of labour across firms and industries.

Source: OECD (2001), Hanel (2008).

Figure 1.15. Share of economic growth, 1970-2010

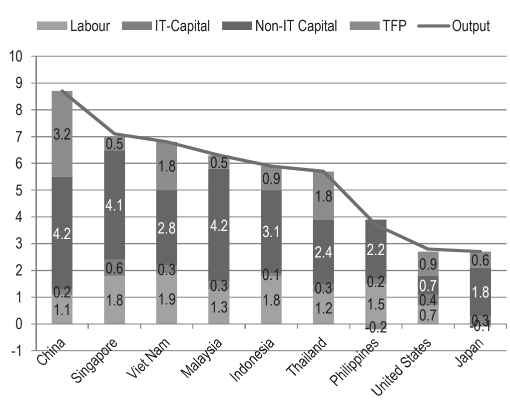
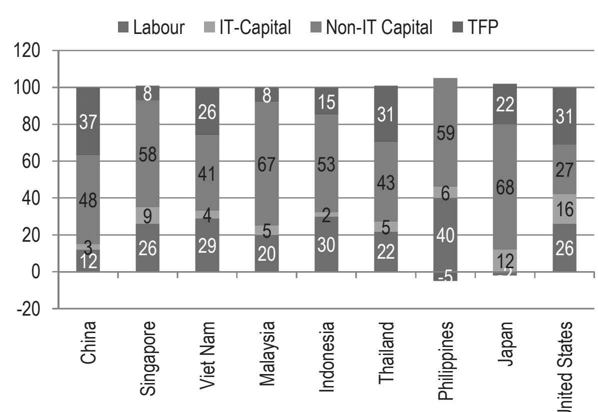


Figure 1.16. Contribution to economic growth, 1970-2010



Source: APO (2012).

The driving forces of economic growth are shifting over time, and so are the relative contributions of various types of capital and TFP. The accumulation of (physical) capital was the dominant factor from 1970 to 1985 and contributed from two-thirds to three-quarters of growth. This suggested that accumulation of physical capital was necessary to allow Southeast Asian countries to embark on a catching-up trajectory. The Asian Productivity Organization finds that in "the subsequent periods, the contribution of capital input became progressively smaller, falling to a share of below 50% on average, while the contribution of TFP became progressively more significant, rising to a share of above 40% on average in the 2000s" (APO, 2012, p. 79). Another important trend is the rise in the contribution of IT capital to the physical capital category. During 1970–85, IT capital accounted for less than 5% of economic growth in Southeast Asian countries. By the 2000s, its share exceeded 5% in most countries, with the notable exception of Indonesia (2%), the region's largest economy. Between 1985–2000 and 2000–10, the contribution of IT capital more than doubled in Viet Nam and Malaysia from 3% to 7% and from 5% to 14%, respectively. Accumulation of IT capital is the basis for potentially productivity-enhancing innovation in a wide range of sectors and industries.[3]

Over the four decades from 1970 to 2010, almost all of the Southeast Asian economies except the Philippines experienced growth of TFP (APO, 2012). In Thailand and Viet Nam TFP growth was 1.8%, twice that of Indonesia (and the United States for comparison), but much lower than that of China (3.2%). Growth of TFP in Singapore and Malaysia was weak by comparison at an average rate of 0.5%, and it declined in the Philippines by -0.2% over the period. In the wake of the Asian crisis TFP growth fell sharply in all Southeast Asian countries except the Philippines over 1995-2000 (APO, 2012) and turned negative in Indonesia, Malaysia and Thailand. Compared to the first half of the 1990s, these countries experienced a drop of 6.9, 4.1 and 4.4 percentage points, respectively. During 2000-05, TFP growth picked up in Southeast Asia and maintained an upward trend in the second half of the 2000s in Singapore, Malaysia and the Philippines. China recorded a sharp drop but TFP growth remained comparatively high even during the second half of the 1990s and has since picked up.

As mentioned, the source of Southeast Asia's countries' economic growth is shifting from accumulation of physical capital to growth of TFP (and within physical capital from non-IT to IT capital). This is consistent with the region's transition from a low-income, capital-deficient region to an increasingly middle-income, capital-abundant region and the advent of diminishing marginal returns to capital (Park and Park, 2010). Under these circumstances, technological change and more sophisticated and more demanding forms of innovation are likely to become more prominent. Projections of TFP growth for a number of Asian countries in the coming decades indicate that it is likely to play a crucial role for growth in countries such as Indonesia, Malaysia, Philippines and Viet Nam (Park, 2010).

Catching up is of course not in any sense inevitable. It requires lagging countries to take measures to facilitate the convergence towards the levels of high(er)-income economies. In addition to favouring the accumulation of traditional inputs such as physical capital and labour (which are in many ways carriers of and prerequisites for innovation) these measures should also support the formation of innovation capabilities to make good use of existing technology and gradually contribute to technological progress and to successful non-technological innovation.

1.2. Trade in Southeast Asia

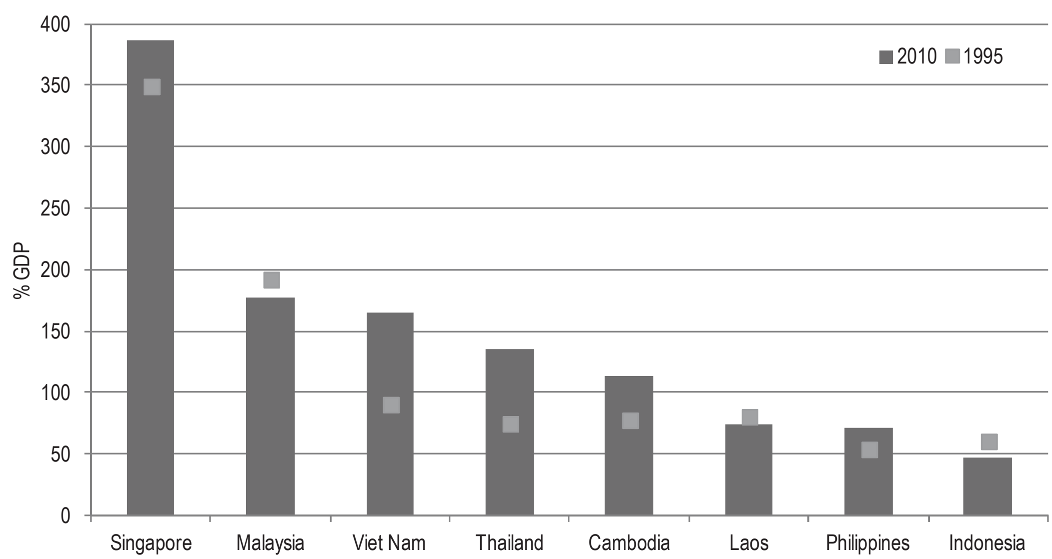
This section outlines the trade performance of Southeast Asian countries and focuses on recent trends in exports. It aims to provide information on the evolving patterns of trade from the perspective of innovation and the reasons for the changes observed, such as the increasing importance of global value chains (GVCs). The first part briefly describes the export structure of ASEAN countries. The second part reviews the evolution of world export and import market shares broken down by type of activity and technological intensity. The third part examines Southeast Asia's role in GVCs.

1.2.1. The export structure of Southeast Asian countries

External trade has been an important driver of economic growth in the countries of the Association of Southeast Asian Nations (ASEAN). In spite of the setbacks in the wake of the 1997-98 Asian financial crisis, ASEAN economies have maintained a comparatively high degree of trade openness. . Singapore's combined exports and imports are nearly four times the size of its GDP. Trade data for Singapore should be interptreted with caution, however, as it is the region's logistics hub and a large part of its trade involves goods that are imported and subsequently re-exported. Even disregarding Singapore, the value of trade flows in most of the region's countries is greater than their GDP (Figure 1.17). Trade has grown notably as a fraction of national output since 1995 in Viet Nam and Thailand, but the pattern across the region has varied over time.

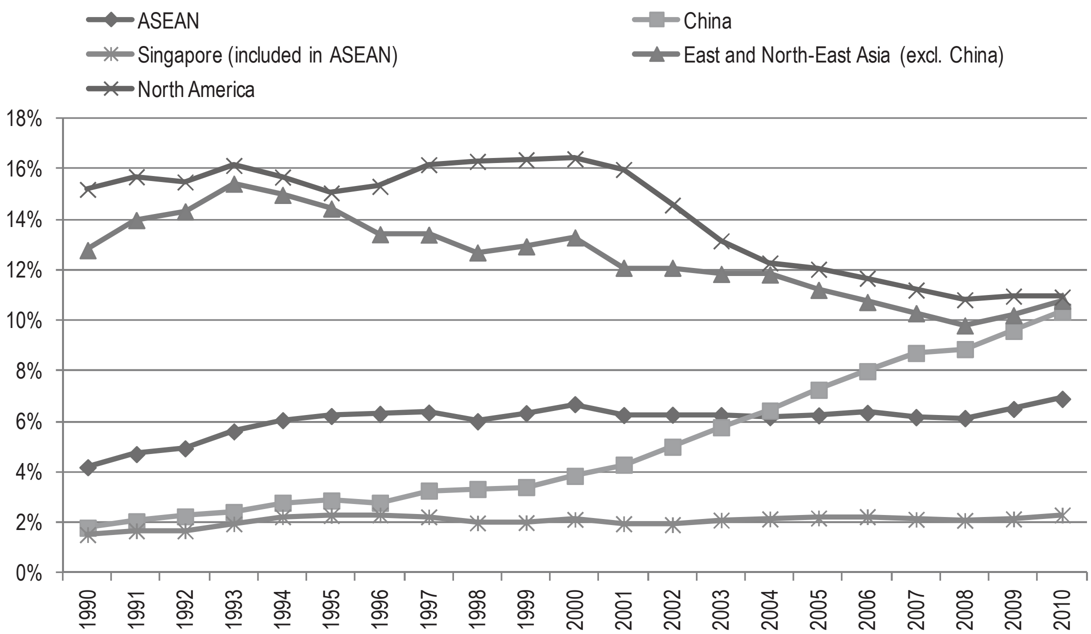
Within the ASEAN region, imports and exports are relatively concentrated. Singapore accounts for around a third of collective trade and Indonesia, Malaysia and Thailand account jointly for about half (UNESCAP, 2011). Singapore was the ninth largest global exporter and importer in 2009. Viet Nam's share of ASEAN trade rose from around 2% at the start of the 1990s to nearly 8% in 2010. Cambodia has experienced the largest proportional increases in trade volumes over the past 20 years, albeit from a very low base.

Figure 1.17. Trade openness (exports and imports as % of GDP), 1995-2010



Source: World Bank World Development Indicators.

Figure 1.18. Share of world exports, 1990-2010

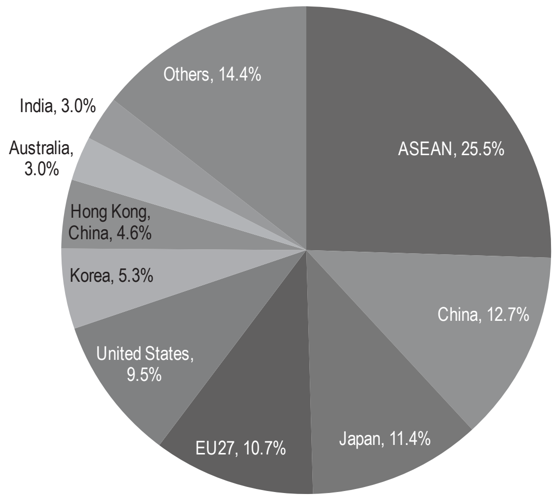


Source: UNESCAP database, 2011.

Southeast Asia as a whole accounted for 6.9% of world exports in 2010. In spite of increases in the early 1990s and in the two most recent years for which data are available, the region's share of world exports was largely constant between 1995 and 2009 at just over 6% (Figure 1.18). The largest ASEAN exporter, Singapore, saw its share of world exports rise in the years preceding the Asian financial crisis but then flatten. The major trend over the period has been the rise of the People's Republic of China (from around 2% of global exports in 1991 to over 10% in 2010) accompanied by a corresponding fall in the share of world exports in the developed regions, including North America. Chinese exports overtook those of Southeast Asia in 2004.

In terms of trading partners, imports and exports between ASEAN countries represented about a quarter of the total in 2010 (Figure 1.19). China, the EU, Japan and the United States all accounted for similar proportions of ASEAN trade, ranging from 9.5% to 12.7% of the total. Trade with other Asian (Korea, India) and Pacific (Australia) countries was also relatively important. In recent years, ASEAN exports to Asian and Pacific destinations have grown fastest (China, India, Australia and New Zealand, intra-ASEAN and Korea), while exports to the EU, Japan and the United States have grown at a slower pace (Petri, 2009). This gap increased during the global economic downturn as consumption and investment in Western economies weakened (OECD, 2010). Over the last decade, the share of exports to the euro zone and the United States fell from 32% in 2000 to around 20% in 2010 (UNESCAP, 2012). However, this has been partly due to the rising share of intermediate goods exports as regional supply chains deepen (see below in this section).

Figure 1.19. Trade with main partners as a share of total ASEAN trade, 2010



Notes: Some figures may not sum to totals due to rounding errors. All figures are preliminary; data for Cambodia and Laos are not available.

Source: ASEAN Merchandise Trade Statistics Database (compiled/computed from data submissions, publications and/or websites of ASEAN members' national ASEAN Free Trade Area (AFTA) units, national statistics offices, customs departments/agencies, and central banks).

In terms of the structure of total ASEAN trade, electronics is the largest category of both exports and imports. It accounted for USD 400 billion and around 20% of the region's total trade in 2010. Electronics is followed by fuels and related chemical products and by machinery in manufacturing, both of which accounted for around 13% of total trade (Table 1.3). Trade is heavily concentrated in these three categories. The next largest group represents only 3% of total imports and exports. The prominence of electronics and manufacturing parts indicates that trade is generally concentrated in relatively sophisticated goods. Southeast Asian countries have a concentration of exports in elements of machinery and equipment that exceeds the world average.

In 2000, electrical machinery accounted for 33% of ASEAN-6[4] exports, manufacturing of machinery and parts for 21%, and fuels for around 10%. Although not fully comparable with data for all ASEAN countries, this suggests that their exports may have become less concentrated over time.

While ASEAN economies share some features, their export structures show large differences (Figure 1.20). Electronics and ICT equipment are important export categories for Malaysia, the Philippines (where they account for 60% of exports), Singapore and Thailand. However, they account for a much smaller share of the merchandise exports of Indonesia and Viet Nam. Textiles and apparel, a relatively low-technology labour-intensive manufacture, is a sizeable export category for Viet Nam and represents nearly 20% of merchandise exports.[5] Agricultural products and raw materials account for a larger than average share of exports in Indonesia (see the country profile in Part II for more detail at the national level).

Table 1.3. Top ten ASEAN commodity groups, 2010

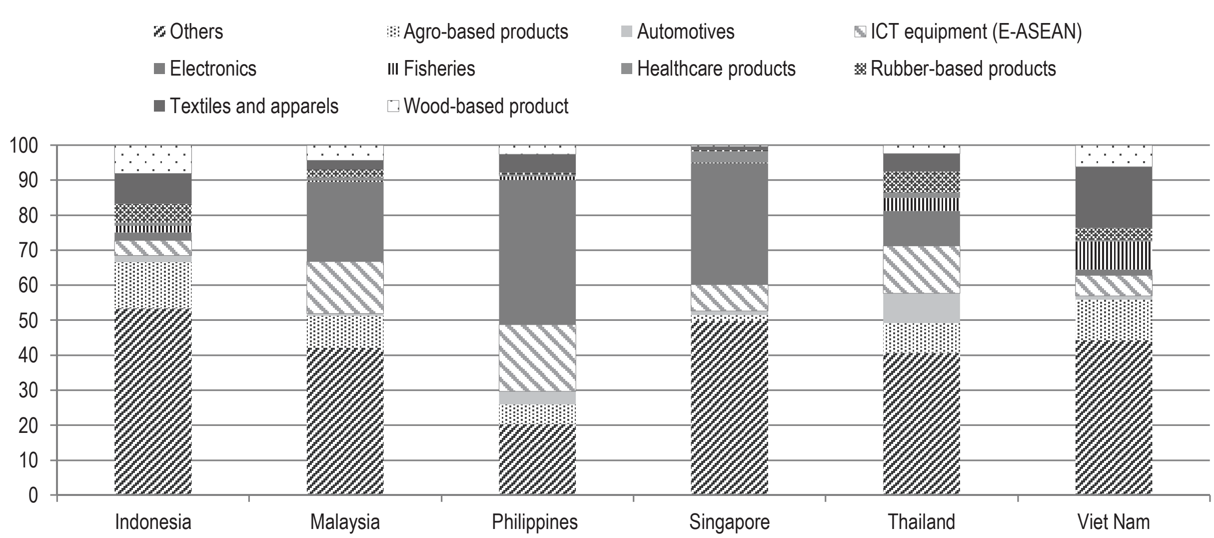
Commodity group[1]		Share of total ASEAN trade (%)		
2-digit HS code	Description	Exports	Imports	Total trade
85	Electric machinery, equipment and parts; sound equipment; television equipment	19.4	19.9	19.6
27	Mineral fuels, mineral oils & products of their distillation; bitumin substances; mineral wax	14.0	12.7	13.4
84	Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof	11.8	13.8	12.8
87	Vehicles, (not railway, tramway, rolling stock); parts and accessories	2.7	3.8	3.2
39	Plastics and articles thereof	2.7	2.9	2.8
40	Rubber and articles thereof	3.4	1.8	2.6
71	Natural or cultured pearls, precious or semiprecious stones, precious metals and metals clad therewith and articles thereof; imitation jewelry; coin	2.2	2.3	2.2
29	Organic chemicals	2.2	1.9	2.0
90	Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments/apparatus; parts & accessories	1.9	2.1	2.0
15	Animal or vegetable fats and oils and their clevage products; prepared edible fats; animal or vegetable waxes	3.2	0.4	1.9
	Top 10 commodities	63.4	61.6	62.6
Others[2]		36.6	38.4	37.4
Total		100.0	100.0	100.0

1. Based on the share of the 2-digit classification (section) of the Harmonized System (HS) in total trade.

2. Includes products with unspecified codes and/or products that could not be explicitly classified according to the current HS. Some figures may not sum to totals due to rounding errors.

Source: ASEAN Trade Database (compiled from data submission and/or websites of ASEAN members' national statistical offices and other relevant government agencies).

Figure 1.20. Merchandise export shares of six ASEAN countries, 2006-08



Note: Except for Viet Nam in which export shares refer to 2006-07 average.

Source: OECD Southeast Asia Economic Outlook 2010, based on UN Comtrade database.

There have been some large shifts in the export shares of leading industries in the Southeast Asian region since 1995, in contrast with the relative stability of the composition of world merchandise exports over the same period (OECD, 2011b). Export shares of labour-intensive products such as textiles, leather and footwear have generally declined in the Southeast Asian region (especially in Indonesia and the Philippines), with the notable exception of Viet Nam. Other large changes have been observed in Thailand (a fall in the share of food products), in Viet Nam (a strong fall in agriculture, forestry and fishing) and in Singapore (a large increase in the share of chemicals and chemical products compensated for by a fall in the share of office, accounting and computing machinery). Some of these trends are relevant to the discussion of global value chains and specialisation later in this chapter.

1.2.2. Revealed comparative advantage and technology intensity across industries

An approach widely used to examine differences in export specialisation focuses on comparative advantage. This concept underlies economic explanations for trade between nations and industries and relates to the relative opportunity costs of producing goods and services. In practice, comparative advantage for a particular country in a particular commodity or industry is measured by an index based on observed trade patterns that is known as revealed comparative advantage (RCA).[6]

Figure 1.21 plots the RCA index of Southeast Asian countries in four industry classes according to their technological intensity. This breakdown is an attempt to capture the level of technology involved in industrial export sectors (defined by R&D intensity) and provides some evidence on possible trends in innovation content. However, some caution should be exercised as regards the categorisation of industries. The technological intensity categories are defined using data for OECD countries (see Annex 1.A1) and it is possible that in Southeast Asia the same industries have different patterns of R&D expenditure. Industrial activities which are classified as belonging to the high-technology sector in advanced countries often involve no or very little R&D in less advanced countries. For instance, Krugman (2008) reports on the vertical specialisation of Intel's manufacturing of semiconductors (a rather homogeneous product) and shows that high-technology fabrication is located in more advanced economies while assembly/test plants are exclusively located in emerging economies (including Malaysia and the Philippines). The activities are of a completely different nature, but the goods leaving the two types of factories are both classified as intermediate products in international trade statistics.

The most economically developed countries in the region, Singapore and Malaysia, have a comparative advantage in high-technology export industries. Thailand has a degree of specialisation in all industry classes similar to the world average, but with a (slightly) stronger specialisation in high technology on the one hand and low technology at the other – a pattern not dissimilar to China’s (Figure 1.21). Cambodia, Myanmar, Viet Nam, and to a lesser extent Indonesia, display a strong comparative advantage in low-technology export industries. Textiles and related industries are part of the explanation for this pattern, especially in Cambodia which has a strong comparative disadvantage in more technology-intensive industries. The Philippines has the largest RCA value in high-technology industries although, as throughout this discussion, caution is warranted owing to its strong specialisation in narrow segments of the electronics industry (as Figure 1.20 suggests).

Overall the pattern is one of considerable differences in technological specialisation in the ASEAN region's export sector. There is a group of countries (typically the region's most developed) whose exports are estimated to be relatively sophisticated alongside a group of countries specialised in low-technology industries.

1.2.3. Product quality and specialisation across product varieties

Empirical measures of product quality can shed further light on the underlying sophistication of Southeast Asian countries' trade and technological capabilities. A measure of the quality of traded goods is also helpful for understanding regional integration and specialisation. Unit values for example can be used to attempt to distinguish between imports and exports of different quality. For imports or exports unit values are defined as the nominal sales of products divided by a measure of quantity (*e.g.* kilograms). The highest-quality products are assumed to have the highest unit value (*i.e.* to be the most expensive per unit). [7] Throughout the supply chain, the more characteristics a good accumulates (these are not observed in most trade data), the higher its expected unit value.

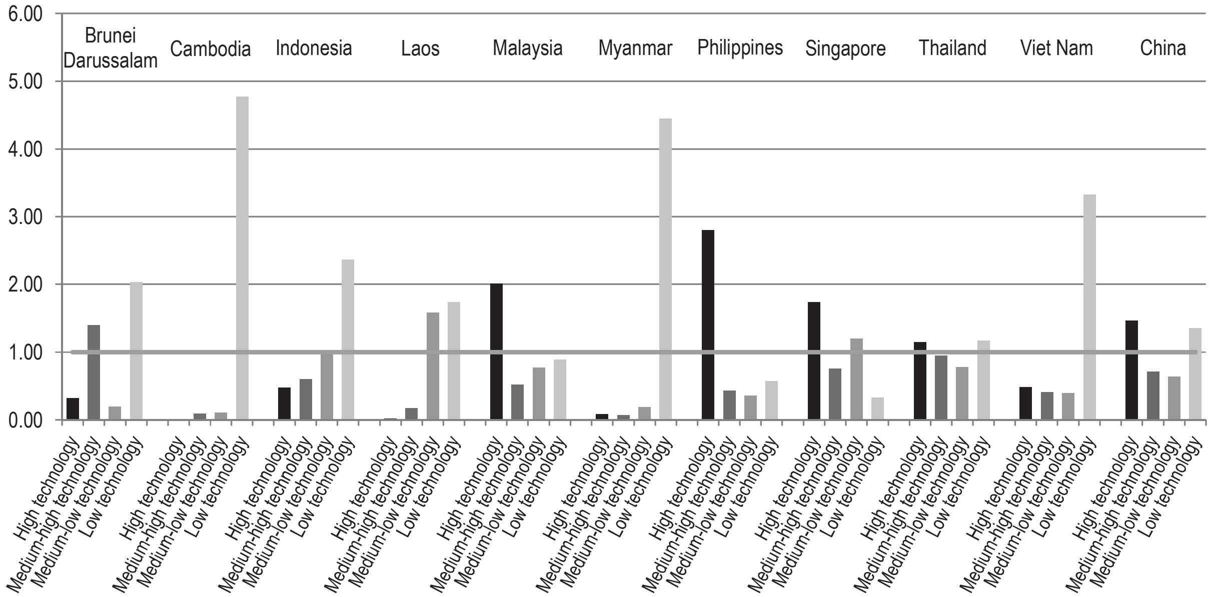
Figure 1.22 shows the median unit values of manufactured goods for Southeast Asian countries.[8] Unit values of manufactured exports increased in most countries between 1995 and 2010. Singapore's exports have a high unit value relative to the world average, an indication that it is specialised in exporting products of high quality. Several countries have increased their median unit values over the period and relative to the world average. However, those of Thailand, Laos and particularly Brunei Darussalam have declined.

In place of aggregate unit values, trade flows can be categorised in terms of low-, medium- and high-quality products (see Annex 1.A2 for a full description). Typically, the export structure of developed countries is more oriented towards higher-quality products (as higher costs prevent pure competition on price). For instance, OECD work shows that about half of the exports of the United States, Germany, France, the United Kingdom and Japan are in the high-quality range; the corresponding figures for emerging countries such as Brazil, China, India and South Africa vary between 20% and 30%. In consequence, emerging countries typically export relatively more lower-quality products than developed countries (OECD, 2011a).

Figure 1.23 summarises the estimated quality of Southeast Asia's exports in 2010 by technological intensity of industries. Singapore stands out with high-quality exports in the high-, medium-high- and low-technology industry sectors and has, like Malaysia, a low share of low-quality exports across industries. A diverse group of countries including Laos, Myanmar and Malaysia have very high shares of medium-quality exports in medium-low technology industries.[9] China has a relatively low proportion of high-quality exports (and a corresponding higher than average share of low/medium-quality exports), especially in technology-intensive industries. Its strong position in high-technology industries (such as computers, radio, TV and communications equipment, and electrical machinery) is still largely based on exports of lower-quality, lower-price products.

Overall, even when different types of industry are considered separately, estimates of the quality of Southeast Asian exports show significant diversity. Figure 1.23 also reveals some large, and potentially unexpected, differences in estimated export quality among industries within the same country. Generally speaking, with the exception of Singapore, there are fewer differences in the shares of low-technology industries.

Figure 1.21. International specialisation of exports of ASEAN countries and China, 2010



Notes:

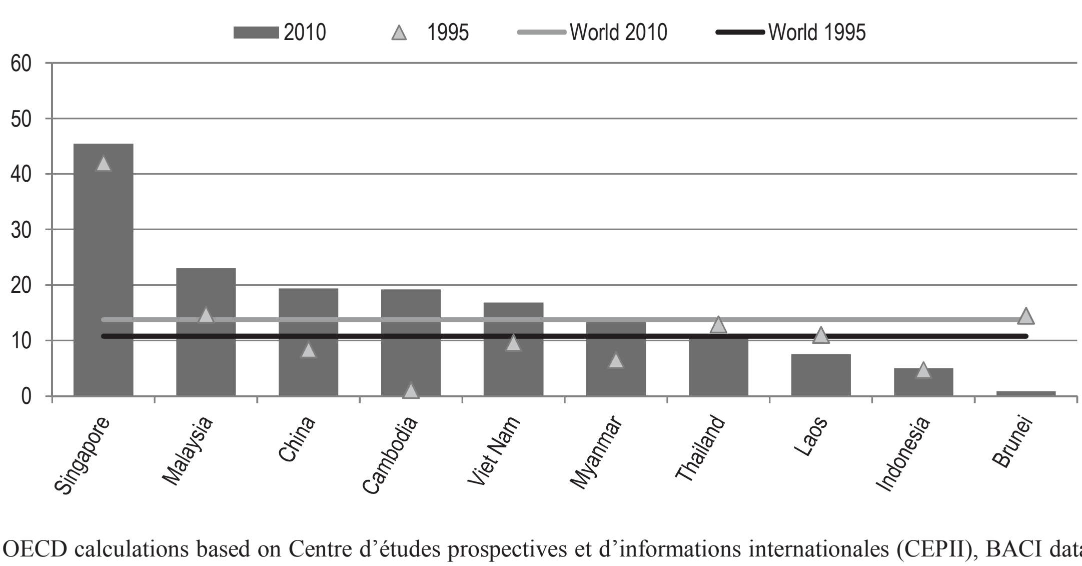
1) International specialisation is calculated using the traditional measure of revealed comparative advantage (RCA) on the basis of total exports at the industry level.

2) OECD methodological work classifies industries in four categories of technological intensity, based on indicators (direct as well as indirect) of technological intensity which reflect to some degree "technology-producer" or "technology-user" aspects. See Annex 1.A1 for a detailed list of industries and their classification.

Source: OECD calculations, based on CEPII, BACI database.

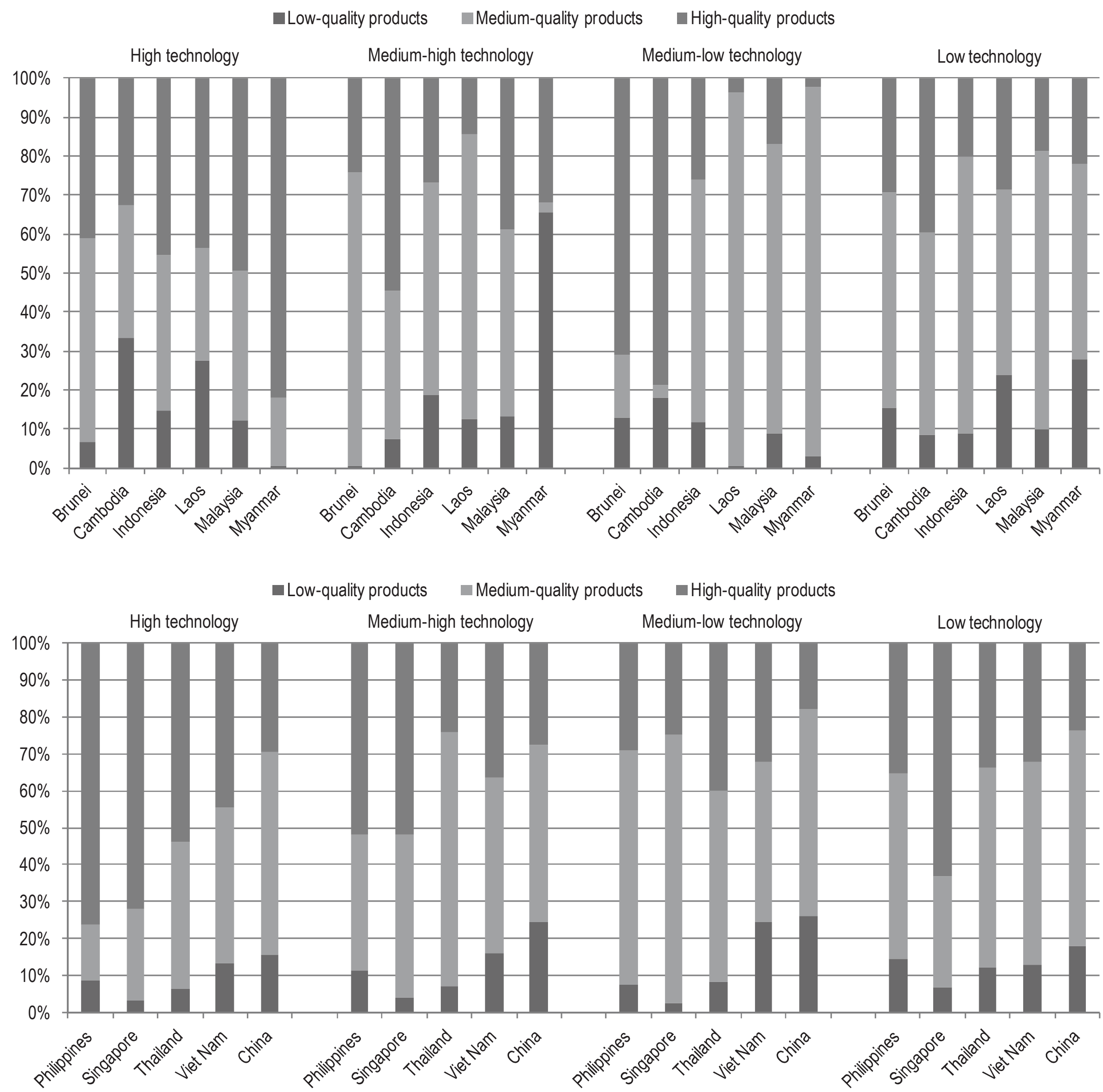
Figure 1.22. Median unit values (UV) of manufactured goods, 1995 and 2010

USD 1 000 per ton



Source: OECD calculations based on Centre d'études prospectives et d'informations internationales (CEPII), BACI database (an international trade database based on UN Comtrade data).

Figure 1.23. Exports by technology level (industry) and quality level (product), 2010



Source: OECD calculations based on CEPII, BACI database.

These observations reflect the conclusions of OECD (2011a) which analyses a broader set of developed and developing countries. That study showed that developed countries export relatively more quality products in each of the technology categories but that differences between emerging and developed countries seem to decrease at lower technology levels. This is because there is more product and quality differentiation in technology-intensive industries between developed and emerging economies (Edwards and Lawrence, 2010).[10] However, the presence of outliers and the differences in quality in medium-low technology industries suggest that other factors also affect the patterns in Figure 1.23.

1.2.4. Industrial specialisation and type of competition

More detailed insight can be gained through analysis of quality ranges and technology categories at the industry level. For instance, industry data on revealed comparative advantage and on the unit values of exports can be used to identify industries in which high unit values signal high quality. High unit values coinciding with a high revealed comparative advantage in an industry are indicative of competitiveness owing to higher quality/product differentiation.

The figures in Annex 3 show the relationship at industry level between the unit value of a country's exports (expressed relative to China's unit value) and an indicator of revealed comparative advantage (*i.e.* the degree of specialisation in certain industries) for 2010. The position of industries provides a broad overview of a country's export portfolio in terms of quality, market shares and technology character of industries (see Annex 3 on how to read the figures).

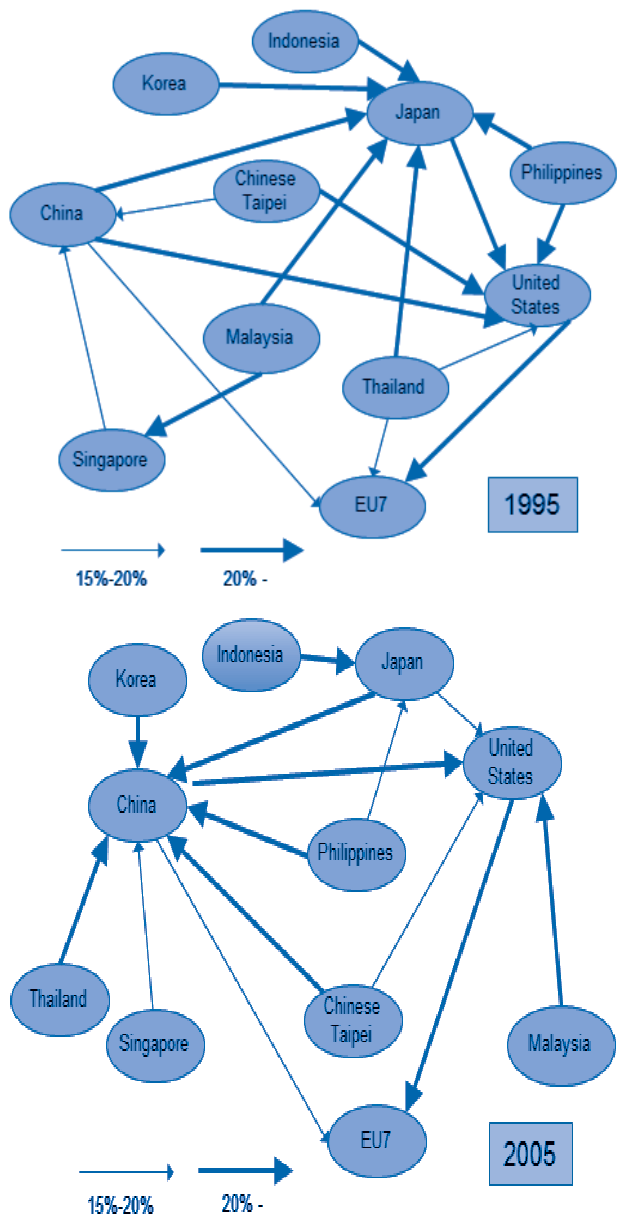
There are relatively few examples of industries in the region with a higher unit value than China in conjunction with a high degree of specialisation. However, there are some successes in the area of electronics and ICT-related products. Malaysia displays a revealed comparative advantage combined with high unit values in radio, TV, and communications equipment. Electronic components are prominent in Thailand, Singapore and Philippines (an outlier), along with electrical machinery in the Philippines. Other industries in the top right quadrant of the charts in Annex 3 are rare but include metals and basic metals (Laos, Indonesia) and textiles and clothing (see below).

Some ASEAN countries' exports were heavily concentrated in more labour-intensive products in 2010. A strong specialisation in textiles characterises the manufacturing exports of Cambodia, Myanmar, Viet Nam and, to a lesser degree, Laos and Indonesia. Unit values of textiles exports in these countries are typically the same as or slightly above the industry average in China. However, as recently as 2007 the unit values for these countries were typically at or below that of China. Several ASEAN countries – Indonesia, Malaysia, Thailand and to some extent Viet Nam – have also specialised in a diversified set of export markets that compete on the basis of low price (*i.e.* industries located in the lower right quadrant). These include chemicals (Brunei Darussalam) and food (Malaysia, Indonesia and Thailand).

1.2.5. International specialisation and global value chains

Trade trends in Southeast Asian economies need to be considered in the context of the significant recent changes in patterns of international production and global trade. In particular, production processes in certain industries have been unbundled, with the design, manufacture and distribution of goods broken down into stages that take place in different countries to take advantage of different factor prices. These trends are driven by factors such as lower transport costs, more advanced and cheaper technology, increased market access, changes to tariffs and trade agreements, and changes to the pattern of consumption. Advances in ICT in the 1990s made it easier for firms to coordinate industrial processes remotely and to locate different production tasks around the world in order to reduce total production costs. Lower communication and transmission costs also facilitate "fractionalisation", *i.e.* the breaking down of production into a greater number of finer stages (Baldwin, 2012). Global value chains (GVCs) are created by the series of intermediate steps across different countries which contribute to the final product's value added.

Figure 1.24. Major trade partners for Asia's intermediate exports in goods and services



Notes: EU7 includes Belgium, Germany, France, Italy, the Netherlands, Spain and the United Kingdom. Arrows are depicted when a partner's share of a country's total exports is greater than 15%. The pointer of the arrow denotes the direction of the flow. Thin arrows denote flows between 15% and 20%. Thick arrows denote flows greater than 20%.

Source: OECD Input-Output Database, March 2010; IDE-JETRO Asian International Input-Output Database 2006; OECD Bilateral Trade Database, March 2010; OECD Trade in Services, January 2010.

GVCs have had wide-ranging effects on international trade. One consequence of the fragmentation of supply chains has been countries' specialisation in tasks rather than final products. In fact, comparative advantage in specific production tasks has in many cases superseded the notion of comparative advantage based on final goods. Another consequence has been increased trade in intermediate goods with products being traded as they move through the supply chain. Excluding fuel, trade in intermediate goods now accounts for the majority of international merchandise trade (WTO/IDE-JETRO, 2011).

The changing nature of international specialisation and global value chains has been particularly important for Southeast Asia and neighbouring regions over the past two decades.[11] ASEAN countries' integration in global value chains has helped increase foreign direct investment (FDI) and change the nature of their international specialisation and production patterns. China has become a focal point for Asian and, indeed, global trade over the period, displacing Japan as the major destination for Asian intermediate exports (Figure 1.24). Case studies on the production of smartphones have demonstrated that high-value parts and components are produced in more developed countries and then exported to various destinations, including Southeast Asian economies and China, for final assembly. The disruptions to regional trade caused by recent natural disasters in the Asian region (the Japanese earthquake and severe flooding in Thailand, both in 2011) have also served to highlight the interconnectedness of supply chains.

1.2.6. Global value chains and changes in trade specialisation

As supply chains have become more international the interpretation of trade data becomes more difficult. Concepts such as country of origin become blurred when final products are assembled in many different locations. Intra-regional trade is an indicator of trade integration; it does not tend to show that global value chains have a strong influence on trade integration in Southeast Asia. Intra-regional ASEAN trade as a percentage of total merchandise trade rose from 18% to 24% from 1990 to 2000 but has risen only slightly since, although intra-regional intermediate trade is higher.

Similarly, intermediate trade volumes measured using the UN Broad Economic Categories (BEC) classification have generally been shown to have grown only at the same pace as trade in final goods and services. Different classifications of goods, however, do show some evidence that intermediates trade has grown faster than total trade (Sturgeon and Memedovic, 2010). Data on trade in intermediate goods at the regional and country level also brings out some aspects of global supply chains. Asia differs from other global regions in that it imports more intermediate goods than it exports. Intermediates accounted for 64% of non-fuel imports and 53% of exports in 2009, compared to the world totals of 52% and 51%, respectively (WTO/IDE-JETRO, 2011). This shows the region's role in the processing and assembly of manufactured goods which are then exported as final goods. The region's role in assembly is driven by China, but Viet Nam and also Thailand import more intermediates than they export. This tends to confirm other evidence of Viet Nam's emergence as a final assembler of low-technology products within GVCs. By contrast, Singapore, Malaysia and Indonesia display roughly similar shares of intermediate goods in their imports and exports.

OECD work on within-industry patterns of trade in Southeast Asia also shows the impact of GVCs. Intra-industry trade is the mutual exchange of goods in the same product category. Supply chain fragmentation should lead to more intra-industry trade, as products move through supply chains that now cross borders. The Grubel-Lloyd index of intra-industry trade[12] across sectors was calculated for ASEAN, other Asian and OECD countries in 2006-08 to provide a measure of trade integration with the global economy (OECD, 2011c). This indicator clearly shows that Singapore has very high levels of intra-industry trade, owing to its role as a regional trade hub. An examination of particular sectors reveals more information. Malaysia, the Philippines, Singapore and Thailand have very high levels of intra-industry trade in the electronics sector, an indication of a high level of integration in global value chains in this industry.[13] The pattern in ICT equipment is less clear and there is a low level of intra-industry trade in apparel and textiles. This may be due to higher trade barriers in these industries but is still surprising in view of the fragmentation of manufacturing and distribution activities.

"Vertical specialisation" offers another means of exploring the link between fragmentation of production and regional integration. This indicator essentially relies on input-output tables, which classify goods according to their use rather than their descriptive characteristics, to measure the proportion of an exported good that is made up of imported inputs. OECD (2011c), using the Hummels-Ishii-Yi indicator of vertical specialisation, finds evidence of significant increases in the import content of exports across Asia between 1995 and 2005, with Malaysia, the Philippines and Thailand standing out. There is more evidence of vertical specialisation in more technology-intensive goods; this echoes the findings on high intra-industry trade in the electronics and ICT sectors. Using the same data, the ratio of re-exported intermediate inputs to the quantity of intermediate exports[14] suggests that the Philippines, Malaysia and Thailand tend to supply intermediate products in the early stages of global supply chains. By contrast, China's relatively lower score suggest its exported intermediates tend to be consumed at the later stages of global value chains.

Overall there is emerging evidence for Southeast Asian countries' integration in global supply chains and (re-)positioning along value chains, although more data, particularly on value added in different production stages, is required to better understand the dynamics involved. More generally, global value chains are a crucial factor in explaining some of the trends in the volume, quality and specialisation of trade discussed above.

1.2.7. Conclusions

There have been significant changes in the structure of trade in the Southeast Asian region in recent years. Although there are some common regional trends, there is also considerable diversity among the region's economies. Most countries have moved away from labour-intensive manufacturing industries, although Viet Nam seems to have specialised in this area and in some sectors has replaced China as an assembler of final goods. Large industries dominated by multinational enterprises make large contributions to total trade in certain countries. As regards export market share and the quality and technology content of trade, countries differ depending on their GDP per capita and development, with Singapore and Malaysia standing out in regional comparisons.

Southeast Asian economies are increasingly part of global value chains, with some diversity among sectors. GVCs have influenced the region's trade structures and strengthened comparative advantages in certain industries through the country-specific location of tasks. The unbundling of production appears to be behind the specialisation (as indicated, e.g. by measures of revealed comparative advantage) of many Southeast Asian countries in sectors such as electrical machinery and radio, television and communication equipment, industries that are relatively open to cross-border fragmentation. FDI is one factor underlying GVCs and trade patterns more generally. A large proportion of FDI in Southeast Asia has been vertical in nature, i.e. export-promoting. This contrasts with FDI to other developing countries, such as India, much of which has been horizontal (market-seeking).

The impact of these various trade trends on innovation activity is difficult to measure. Traditional measures of trade performance may become less reliable indicators of value creation, competitiveness and innovation. The breaking down of the production process into tasks means that large volumes of exports in high-technology products do not necessarily mean a high level of R&D activity. The extent of spillovers of knowledge, technology and expertise is therefore likely to affect how local economies benefit from recent changes in trade activity and GVCs. Investment by multinational enterprises as well as off-shoring have brought advanced technical knowledge and managerial experience to the region. Some authors have argued that this process helps explain Southeast Asia's rapid export-led economic growth, and how this differs as a development model from the earlier longer process of building industries through learning by doing. However, it has also been argued that a large fraction of the technology underpinning GVCs and the location of production tasks may be firm-specific if firms face strong incentives to protect this knowledge and limit spillovers to local economies (Baldwin, 2012).

The effects on national innovation may also be related to sectors of specialisation in addition to a wide range of country-specific innovation system factors, the business environment and government policies. In particular, sectors such as electronics may be more conducive to future technological upgrading than others (such as textiles) and may create a greater legacy in terms of skills and cumulative competencies. Overall, however, it is hard to draw strong conclusions about the effect of changes in global trade and development patterns on innovation in individual countries. A more detailed examination is provided in the country profiles in Part 2 of this review.

1.3. Economic change and the role of innovation

1.3.1. Drivers and prospects

A number of factors, both exogenous and endogenous to the region, can be expected to shape the future of the economies of Southeast Asia as regards aggregate growth and the direction of change. Among these factors, which are interrelated in various ways, are the following:

- *Overall global economic environment*. Southeast Asian economies are very open, including to foreign trade. A strong export orientation was a key ingredient in the economic success of East Asian countries. The economic prospects of Southeast Asian countries are exposed to shifts in the longer-term growth of the world economy, particularly that of their main trade partners.
- *Foreign direct investment*. Many Southeast Asian countries have relied on FDI to develop and restructure their economy. The main issue here is whether the region remains attractive to foreign investors, even in a fiercely competitive environment for the location of investment projects. Following the globalisation of production, foreign direct investment in R&D has also become increasingly globalised. Multinational enterprises are restructuring their R&D activities according to their global strategies and are adopting more open models of innovation. Developed countries' MNEs often expand their R&D abroad to knowledge centres not only in other OECD countries but also in emerging economies.

- *Global value chains*. As shown above, the integration of Southeast Asian countries in GVCs has increased, and the structure of GVCs is changing. China has become a dominant attractor (destination) of intermediate goods exports from Southeast Asia. GVCs are shaping the international division of labour and have pervasive effects on national economies (De Backer and Yamano, 2012) in the Southeast Asian region.
- *Demographic change and urbanisation as well as climate change and environmental degradation* are among the great societal challenges which cannot be overcome without a massive contribution of science, technology and innovation.

In Southeast Asia, the evolution of many of these factors is strongly influenced by the development of the region's largest neighbour, China. China has an immediate impact on the economies of Southeast Asia via the increasing bilateral trade and investment flows and cross-border flows of various forms of knowledge. In addition it has an impact through competition on third markets. Advances and structural change in the Chinese economy will also sometimes have more subtle consequences for Southeast Asian countries. China and, to a lesser but perhaps increasing degree, India are reshaping the industrial landscape of Southeast Asia (Yusuf et al., 2007). The rise of China affects the economies of Southeast Asia in different ways, depending for example on the intensity of their interconnectedness, their level of income, their specialisation, and the sophistication or innovativeness of their economic activity. On some, China's surging demand for raw materials had an important impact. Others have benefited from the relocation of industries. Overall, the economies of Southeast Asia have gained from China's increasing demand for a broad range of goods.

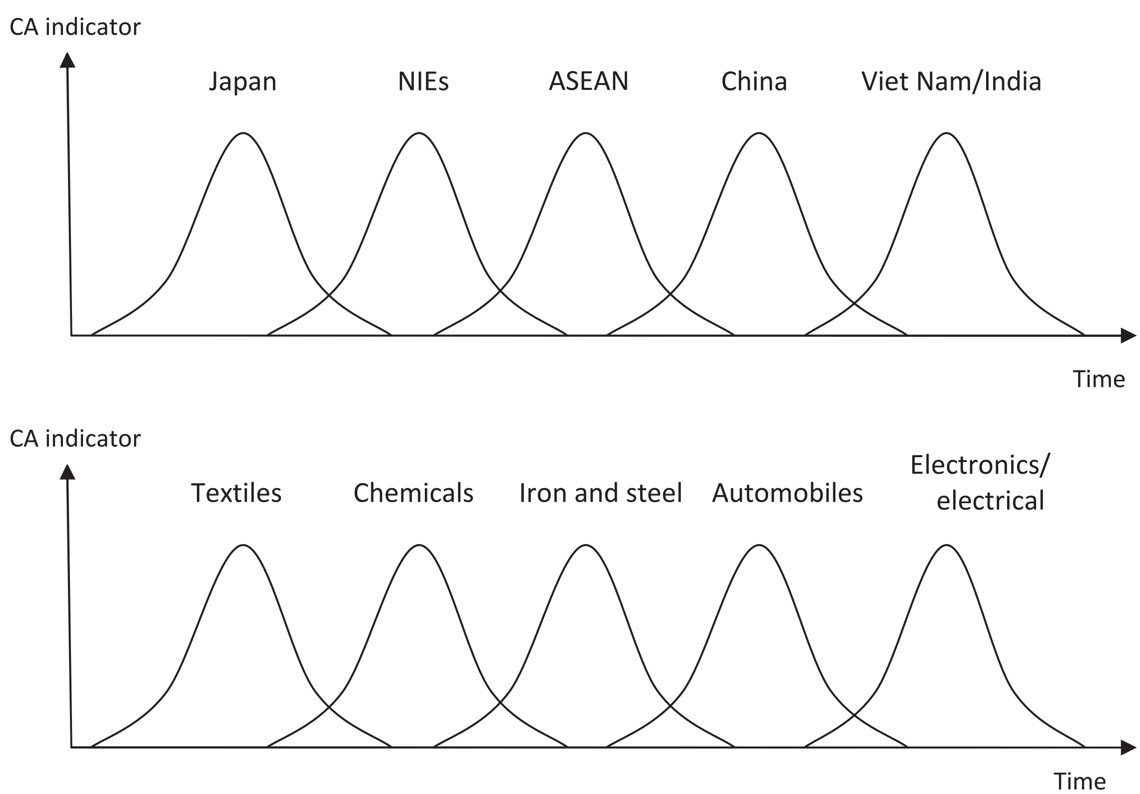
Yusuf (2008, p. 5 ff.) notes several aspects of China's development that seem particularly important in terms of their impact on growth and the pace and direction of structural change in Southeast Asia:

- Above all, aggregate growth of the Chinese economy has been extraordinarily high for an extended period of time (although it has slowed recently). Growth on this scale generates high demand for imports from trading partners. Overall, Southeast Asia has benefited and is likely to continue to gain from China's strong demand for a wide range of export goods.
- At the same time, the growth of China's exports, as well as their composition, affects the competitiveness of Southeast Asian exports both to China and to third markets. In particular, the improvement of China's manufacturing capabilities and the pace at which it moves up the value chain could have a potentially strong impact on Southeast Asia, notably its middle-income economies. China has so far specialised in the final assembly of a range of goods, including consumer electronic products, cars, and engineering products of various kinds, for which many parts are imported from abroad. However, China appears to be in a favourable position to succeed in the "backward integration" that would raise competitive pressure on, and to some extent replace, imports.
- The further rise of China may have an impact on the flows of FDI, including their geographical structure. As mentioned, FDI plays a critical role in the electronics industries of countries such as Malaysia and Thailand. In China, too, foreign-invested enterprises are a large share of the electronics industry, although China is progressively creating its own companies and brands. Southeast Asian countries may have to step up their efforts to develop new comparative advantages and may have to rely more on the mobilisation of domestic resources in the contested market for the localisation of FDI.

Box 1.3. The "flying geese" analogy

The "transmission" of economic dynamism from Japan to the NIEs and then to Southeast Asian countries and China has come to be represented by the flying-geese pattern. "The flying-geese model was first used to describe the life cycles of industries in the course of economic development (Akamatsu, 1962), with the focus on specific industries in specific countries. Subsequently, it has been extended to study the dynamic changes in the industrial structure (that is, the rise and fall of different industries) in specific countries, and further to the shift of industries from one country to another" (Kwan, 2001, p. 2.). While countries specialise in the export of products in which they have a comparative advantage, they seek to upgrade their industrial structure by augmenting their endowment of capital and technology. FDI from more advanced countries to relocate industries drives this process. A less developed economy catches up through trade and FDI in four stages. Figure 1.25 exemplifies this pattern of economic development for both a particular country and for a particular industry *(e.g.* textiles).

Figure 1.25. The "flying geese" pattern of economic development



Note: CA = competitive advantage.

Source: Kwan (2002).

The "flying geese" pattern can be stylised as comprising the following stages:

- The less developed country starts to import consumer goods from advanced economies and exports primary products in exchange.
- Domestic industry starts to produce consumer goods previously imported from advanced economies; at the same time it starts to import machinery (*i.e.* capital goods) from developed economies. This is critical for the development of the domestic consumer goods industry. Moreover, the establishment of this industry requires the use of energy resources, once that machinery is in place, and this induces the development of the energy sector.

…/…

Box 1.3. The "flying geese" analogy *(continued)*

- The domestic consumer goods industry becomes an export industry (Akamatsu, 1962). Exports become possible as consumer goods are produced on a larger scale. During this phase the country increases the number of overseas markets for its export products. At the same time domestic production of previously imported machinery starts, while imports of capital goods from advanced economies begin to decrease.
- The consumer goods sector catches up with similar industries in developed countries. Consumer goods exports decrease and capital goods used in producing consumer goods are now exported (Kumagai, 2008). Consumer goods production starts to decline because it now takes place in other less advanced economies: this is the development of the flying geese pattern. The formerly less advanced economy had become a developed economy at the previous stage and it now strengthens this status.

Chinese Taipei, Singapore and Hong Kong, China, were the first destinations for relocation of industrial production from Japan. As labour costs in these NIEs increased, FDI flows were diverted towards (other) ASEAN countries. The close economic interconnection between these countries has been important for the development of regionalism in this area and is part of what has been called the "Asian miracle" (Nicolas, 2010; Capannelli-Filippini, 2009).

It is obvious that these factors are closely related to progress in building innovation capability in China. While it is an enormously complex task to build a modern, business-centred innovation system, transforming the inherited system and building some parts more or less from scratch, China has used its strong economic growth to invest more than proportionally in R&D and human resources (OECD, 2008). Even when accounting for friction and some degree of waste in building S&T and innovation capacities so rapidly, much progress has been made over the past two decades.

Symmetrically, the outcome of the dynamic interaction between China and Southeast Asian countries is closely related to the evolution of the latter's innovation capabilities. This is reminiscent of the discussion of the extent to which the "flying geese" analogy (Box 1.3) will be applicable in the future (Kwan, 2002; Ahearne et al., 2006).[15] There is some reason to think that even stylised models representing processes of "transfer" or "assimilation" will have to account for more complex modes of interaction.

1.3.2. The role of innovation: Southeast Asia's innovation imperative

The future position of Southeast Asian countries in the region and the world will greatly depend on their ability to further upgrade innovation capabilities. In the course of their structural transformation, Southeast Asian economies such as Indonesia, Malaysia and Thailand have already acquired important manufacturing capabilities, in particular in the electronics industry, electrical engineering and the automotive industries. However, in certain respects, they did not achieve what their East Asian Tiger forerunners – Chinese Taipei; Korea; and Hong Kong, China – were able to realise. For one this includes building their own "indigenous capacity to design, to innovate, and to diversify into new and more profitable areas with good long-run prospects, and very few of their firms have created regional – much less global – brand names. They are adept at assimilating technologies from overseas and have the production and plant management skills to match the labor productivity levels of industrial countries in the production of standardized commodities. However, innovation – product or process – remains mainly a preserve of the MNCs; indigenous firms do very little innovation. More disquieting is the sparseness of backward links from MNC operations, which would signify progressive industrial deepening, as has occurred in Korea and Chinese Taipei, and as is already under way in China. This lack of backward links means that domestic value added in manufacturing remains low. Moreover, none of these countries has nurtured large and dynamic producers of tradable services, à la India in information technology and à la Hong Kong, China, and à la Singapore in finance, logistics, and other business services." (Yusuf and Nabeshima, 2009, p. 10) Yusuf and Nabeshima also point out that Southeast Asian countries have been slow to develop an "innovation culture" that would be necessary to support value-adding diversification in new areas of production. Addressing these issues in an effective manner will be critical for turning competition and co-operation with China in the dimensions discussed in the previous section into a "positive-sum game".

Some countries, particularly those making use of their "advantage of backwardness" (Gerschenkron, 1962) and realising rapid "catch-up" growth, have sustained high growth rates for relatively long periods via factor mobilisation rather than growing along the TFP-dominated trajectory described above (*e.g.* Krugman, 1994). However, there are limits to this type of "extensive" growth. As Southeast Asian countries climb up the income ladder and are exposed to new competition, innovation will increasingly have to become a determining factor for their economic growth in the longer term (see Box 1.4). This is more evident for those countries which have already moved well into the middle-income range and perhaps less so for the new cohort of catching-up economies in the region, which still have reached lower level incomes and a more modest level and range of manufacturing capabilities. Yet, these countries too have to look ahead and build the resources and capabilities to innovate which will allow them to move up the ladder in the future and avoid getting locked-in to low-value adding activities.

Box 1.4. The role of innovation in driving long-run economic growth

Economic growth (apart from short-run movements of output, *e.g.* the cyclical fluctuations that are the purview of macroeconomic stabilisation) stems from two broad sources. One is the accumulation of so-called "factor inputs", typically consisting of physical capital (buildings, machinery, tools and other productive infrastructure) and labour (the measurement and definition of which varies, ranging on occasion from crude population headcounts to sophisticated human capital-adjusted full-time-equivalent workers). Another source of long-run growth is productivity improvements, which can be due to the effects of trade (and thus specialisation in activities with lower opportunity cost) or due to the effects of innovation (improving the rate at which capital and/or labour translate into concomitant outputs) (Mokyr, 1992; Snowdon and Vane, 2005).

Attempts to explain long-run growth have a lengthy history in economic thought. Formal modelling dates back at least to Solow (1957) who observed that a large proportion of variation in economic output in the United States over time could not be explained by contemporary accumulation of capital and expansion of labour. Solow reasoned that the part that could not be explained may be attributable to "technical progress". To this day, estimates of TFP follow this measurement-by-elimination approach (see Box 1.2), and despite refinements, they are essentially indicators of the magnitude of increases in output that cannot be explained by observed increases in inputs.[1] (See also the empirical results of Abramovitz, 1956, and Kendrick, 1963.) A number of empirical studies find a positive association between TFP and other proxies of innovation activity, such as R&D expenditures and patents (*e.g.* Scherer, 1982; Griliches and Lichtenberg, 1984; Aghion and Howitt, 1998; Guellec and van Pottelsberghe de la Potterie, 2001; Griffith et al., 2004; Zachariadis, 2003). Therefore, and especially when sufficiently narrowed to control for other influences, TFP is now seen as a fair approximation of productivity improvements due to innovation.

…/…

Box 1.4. The role of innovation in driving long-run economic growth *(continued)*

The relative contribution of factor accumulation and innovation-driven TFP to economic growth varies across countries, and within the same country, over time. The empirical record suggests that factor accumulation is the principal source of growth for low-income countries whereas TFP is much more important for high-income countries. This can be seen with a cursory consideration of the process of economic development. In low-income countries growth is of the "catch-up" variety. Starting from a low level of factor inputs, the accumulation of capital and labour combines with knowledge transferred from abroad (or new-to-the-country innovation) to produce rapid growth. As low-income countries grow and their incomes converge with those of high-income countries, they progressively exhaust the possibilities for growth afforded by capital and labour accumulation. Growth slows down and would grind to a halt were it not for sustained innovation.As demonstrated by so-called "endogenous" variants of long-run growth models, it is the purposeful search for new ideas (typically motivated by profit) that permits growth to resume in countries rich in physical and human capital (Romer, 1990). Therefore, R&D and other innovation inputs committed to the search for economically useful ideas ensure that progressively more can be produced with a more or less constant amount of inputs. Far from being relevant only to high-income countries, R&D is crucial for low-income countries too. Coe et al. (1997) empirically demonstrate that low-income countries benefit from the R&D investments of their wealthier trading partners and that the magnitude of such benefits depends upon the extent to which they themselves perform R&D.[2]

Even in high-income countries, however, the role of innovation is not confined to aggregate productivity improvements.[3] The emergence of radical innovations, sometimes referred to as general purpose technologies (GPTs), may in fact reignite the process of factor accumulation. Common to the emergence of electricity, the internal combustion engine and information and communication technologies (ICTs) was an extensive subsequent process of physical capital upgrading and human capital re-skilling. Biotechnologies, nanotechnologies and green technologies may have a similar effect in the future.

1. Thus defined, TFP potentially captures not only the impact of innovation on growth, but also that of trade (which from a different perspective can be considered a form of technology on a grand scale) and even of supply shocks that do not leave an imprint on capital or labour statistics (*e.g.* adverse weather). Estimates of TFP are also highly sensitive to the definition of "capital" and "labour". For example, TFP estimates that control separately for the contribution of human capital are typically much smaller.

2. The precise mechanisms by which this occurs are a matter of speculation. It is likely that familiarising researchers with state-of-the-art R&D facilitates the transfer of knowledge from abroad and, within the country, across industries and firms. It may also encourage investment to flow to the most efficient and effective varieties of physical capital and may contribute to the quality of human capital accumulation by improvements in education.

3. Implicit in Solow (1957) and many subsequent attempts to explain long-run growth using the aggregate production function method are the assumptions that the contribution of the various sources of growth are independent of one another and that they may be summed to produce observed economic output. As Abramovitz (1993) points out, both assumptions can be questioned.

In the longer term, an increasing share of growth will have to be driven by innovation, some of it based on own R&D, as Southeast Asian countries will more and more need to compete with the other rapidly advancing economies in Asia, notably China and India, and beyond. Traditional sources of economic growth such as labour and physical capital accumulation alone cannot be expected to support long-run economic growth. However, innovation capabilities vary widely across countries in the region: a few have achieved a considerable level of such capabilities but most have not. This calls for customised and forward-looking innovation strategies that are well adapted to countries' specific initial conditions and help build the capabilities required to seize the opportunities ahead.

Annex 1.A1
Technology classification of industries

Manufacturing industries are classified according to technology intensity using the ISIC Rev. 3 breakdown of activity. The classification is based on a ranking which uses data on R&D expenditure divided by value added, and R&D expenditure divided by production for 12 OECD countries during the period 1991-99.

High-technology:

- Pharmaceuticals (ISIC 2423)
- Office, accounting and computing machinery (ISIC 30)
- Radio, television and communication equipment (ISIC 32)
- Medical, precision and optical instruments, watches and clocks (ISIC 33)

Medium-high-technology:

- Chemicals excluding pharmaceuticals (ISIC 24 less 2423)
- Machinery and equipment not elsewhere classified (ISIC 29)
- Electrical machinery and apparatus not elsewhere classified (ISIC 31)
- Motor vehicles, trailers and semi-trailers (ISIC 34)
- Railroad equipment and transport equipment not elsewhere classified (ISIC 352 plus 359)

Medium-low-technology:

- Coke, refined petroleum products and nuclear fuel (ISIC 23)
- Rubber and plastics products (ISIC 25)
- Other non-metallic products (ISIC 26)
- Basic metals and fabricated metal products (ISIC 27-28)
- Building and repairing of ships and boats (ISIC 351)

Low-technology:

- Food products, beverages and tobacco (ISIC 15-16)
- Textiles, textile products, leather and footwear (ISIC 17-19)
- Wood and products of wood and cork (ISIC 20)
- Pulp, paper, paper products, printing and publishing (ISIC 21-22)
- Manufacturing not elsewhere classified and recycling

Annex 1.A2
Categorising export quality levels

The following explains the quality categorisation of bilateral trade flows for Figure 1.5.

Trade flows are broken down into three similar-sized groups according to the principle that the highest-quality products have the highest unit values. Following Fontagné et al. (2008), the world unit value $UV_{i,\ world}$ is calculated for each 6-digit harmonised system (HS-6) product as the median of the unit values of all bilateral transactions UV_{ijk} (i being product i, j the exporting country and k the country of destination) for that product. The three quality ranges are then defined as follows:

- high quality: UV_{ijk} in the last nine deciles of the range [$1.25xUV_{i,\ world}$; max(UV_{ijk})]
- medium quality: trade flows with unit values that differ from the world average by less than 25%, *i.e.* UV_{ijk} in the interval [$0.75xUV_{i,\ world}$;$1.25xUV_{i,\ world}$], plus trade values that are in the first decile of [$1.25xUV_{i,\ world}$; max(UV_{ijk})] and in the last decile of [min(UV_{ijk}); $0.75xUV_{i,world}$]
- low quality: UV_{ijk} in the first nine deciles of the range [min(UV_{ijk}); $0.75xUV_{i,world}$]

The use of the median and intervals takes into account the sometimes high variability of unit values; the medium range is defined more broadly in order to capture a significant share of trade. Given that the data refer to bilateral transactions, one country may have exports/imports of the same product in all three quality ranges, reflecting the fact that this country may export/import different product varieties to different trade partners.

Unit values have been calculated for each country across industries. Average unit values have been calculated for each reporting country j on the industry level by taking the median of all UV_{ijk} of all HS-6 products belonging to that industry.

The product-level information has been aggregated at the industry level using concordance tables between product (HS) and industry (ISIC) classifications. Products at the HS level have also been linked to the Broad Economic Categories Classification (BEC) of the United Nations in order to distinguish between capital, consumer and intermediate goods within each industry. This makes it possible to relate the analysis of unit values and product quality directly to the international fragmentation of production, following the increased trade of intermediates in GVCs.

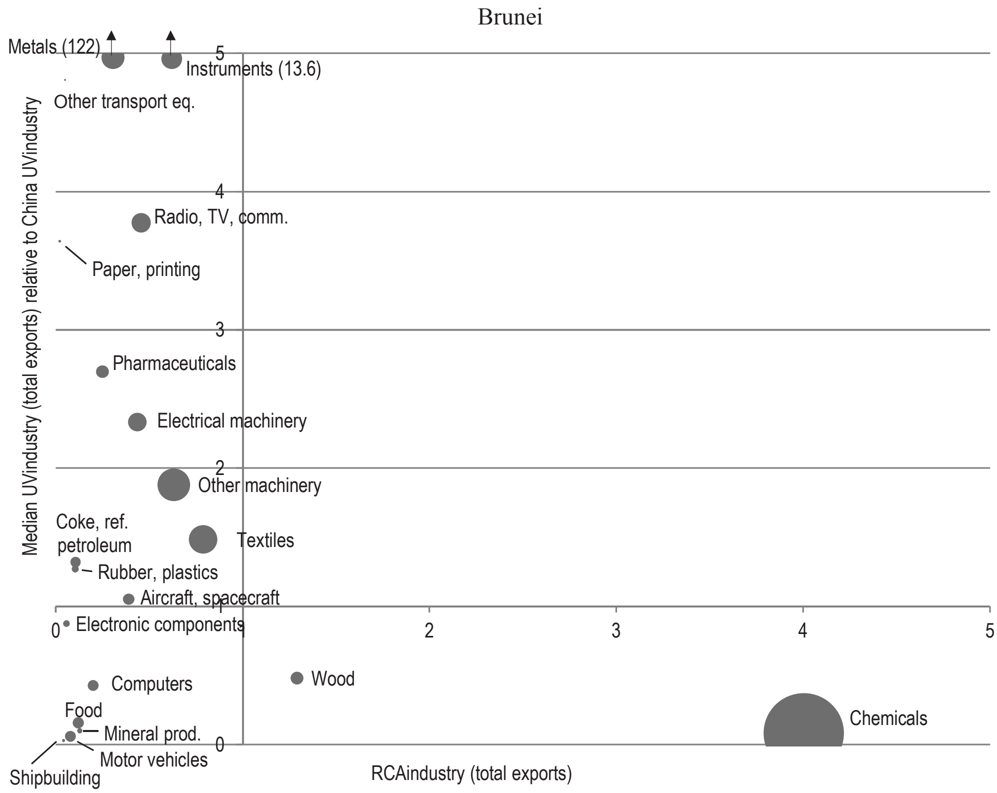
Annex 1.A3
Revealed comparative advantage and quality of exports

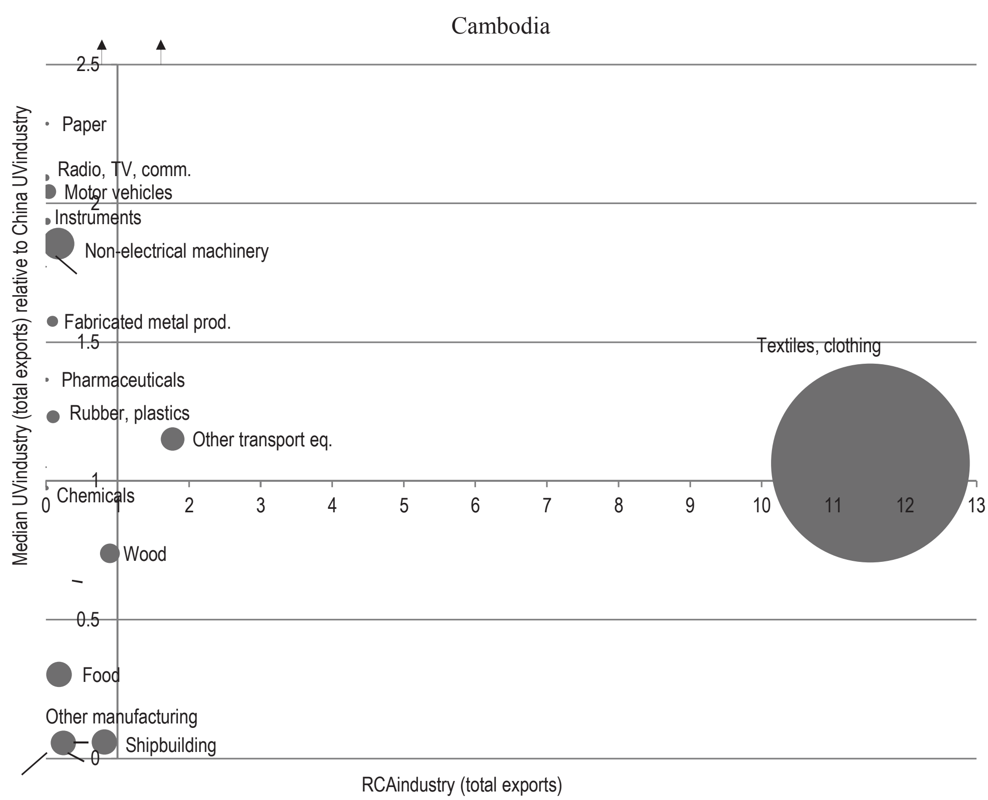
The following charts link the unit value of a country's exports and an indicator of revealed comparative advantage (RCA) at the industry level. Unit values are expressed relative to China in order to provide a consistent benchmark with an increasingly important trade partner and competitor. Exports in most Chinese industries have a unit value below the world median, suggesting that Chinese companies compete relatively more on price (and costs) on international markets. For each country chart, industries above the horizontal axis have export unit values higher than the same industries in China, while industries below the horizontal axis have unit values lower than China. Industries to the right of the vertical axis showing a RCA greater than unity are those in which the country is internationally specialised, with export shares above the world average. The size of the circles indicates the value of the industry exports, hence is an indication of the importance of the industry for the country in question.

The position of industries in this framework provides a broad overview of the export portfolio of countries along the dimensions of export specialisation and quality, which relate, to some extent, to the technology characteristics of industries. For industries positioned in the upper right quadrant, quality competition pays off: exports are sold on international markets with a price premium (relative to China) and higher quality (owing to technical specificities, technological characteristics, branding and marketing, etc.) and result in a comparatively high world market share. Industries in the bottom right quadrant also show a comparative advantage which seems to be based on lower prices rather than on higher product quality; the source of competitive advantage seems to be related to price competition. For industries in the quadrants left of the vertical axis, the framework suggests that the chosen strategy (quality competition in the upper left quadrant and price competition in the bottom left quadrant) is less successful; the right strategy will depend on the competitive strengths of other countries/companies and the price-elasticity characteristics of the products.

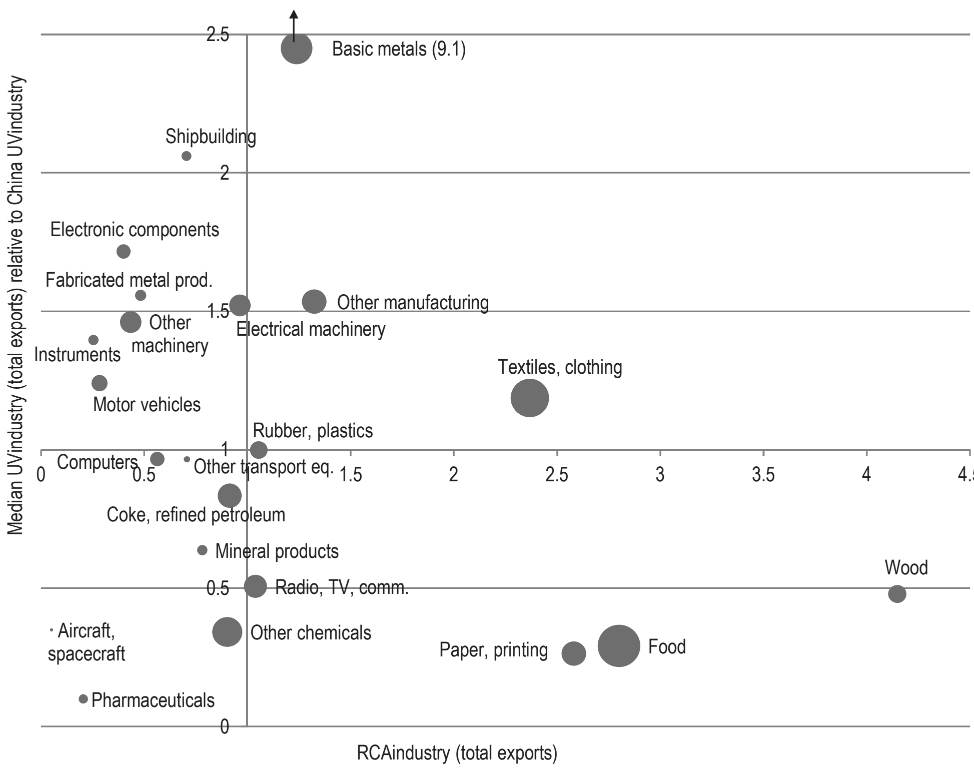
Unit values are only approximate indicators of the quality of trade quality since they may reflect other factors that allow countries to sell their products at high prices. As they are considered more accurate at more disaggregated levels, the positioning in the charts may reflect to some extent the exact composition of the product categories.

Figure 1.A3.1. International specialisation (RCA – total exports) and price/quality competition, 2010

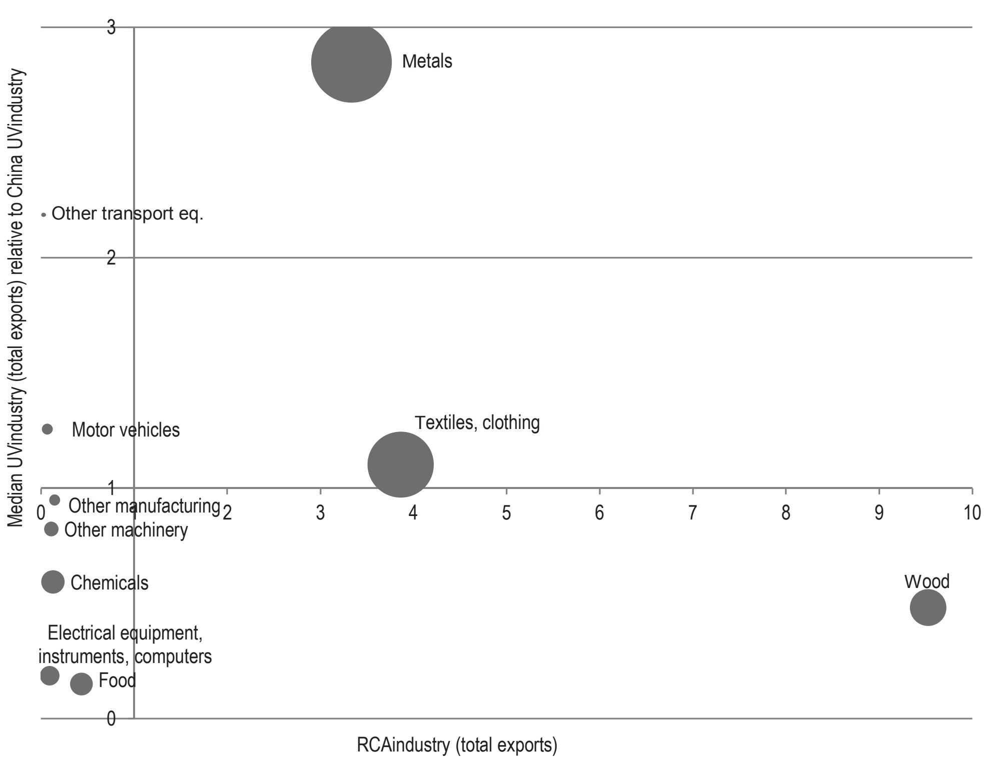




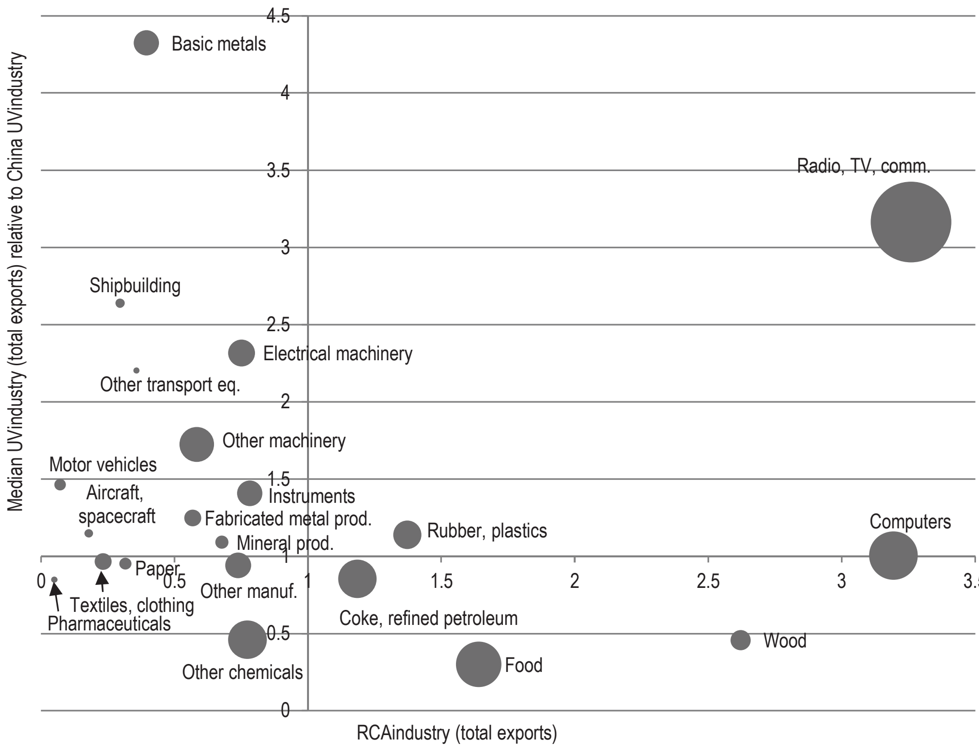
Indonesia



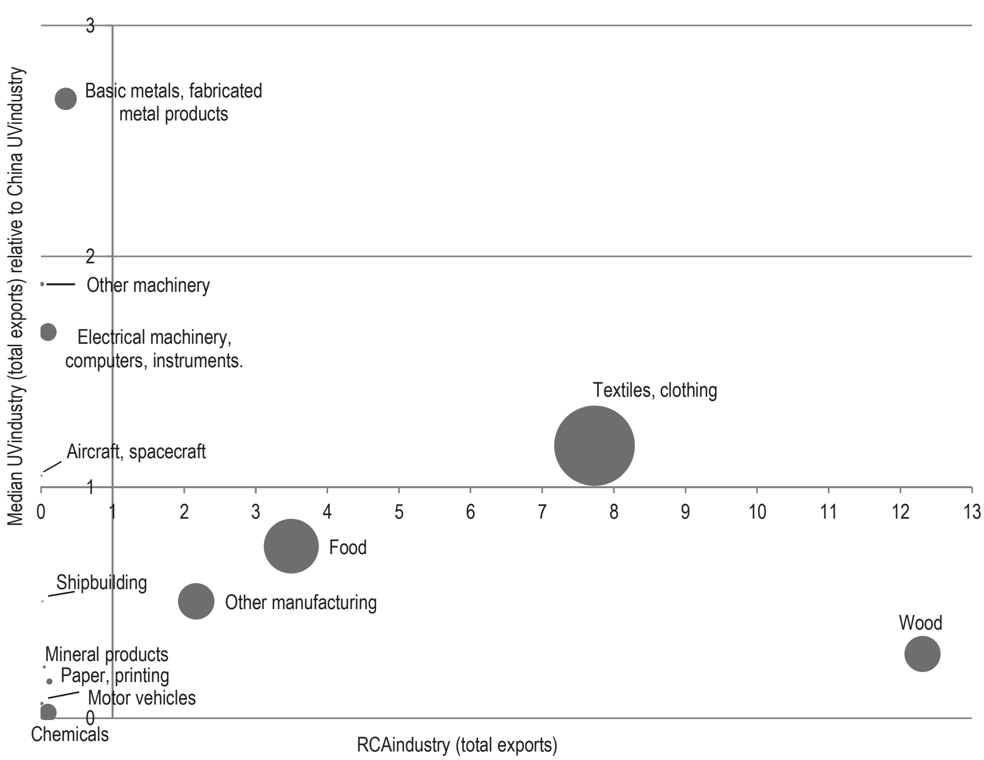
Laos



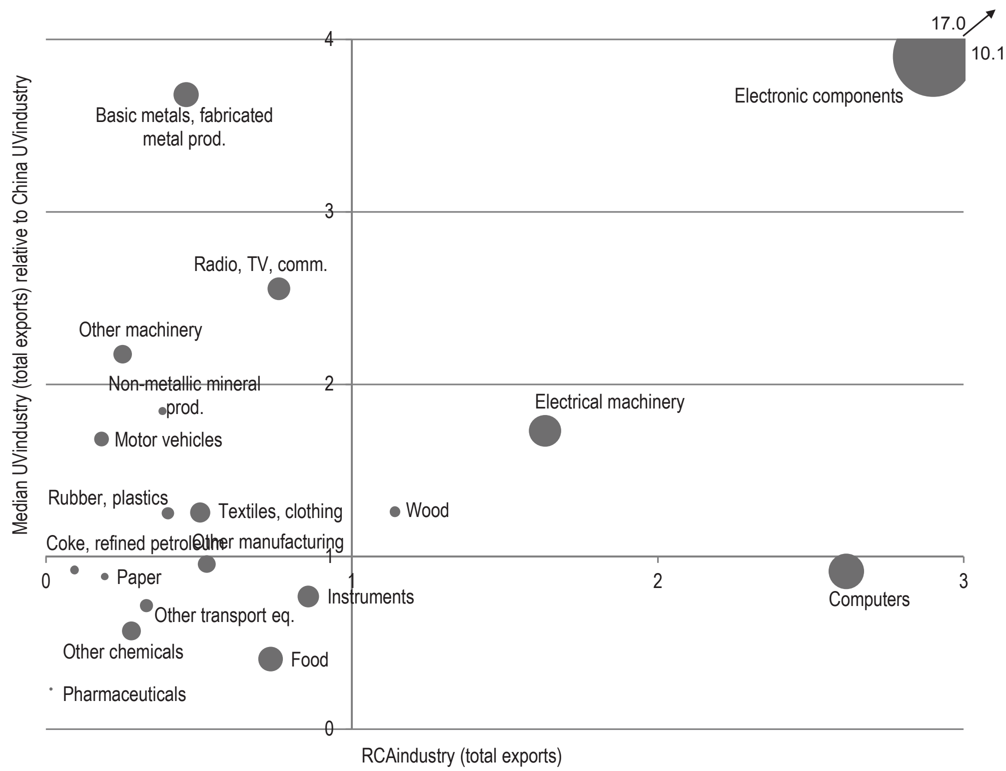
Malaysia



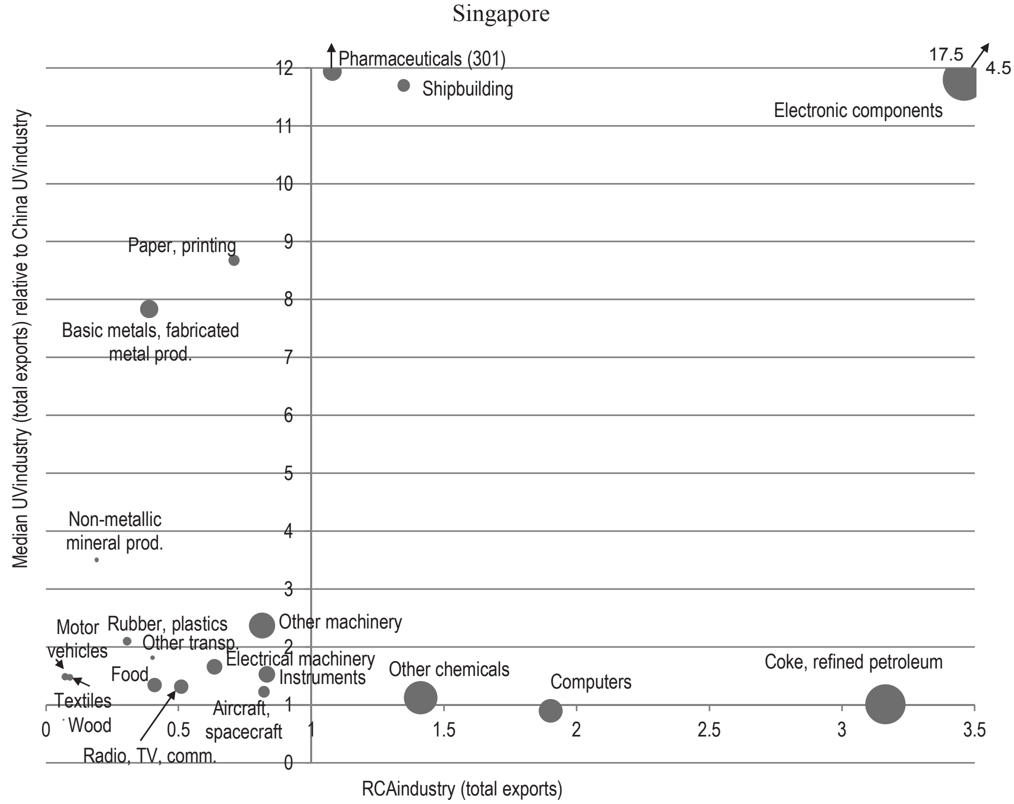
Myanmar



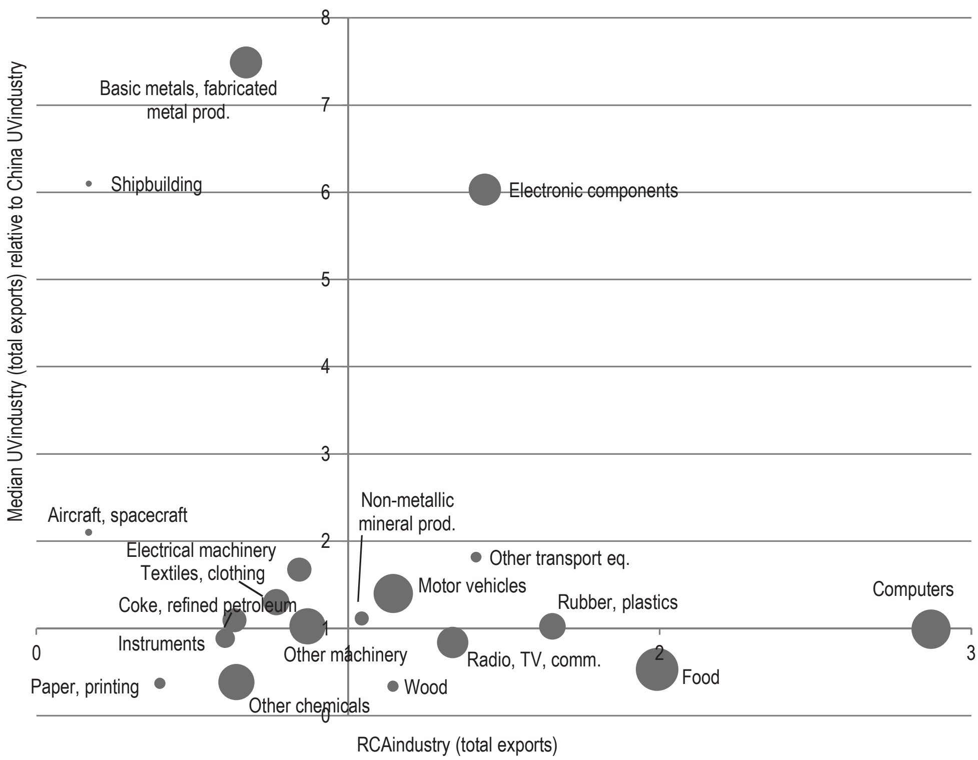
Philippines



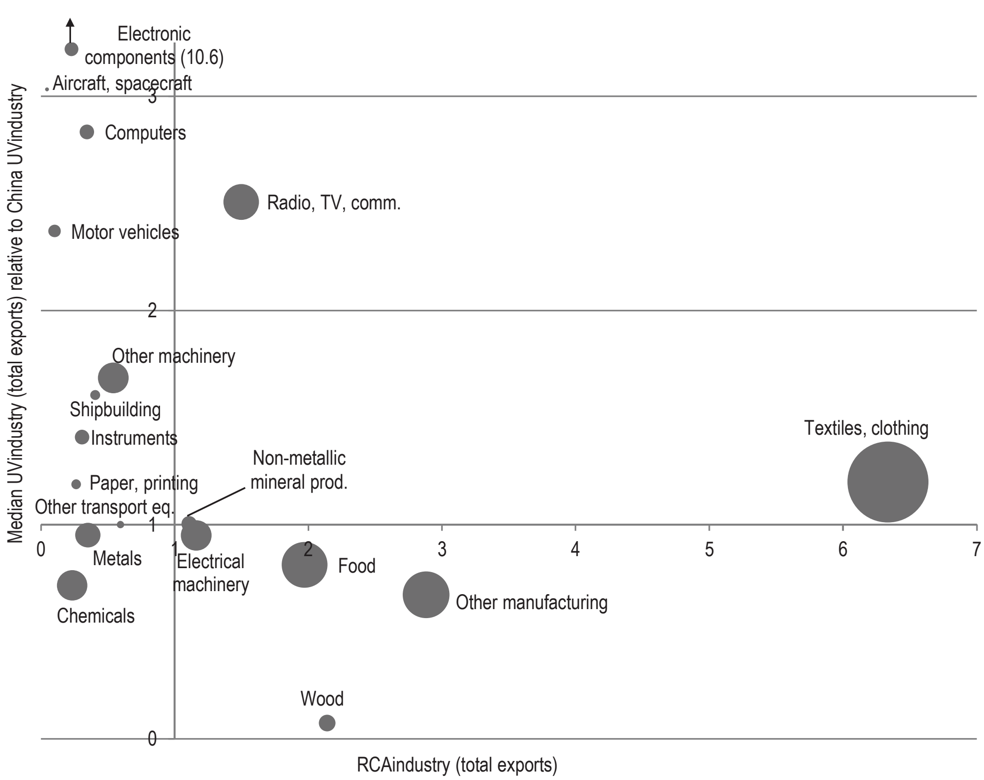
Singapore



Thailand



Viet Nam



Notes

1 This analysis does not cover the entire world economy. In particular, some of the world's poorest regions are not included.

2 In the short term there may be a trade-off between levels of labour productivity and labour utilisation as less productive workers may be employed.

3 "Reflecting on these results, capital accumulation appears to be a necessary step to economic growth, and countries may go through cycles of capital accumulation and assimilation. Although a prerequisite, capital accumulation does not guarantee TFP growth. Some countries may be more capable than others in reaping the benefits through capital assimilation" (APO, 2012, p. 79).

4 Brunei Darussalam, Indonesia, Malaysia, the Philippines, Singapore and Thailand.

5 Textiles are also likely to account for a large share of merchandise exports from Cambodia.

6 RCA is usually defined as a country's share of world exports in a particular commodity or industry, divided by the share of that country's world exports in all commodities: $RCA_{i,c} = (X_{i,c}/X_{i,\ world})/(X_{total,\ c}\ /X_{total,\ world})$, where $X_{i,c}$ and $X_{i,\ world}$ are respectively the exports of industry i by country c and the world, while $X_{total,\ c}$. and $X_{total,\ world}$ refer to total (manufacturing) exports by country c and the world. A value larger than one indicates that country c possesses a comparative advantage and is specialised in industry i, while a value smaller than one points to a comparative disadvantage.

7 High unit values can indicate higher quality but may also be due to higher prices for similar products (in which case the market share would probably be small). They can be influenced by the composition of a country's or industry's exports (Edwards and Lawrence, 2010) or may reflect other factors (Hallak and Schott, 2011). It is generally preferable to examine unit values at more disaggregated levels.

8 The data in Figure 1.22 reflect some of the issues involved in using unit value data at the aggregate level and should be considered as illustrative. For example, the Philippines is excluded from the figure because it is an outlier in terms of median unit values (USD 2 437 000 per ton in 2010). This occurs essentially because two manufacturing industries with high unit values (radio, TV and communication equipment; electronic components) account for an unusually large share of total exports and strongly influence the median value.

9 Even at a more disaggregated level, some unexpected results are likely driven by the dominance of certain industries in some countries. For example, the proportion of high-quality exports in high-technology industries in the Philippines and Myanmar stand out.

10 In addition, the notion of differentiation also qualifies the classification of industries into technology categories, as the products exported by developed and emerging countries may differ in many ways (in terms of quality, branding, R&D, innovation, etc.).

11 See Kimura and Ando (2005) for a detailed exposition of fragmentation and its application to East Asia.

12 This index measures the extent to which products in the same class are exported and imported within an industry.

13 Intra-industry trade can also be driven by horizontal and vertical differentiation of final goods (similar goods of different varieties and goods of different quality, respectively). There is some debate in the literature regarding the extent to which intra-industry trade reflects the trade of intermediate goods along GVCs (see OECD, 2012).

14 This measure is higher if a country's intermediate exports are used in the assembly of final products which are subsequently re-exported, and is lower if the intermediates are used as inputs in domestically-consumed goods.

15 Some debate followed a 2001 *White Paper on International Trade* published by Japan's Ministry of Economy which, according to Kwan (2002, p. 3), suggested that "owing to the emergence of China in East Asia, there has been some disruption in the conventional orderly catch-up process of the flying-geese pattern led by Japan, followed by the NIEs, ASEAN members, and China. It argues that, through receiving direct foreign investment, China has been gaining competitiveness not only in labor-intensive products, but also IT and other technology-intensive products. As a result, the complementary international division of labor according to the level of economic development has given way to stiffer competition, including in high-tech industries. In the long-term, such increased competition. could bring overall benefits to the regional economy by improving productivity. In the short-term, however, increasing competition between China and ASEAN members could have negative repercussions on the latter, as illustrated by the 1997-98 Asian financial crisis."

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Chapter 2

Science and technology performance and linkages

Measuring countries' innovation performance and linkages is notoriously difficult, and even more so for non-OECD countries where much data is scarce and where traditional indicators, such as R&D expenditures, are perhaps less relevant. Acknowledging these limits, this chapter presents such indicators, where data is available, to assess the science and technology performance of Southeast Asian countries and the knowledge links between them and with other countries outside the region. A first section compares patterns of R&D expenditures and funding and R&D personnel across the region and beyond - essentially R&D inputs and capabilities. This is followed by a discussion of scientific and technological outputs across the region, in the form of publication and patent data and the impacts and specialisation patterns these suggest. A final section covers international linkages and knowledge flows - which are especially significant in catching-up contexts - specifically in the form of scientific collaboration, co-inventions, and technology flows.

2.1. Science and technology capabilities

R&D expenditures and funding

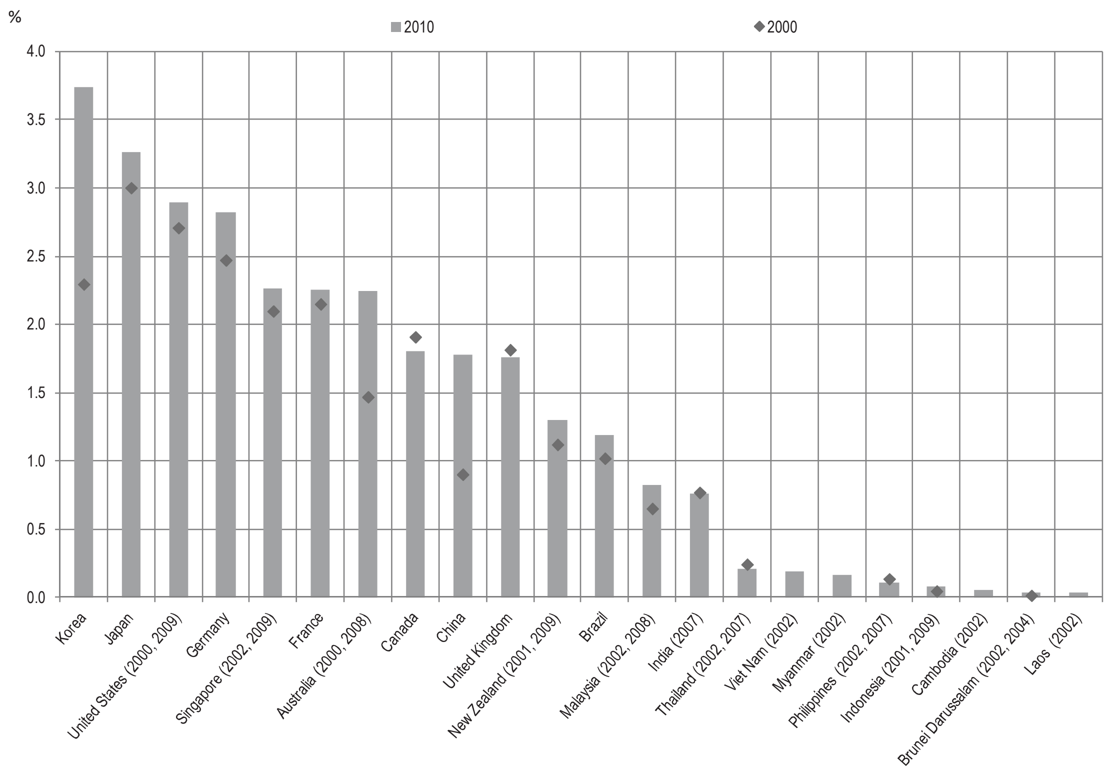
Of the different types of science, technology and innovation (STI) indicators, research and development (R&D) statistics are probably the most widely used. In recent years several emerging economies, the People's Republic of China in particular, have become significant actors in the global innovation system. There is evidence that R&D played a role in the takeoff of Asian economies such as China and Korea (Ang and Madsen, 2011). Along with other economic and social objectives, R&D aims to increase the stock of knowledge in order to introduce new applications and products, processes and services. R&D can enhance productivity in various ways: by widening the product portfolio or inputs available or simply by reducing the costs of existing products. As an outcome of R&D, profits may increase, and price reductions in input factors as well as the creation/ destruction of firms may occur. In addition, knowledge produced through R&D may spill over to other firms/sectors/countries and may in turn induce productivity effects (Hall, 2009).

However, R&D-related indicators are an imperfect measure of innovation inputs. Other types of expenditures, such as investment in tangible and intangible assets, labour training and public procurement may also contribute to the commercialisation of inventions. Moreover, the limitations of input measures as proxies for innovation underline the importance of also looking at other indicators such as output measures and evaluating the efficiency of innovation processes themselves (OECD, 2007).

R&D intensity (R&D expenditure as a percentage of gross domestic product [GDP]) is an indicator of an economy's relative degree of investment in the production of knowledge and is widely used for target-setting purposes. Southeast Asian economies differ widely in their R&D intensity (Figure 2.1). Singapore has the highest R&D intensity, with gross domestic expenditure on R&D (GERD) of 2.3% of GDP, followed by Malaysia with 0.8%. R&D spending in economies such as Thailand, Viet Nam, Myanmar and the Philippines account for 0.1-0.2% of GDP. Indonesia, Cambodia, Brunei Darussalam and Laos are among the least R&D-intensive countries in Southeast Asia, with GERD ranging between 0.03-0.08% of GDP. The OECD average stands at 2.4%, but Korea's and Japan's expenditures are well above this benchmark. China's R&D expenditures, which have doubled over the past decade, reached 1.7% of GDP in 2010. In emerging economies such as Brazil and India, R&D expenditures amounted to 1.2% and 0.8% of GDP, respectively. While the general trend in the OECD area is one of slowly increasing R&D intensities over time (OECD, 2012a, p. 21), Canada and the United Kingdom have experienced moderate declines, especially in the aftermath of the financial and economic crisis (OECD, 2012b). In Southeast Asia, comparisons over time are not possible for Viet Nam, Myanmar, Cambodia and Laos, as recent figures on R&D expenditures are not available. Thailand and the Philippines experienced moderate decreases in R&D intensity.

Figure 2.1. Gross domestic expenditure on R&D in Southeast Asia and in selected OECD and key emerging economies countries, 2010 or latest available year

As a percentage of GDP



Source: UNESCO, OECD, MASTIC.

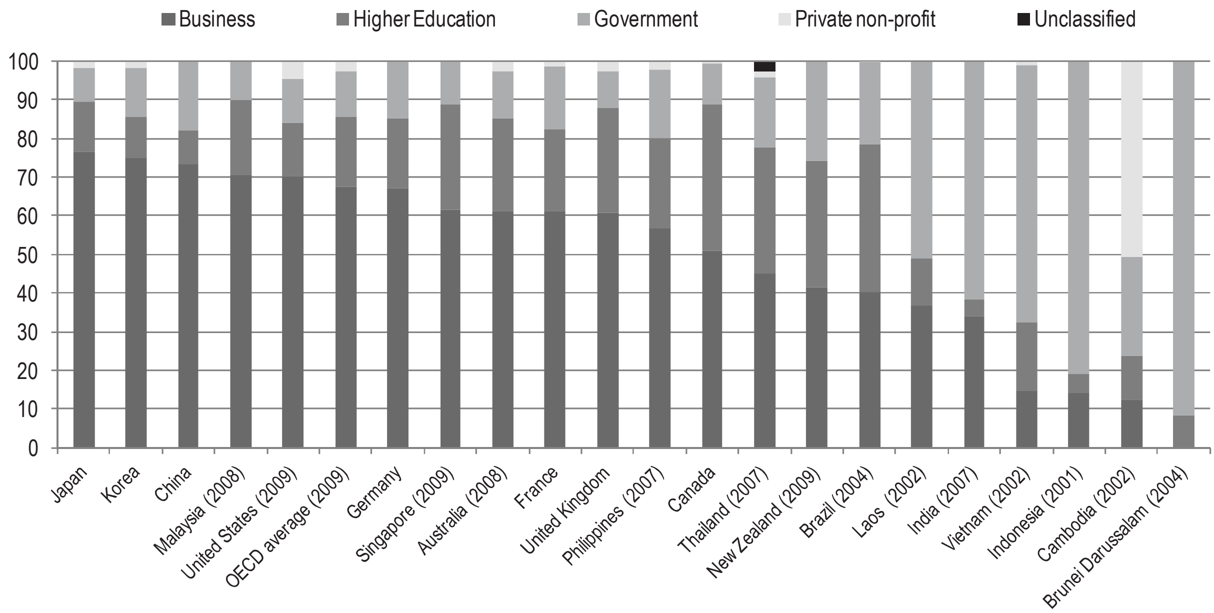
Performers of R&D

National data on R&D track spending patterns of all major performers in the overall R&D system: government, higher education, business and private non-profit institutions. The business sector is the main performer of R&D in many economies, especially the more advanced ones (Figure 2.2). In the OECD area it accounts for nearly 70% of the R&D performed. Japan's and Korea's business contribution to GERD is among the highest in the OECD area, with 77% and 75% respectively. In Southeast Asia, Malaysia's business sector accounts for the largest share of GERD, with around 71% of total R&D in 2008, followed by Singapore (62%) and the Philippines (57%).

In contrast, in Indonesia, Brunei, Viet Nam and Laos government institutes conduct the largest share of GERD, significantly more than the business sector. In Indonesia, for example, government institutes perform 81% of GERD. Most countries that are now at the technological frontier have experienced a slow shift from a system in which government institutes are the main public performers of research to a system in which universities are central. Countries differ, but the direction of the trend is clear in most OECD countries. In Southeast Asia, however, R&D expenditures in the higher education sector vary strongly across countries. Higher education has the highest shares of GERD in Thailand (33%) and Singapore (27%) and the lowest in Indonesia (5%). Cambodia has a somewhat different pattern of R&D expenditures: private non-profit organisations such as international aid agencies and non–governmental organisations account for the bulk of GERD.

Figure 2.2. Gross expenditures on R&D by performing sector in Southeast Asia and in selected OECD and key emerging economies, 2010 or latest available year

As a percentage of GERD



Source: UNESCO, OECD, MASTIC.

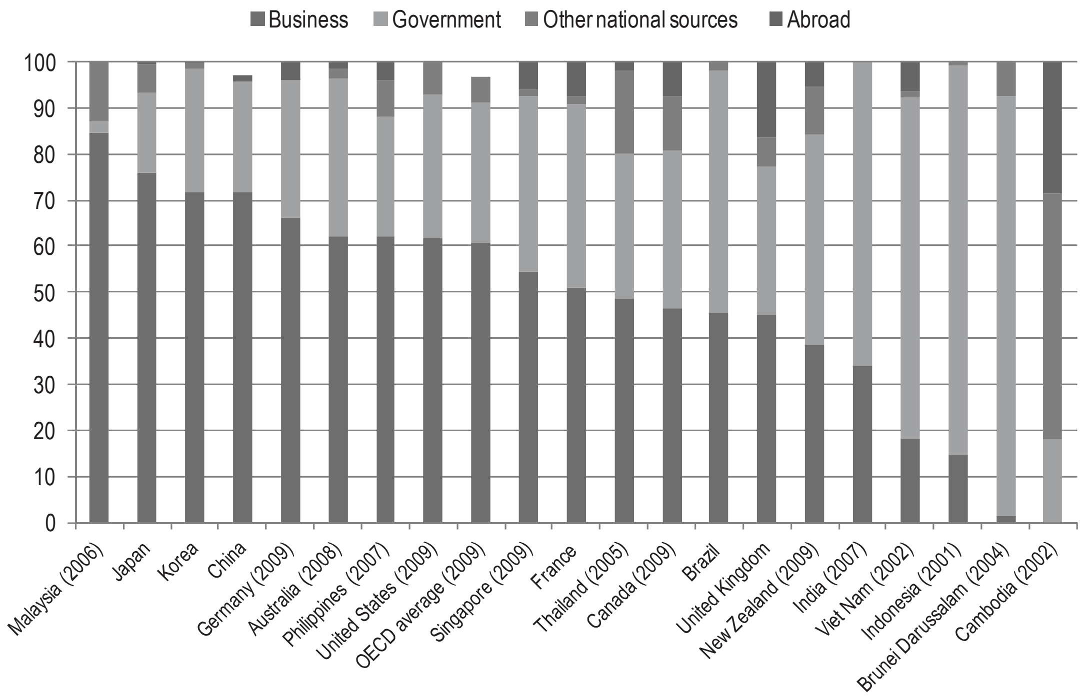
Sources of R&D funding

The distribution of national R&D funds by source can be a useful indicator of government and business commitment to R&D, of the prominence of other national sources and of funding from abroad. With regard to funding of R&D, the business sector is the dominant source for all OECD countries except New Zealand, and for Malaysia, China, Singapore and the Philippines (Figure 2.3). Funding for about 85% of Malaysia's total domestic R&D in 2006 came from the business sector. The corresponding figures for Singapore and the Philippines are also high, in the 56-62% range. R&D funding from the business sector is notably lower, but still dominant, in Thailand, at 49%.

While government funding of R&D is the second major source in most OECD countries, it is the most common funding source in Brunei, Indonesia and Viet Nam. There are some variations in funding sources however; they illustrate the heterogeneity of countries' R&D systems. In addition to government funding, funding from abroad refers to funding from businesses, universities, governments, and other organisations located outside of the country. Funders from abroad accounted for around one-third of Cambodia's total national R&D; this corresponds to the R&D-performing role of international aid agencies and non–governmental organisations. Funding from abroad is also above average for Malaysia and Thailand, reflecting the important commitments of multinational affiliates there.

Figure 2.3. Gross expenditure on R&D by funding source in Southeast Asia and in selected OECD and key emerging economies, 2010 or latest available year

As a percentage of GERD



Source: UNESCO, OECD.

Supply of R&D personnel

The stock of human capital – defined as the knowledge, skills, competences and attributes that facilitate the creation of personal, social and economic well-being – is an essential determinant of a country's capabilities to innovate. R&D personnel include all persons employed directly in R&D activities, such as researchers, technicians and support staff. R&D personnel constitute an important part of a country's human capital, since the effectiveness of R&D expenditures depends on the supply, allocation and efficiency of the human resources directly involved in performing R&D. The number of R&D personnel is therefore an important indicator of a nation's scientific and technological capabilities; a lack of domestic human capital may undermine otherwise promising development paths. Quantities and types of R&D personnel may affect the rate of innovation, but cross-country variation in skills and measurement difficulties limit the explanatory power of such indicators. Moreover, without controlling for other influences on innovation, it may be difficult to spot clear relationships at this level of analysis (OECD, 2011a).

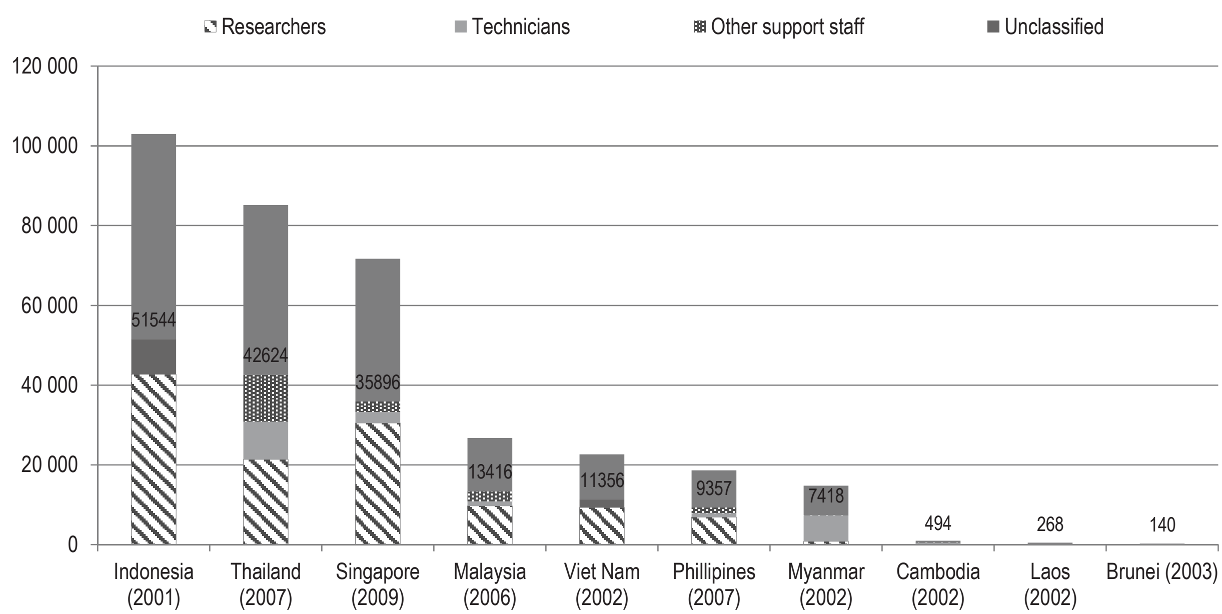
The available data show that most R&D personnel in Southeast Asia are in Indonesia, Thailand and Singapore (Figure 2.4). R&D personnel in Malaysia, Viet Nam, the Philippines and Myanmar range from 7 000 to 13 000 (in full-time equivalents) to a few hundred in Cambodia, Laos and Brunei Darussalam. However, the latest figures for some countries are quite old and, given the growth rates in R&D personnel, absolute numbers are likely to have changed significantly. In Indonesia, for example, the R&D workforce shrank by 9% from 2000-01, while those of Singapore, Thailand and Malaysia increased at average rates of 9% (1999-2009), 8% (1999-2007) and 4% (2000-06), respectively. In this regard, the latest data available for Malaysia (2008) list 22 287 R&D personnel, a significant increase from 2006 (see Chapter 7). An insight into the relative proportions of researchers, technicians and other supporting occupations is also provided in Figure 2.4. The proportions of R&D personnel correspond to international standards, except in Myanmar.

Figure 2.5 looks at an important subgroup of R&D personnel: researchers. Researchers are defined as "professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and in the management of the projects concerned" (OECD, 2002). In 2010, more than 4.2 million researchers were engaged in R&D in the OECD area, or 7.6 researchers per thousand employees, a significant increase from 6.6 per thousand in 1999 (OECD, 2011b). Among Southeast Asian countries, only Singapore employed more researchers per thousand employees than the OECD average. In contrast, other Southeast Asian countries' employment shares are lower than those of China or Brazil. Malaysia is the country with the proportion of researchers per thousand closest to China's, followed by Brunei and Thailand.

There is great diversity in the range of R&D activities undertaken and, consequently, considerable diversity in the occupational structure of researchers. The distribution of researchers across sectors of performance broadly aligns with the distribution of R&D expenditures by sector (Figure 2.6). However, Malaysia shows strong structural variations. Although the Malaysian private sector accounted for 85% of R&D expenditure in 2006, it remained a relatively minor employer of researchers (36%).

Figure 2.4. R&D personnel by occupation in Southeast Asia, latest available year

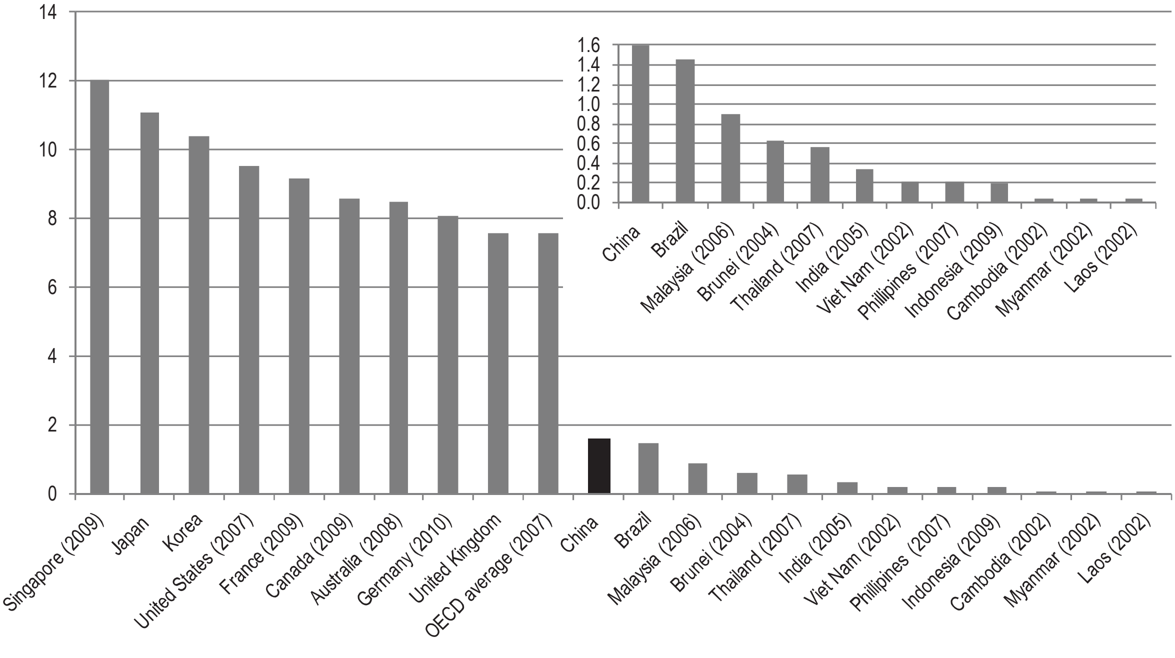
In full-time equivalents



Source: UNESCO, OECD.

Figure 2.5. Researchers in Southeast Asia and in selected OECD and emerging economies, 2010 or latest available year

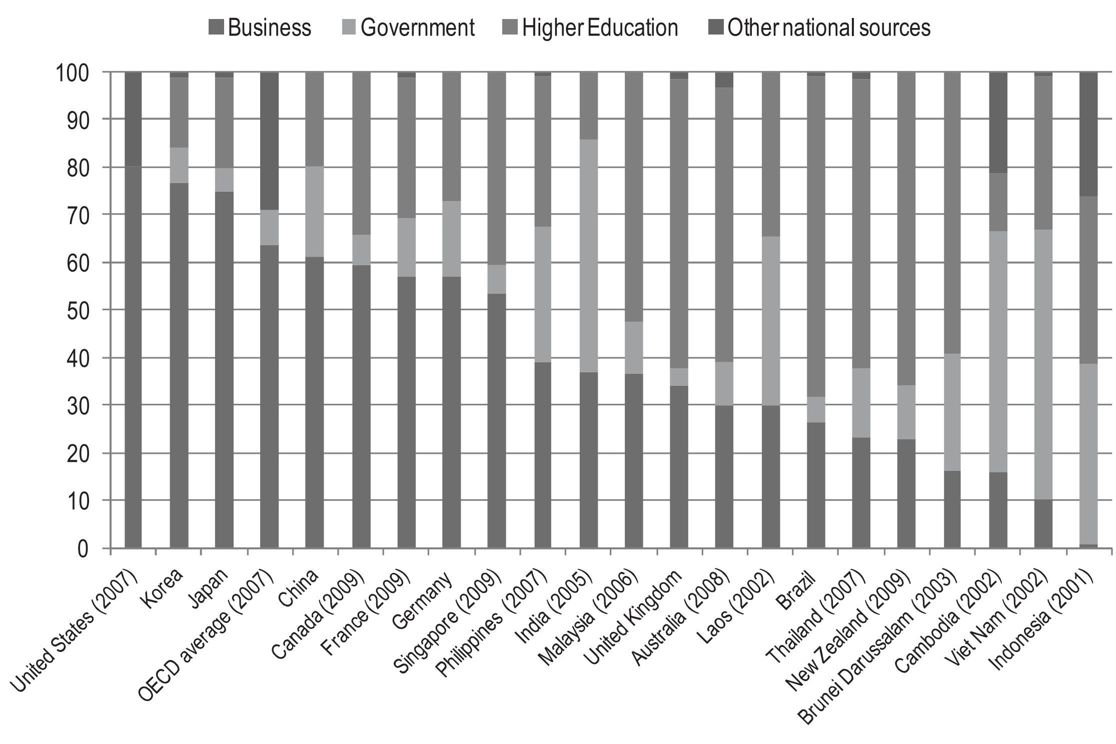
Per thousand employment



Source: UNESCO, OECD.

Figure 2.6. Researchers by R&D-performing sector in Southeast Asia and in selected OECD and key emerging economies, 2010 or latest available year

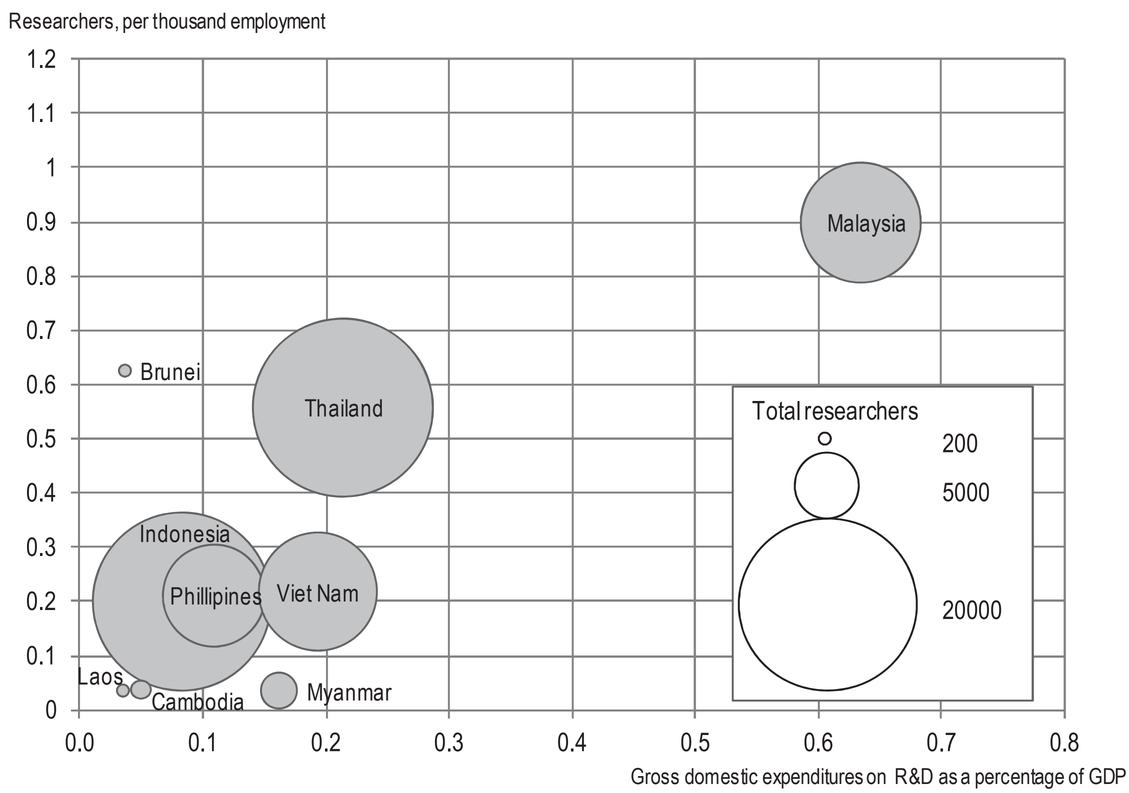
As a percentage of national total



Source: UNESCO, OECD.

Trends in the number of researchers typically follow patterns of R&D expenditure since salaries represent a sizeable share of R&D expenditure. This explains the close relationship between R&D as a percentage of GDP and number of researchers as a percentage of total employment (Figure 2.7). In practice 50% or more of R&D investments are the wages and salaries of scientists and engineers (Hall, 2009). Among Southeast Asian countries, Singapore has the highest research intensity on both measures, followed by Malaysia. Myanmar, and to a much lesser extent Viet Nam, have fewer researchers than suggested by their R&D intensity, whereas Brunei and Thailand have considerably more. Variations can be related to various factors: differences in the price of R&D inputs, such as researcher costs, *e.g.* if few researchers are available, researcher salaries may rise (Goolsbee, 1998); the pattern of R&D specialisation and the requirements in terms of capital expenditure; and the possibility that some countries may be developing their research infrastructure for future use (OECD, 2011b).

Figure 2.7. Researchers in selected Southeast Asia countries, latest available year



Note: Indonesia (2009), Viet Nam (2002), Thailand, 2007, Malaysia (2006), the Philippines (2007), Myanmar (2002), Cambodia (2002), Brunei (2004), Laos (2002); excluding Singapore.

Source: UNESCO.

2.2. Science and technology performance

Scientific output

Published articles are a major output of scientific research and their numbers are used extensively to assess different facets of scientific activity (Box 2.1). Singapore dominates article output in Southeast Asia, with around 200 000 articles authored or co-authored during 2000-10. This represents 44% of the regional total (Figure 2.8). During the same period, around 107 000 articles were published by authors in Thailand, closely followed by authors in Malaysia with around 104 000. The other countries in the region account for far fewer publications.

When looking at trends in publication over time, it is important to bear in mind that the number of articles published worldwide has increased substantially, particularly over the last decade or so. This is highlighted in Figure 2.9, which shows that more than 1.8 million articles were published worldwide in 2010. Viewed regionally, Figure 2.10 shows that the dominance of the United States and the EU has declined in recent years as the numbers of publications from East Asia, notably China, have increased dramatically. In Southeast Asia, annual growth in scientific publications averaged 14% over the 2000s, rising from around 19 000 articles in 2000 to more than 80 000 in 2010. This growth outstripped the worldwide growth rate, so that the Southeast Asia region has increased its world share of scientific articles from 2.5% to 4% over the same period (Figure 2.11).

Publication growth rates of countries in the region have varied considerably (Figure 2.12). The least developed countries, Cambodia and Viet Nam, have shown impressive growth from low starting points. By contrast, the region's most developed country, Singapore, had the most modest growth rate at an average 9% a year, though it still outpaced most OECD countries. Of all the countries in the region, Malaysia has exhibited the most impressive growth, particularly since 2007. By 2010, it had overtaken both Thailand and Singapore in number of articles published annually (Figure 2.13). Publications in information science and technology, starting from a very low base in 2000, have provided one of the largest contributions to this growth.

Overall growth in the number of Malaysia's articles can be at least partly attributed to a recent expansion in numbers of R&D personnel – from around 13 000 full-time equivalents in 2006 to around 22 000 in 2008 (MASTIC, 2012). A large share of these personnel (45%) are based in universities (Day and Muhammad, 2011), where the incentives to publish in academic journals are greatest. Although less spectacular, Thailand's impressive growth rate can be explained by similar factors, as the majority of its R&D personnel are based in universities (Figure 2.6). By contrast, Indonesia's performance appears sluggish: although it employs the largest number of R&D personnel in Southeast Asia, it accounted for less than 5% of the region's scientific publications over 2000-10 (Figure 2.8). Moreover, growth in the number of publications is comparatively modest (Figure 2.12). At least part of the explanation for this pattern is the location of R&D personnel: only about one-third of researchers are based in universities. Also significant is the balance of expenditures on R&D between public research institutes and universities, with the former spending significantly more on R&D than the latter (see Chapter 4). Incentive systems in public research institutes tend to place less emphasis on academic publication and probably contribute to Indonesia's weaker performance.

Box 2.1. Bibliometric data and approach

The last decades have seen a steady increase in the growth of assessments of science at different levels in the science system, and by different actors within that system. Bibliometrics has become a generic term for a range of specific measurements and indicators that attempt to measure the output of scientific and technological research through data derived from scientific literature and patents.

A range of bibliometric indicators is used to analyse activity and impact profiles in science and technology. Bibliometric analysis uses parameters such as the publication output (productivity/activity), co-authorship (collaboration), citations rates (reception/impact), co-occurrences of words/classifications/citations (cognitive structures) or a combination thereof. The following bibliometric approaches are used in this chapter:

***Publication activity*: **Full-counting. In the full-counting method, each paper is counted once for each entity listed in the address field. For example, if a paper is authored by two researchers from Thailand, one from Laos and one from Germany, this paper is counted once for each country.

***Impact*:** Average of relative citations (ARC): This is an indicator of the scientific impact of papers produced by a given entity (*e.g.* on the world, a country, an institute) relative to the world average (*i.e.* the expected number of citations). The number of citations received by each publication is counted for the year in which it was published and for two subsequent years. To account for different citation patterns across fields and subfields of science (*e.g.* there are more citations in biomedical research than in mathematics) and for differences in the age of publications (e.g. older papers have accumulated citations over a longer period), each publication's citation count is divided by the average citation count of all publications of the corresponding document type (*i.e.* a review is compared to other reviews, whereas an article is compared to other articles) that were published the same year in the same subfield to obtain a relative citation count. When the ARC is above 1, it means that an entity scores better than the world average; when it is below 1, it means that on average, an entity publishes papers that are not cited as often as the world level.

***Specialisation*:** The specialization index (SI) is an indicator of research intensity in a given entity (*e.g.* an institute) for a given research area (*e.g.* a field), relative to the intensity of a reference entity (*e.g.* the world, or the entire output as measured by the database) for the same research area.

$$\mathbf{SI} = \frac{(\mathbf{X_S}/\mathbf{X_T})}{(\mathbf{N_S}/\mathbf{N_T})}$$

XS = Publications from entity X in a given research area (*e.g.* papers by the European Union in Economics & Business);
XT = Publications from entity X in a reference set of papers (*e.g.* total papers by the European Union);
NS = Publications from reference entity N in a given research area (*e.g.* world papers in Economics & Business);
NT = Publications from reference entity N in a reference set of papers (*e.g.* total world papers).

International collaboration: A co-publication is defined as a publication co-authored by different authors. The number of co-publications with co-authors from at least two different countries gives the number of international collaborations. The number of international collaborations of an institute divided by its total scientific output gives the international collaboration rate.

Collaboration index (CI): There is often a power law relationship between an entity's (*e.g.* country's) number of papers and its number of co-publications (or collaborations). In cases where a power law relationship exists between two variables, it is better to use scale-independent indicators than percentages to take account appropriately of the relative size of the entities compared; percentages, such as the percentage of publications authored in collaboration, assume a linear relationship. When both indicators are log transformed, power law relationships can be analysed using linear regression models. Therefore, the approach used to compute the CI consists of performing a log-log linear regression analysis between the number of co-authored publications and the number of publications at a specific aggregation level (*e.g.* countries) in order to estimate the constants (a and k) of the power law relationship:

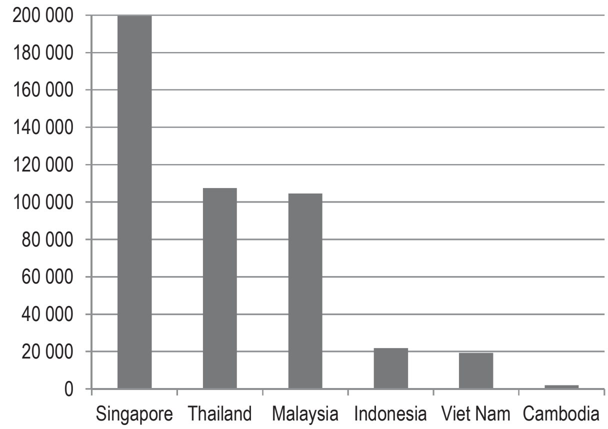
$$Expp\ (M)\ =\ a * (M\hat{}k)$$

where Expp = the expected number of co-authored papers of an entity (*e.g.* a country) based on the regression model; and M = the observed number of publications of the entity (*e.g.* country) being measured. The log-log linear regression analysis is performed using reduced major axis (RMA) to estimate the constants (a and k) of the regression model. The indicator is simply the ratio of observed-to-expected co-authored publications. When the indicator is above 1, an entity produces more publications in collaboration than expected based on the size of its scientific production, while an index value below 1 means the reverse.

Database: Access to a database containing the most complete bibliographic information on scientific journals published worldwide is essential for the production of bibliometric data. In this study, the Scopus database (by Elsevier) was used.

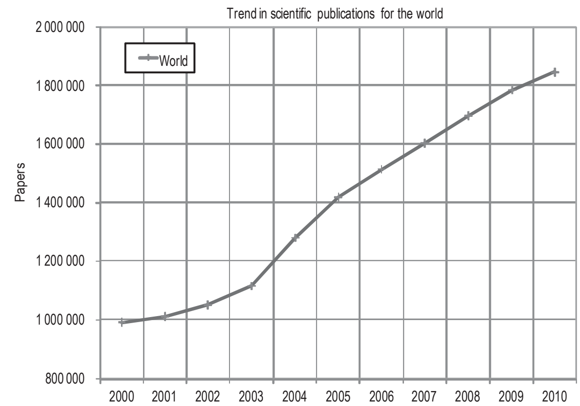
Source: Okobu (1997), Hinze and Glänzel (2012), and Science Metrix.

Figure 2.8. Total scientific publications in Southeast Asia, 2000-10



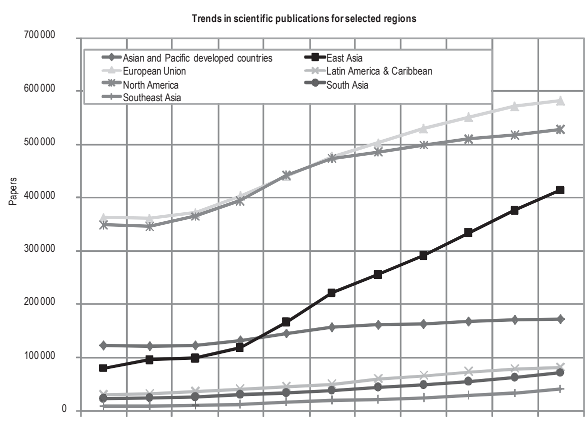
Source: Science-Metrix using the Scopus (Elsevier) database.

Figure 2.9. World scientific publications, 2000-10



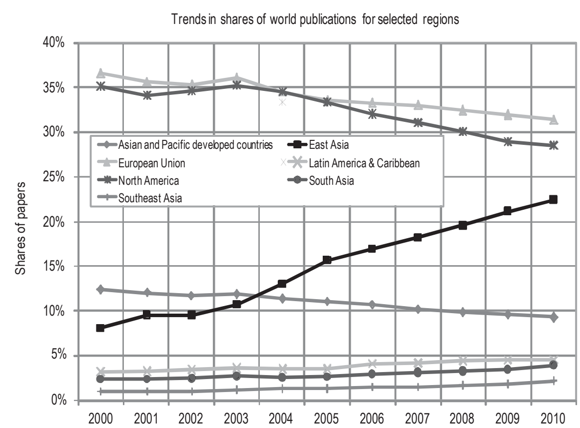
Source: Science-Metrix using the Scopus (Elsevier) database.

Figure 2.10. Scientific publications for selected regions, 2000-10



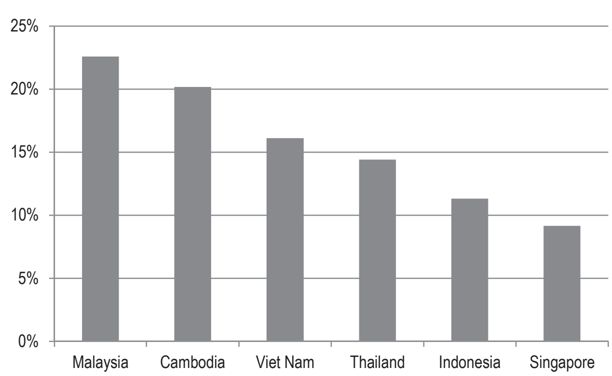
Source: Science-Metrix using the Scopus (Elsevier) database.

Figure 2.11. Trends in shares of world publications for selected regions, 2000-10



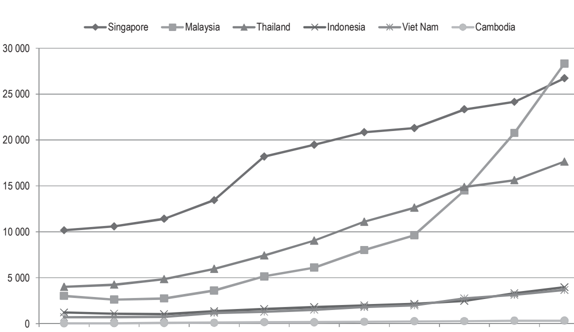
Source: Science-Metrix using the Scopus (Elsevier) database.

Figure 2.12. Scientific publications, average annual growth rates, 2000-10



Source: Science-Metrix using the Scopus (Elsevier) database.

Figure 2.13. Scientific publications in Southeast Asia, 2000-10



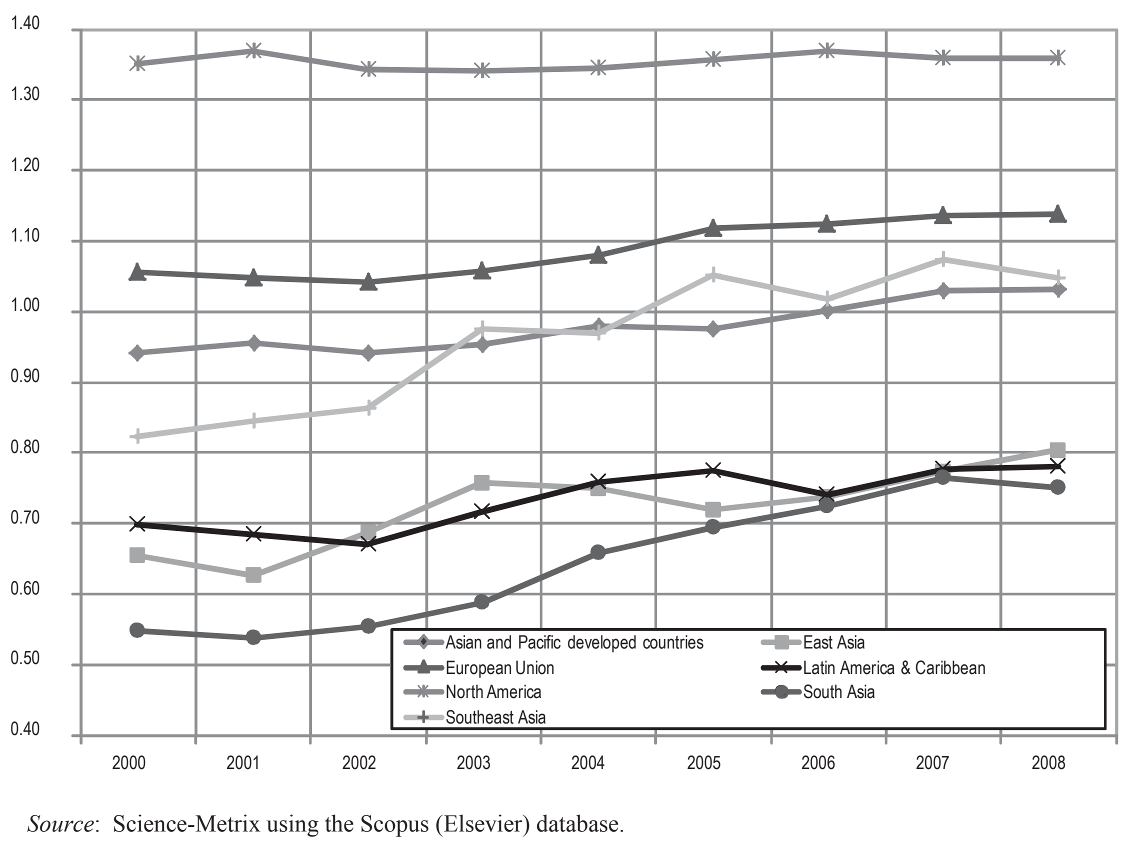
Source: Science-Metrix using the Scopus (Elsevier) database.

Impact and specialisation

Although it is difficult to measure the quality or importance of scientific publications, the number of citations they receive from other authors has become an internationally used measure of their impact. In this report, average relative citations (see Box 2.1) are used as a measure of scientific impact and research excellence. As Figure 2.14 shows, the average relative citations for North American and European authors are above the world average. The relative impact of scientific publications from Southeast Asia was below the world average in 2000, but by 2010 it was above the world average, surpassing even Asian-Pacific developed countries. This evolution can be mainly attributed to Singapore, given its volume of publications and its high average relative citations value (Figure 2.15). Malaysia's low average relative citation value should be interpreted with particular care: 47% of its articles for 2000-10 were published in 2009-10 (27% were published in 2010 alone), giving little time for citations to accrue, even within the narrow three-year citation window used here (see Box 2.1). The impact of its publications is therefore likely underestimated in Figure 2.15. A similar, though probably less pronounced effect, may also apply to Indonesia, with around one-third of its articles for 2000-10 published in 2009-10.

Figure 2.14. Scientific impact of selected regions, 2000-10

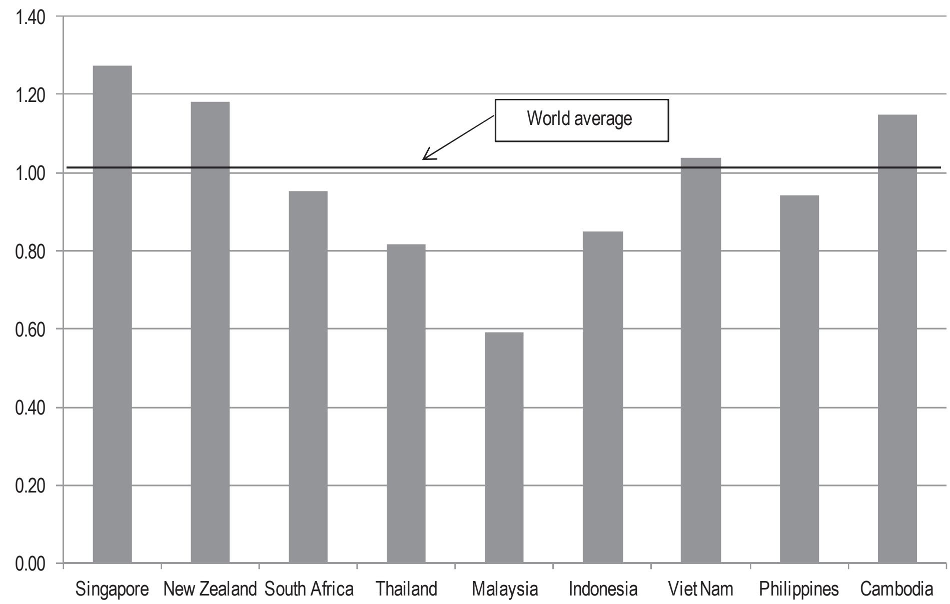
Average of relative citations (ARC)



Source: Science-Metrix using the Scopus (Elsevier) database.

Figure 2.15. Scientific impact of selected countries in Southeast Asia, 2000-10

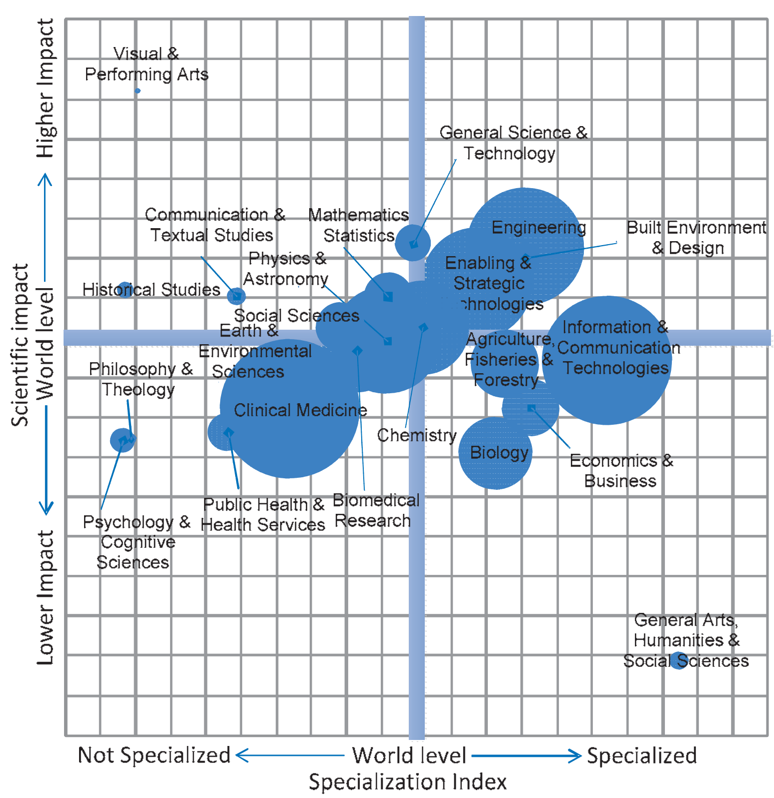
Average of relative citations (ARC)



Source: Science-Metrix using the Scopus (Elsevier) database.

Figure 2.16. Positional analysis of Southeast Asia, 2000-10

Number of papers (circles), scientific impact (ARC), specialisation index (SI)



Source: Science-Metrix using the Scopus (Elsevier) database.

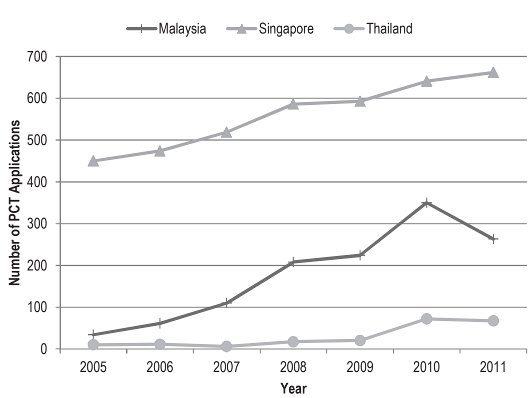
Figure 2.16 shows Southeast Asia's relative impact and specialisation pattern in different subject fields. Taken together, the region is relatively specialised in engineering, enabling and strategic technologies, and environmental sciences. Papers in these fields are also more frequently cited than the world average. The region is also relatively specialised in information and communication technology (ICT), biology and agriculture sciences, though citations are below the world average in these fields.

Patents

Patents are another way to measure R&D output. When using patent statistics, it is important to recall that not all inventions are patented. Other more informal modes are trade secrets, lead time in research and the complexity of inventions. Furthermore, different fields and sectors demonstrate a varied proclivity to patent. Figure 2.17 shows the number of patent applications in selected Southeast Asian economies under the Patent Cooperation Treaty (PCT). Singapore is ahead in the number of PCT applications, followed some way behind by Malaysia and Thailand. The other countries in the region have few PCT applications: for example, in 2011, there were 21 from the Philippines, 18 from Viet Nam and 13 from Indonesia (Figure 2.18).

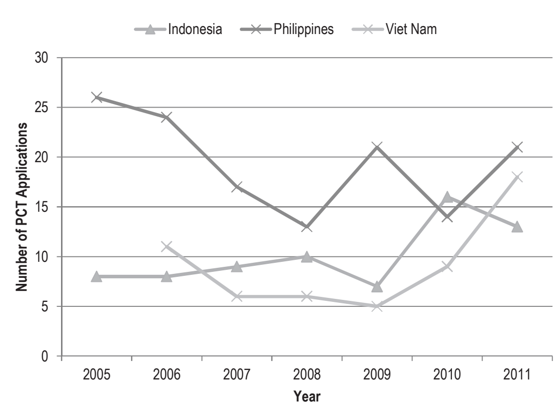
As in the case of published articles, the number of PCT applications has increased over time worldwide. In general, PCT data indicate that applications in emerging economies, such as Brazil, China and India, are increasing, while those in OECD countries are little changed, with the notable exceptions of Korea and Japan. In Southeast Asia, Malaysia shows strong growth in patenting, though from a low base – the average annual growth rate was 21% during 2000-09 (Figure 2.19). Annual growth rates in other Southeast Asian countries, such as Singapore (8%), Thailand (6.5%), and the Philippines (3.2%), were less spectacular but still above the OECD average of 3% a year. Indonesia's patent filings showed a downward trend of 0.3% for the same period.

Figure 2.17. PCT patent applications in Singapore, Malaysia and Thailand, 2005-11



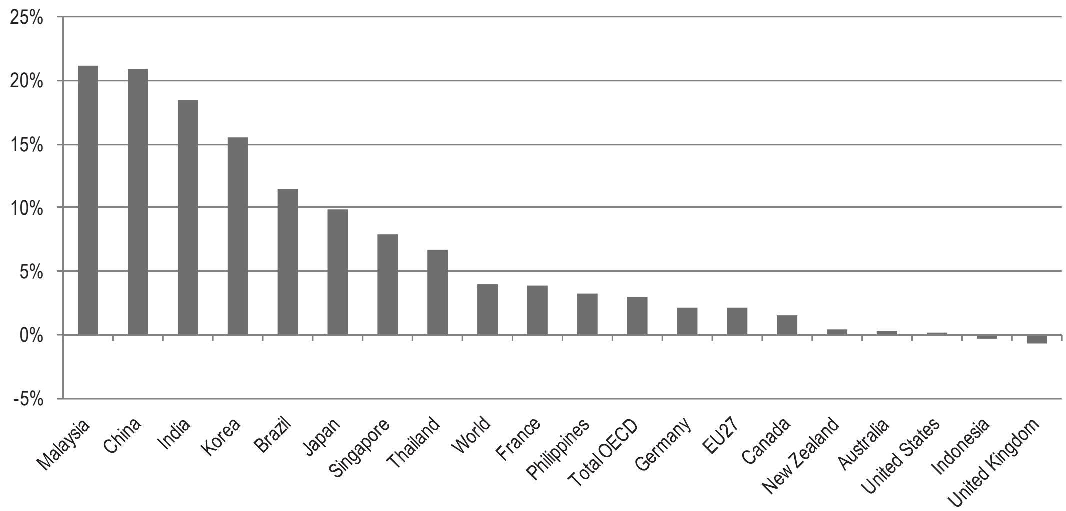
Source: WIPO Statistics Database, September 2012.

Figure 2.18. PCT patent applications in the Philippines, Viet Nam and Indonesia, 2005-11



Source: WIPO Statistics Database, September 2012.

Figure 2.19. PCT patent applications, average annual growth rates, 2000-09



Source: OECD Patent Database.

2.3. Linkages and knowledge flows

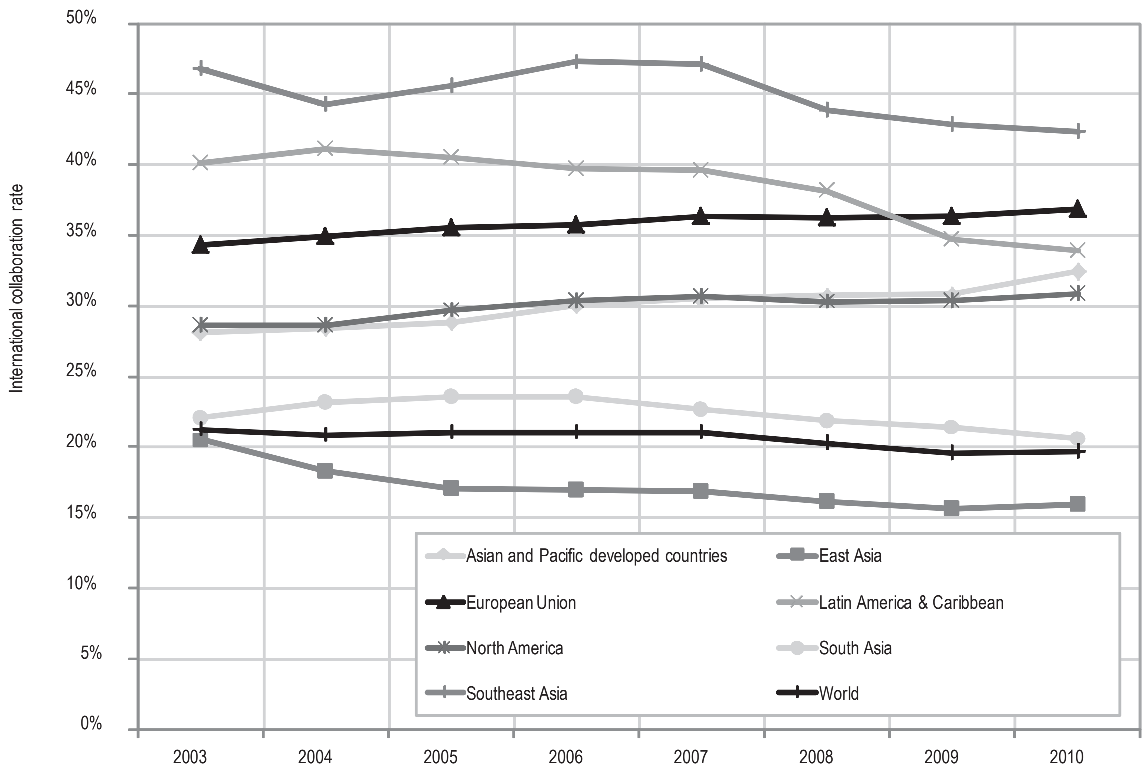
One of the key functions of R&D is to facilitate the identification, adjustment and assimilation of economically useful innovations originating from outside the country's borders. A country's ability to generate new-to-the-world innovations crucially depends upon its capacity to absorb and build upon the body of existing ideas, most of which are inevitably foreign. Thus, international knowledge linkages are central to the development of a national innovation system (OECD, 1997) and are often viewed as a catalyst for economic development (Coe et al., 1997). Such foreign technology and knowledge linkages may include FDI, licensing, international co-invention, labour migration and international trade. Non-market interactions, such as scientific collaboration and aid from governments in the form of development assistance, also play an important role in technology transfer and in capacity building.

Scientific collaboration

International scientific collaboration is important for capacity building and for fostering excellence, for integration into global knowledge production networks, and therefore for the relevance of national research to frontier-shifting scientific debate. Indicators of scientific collaboration include measures derived from registries of collaborative research projects (such as the EU's Framework Programme for Research or the EUREKA initiative) and bibliometric data derived from databases of scientific publications. Though not without drawbacks, such data are a unique source of information in terms of coverage across countries and over time. Internationally co-authored publications have been shown to attract a greater number of citations (Glänzel et al., 1999).

The ratio of articles with co-authors based abroad to total articles produced in a country is a commonly used indicator of international scientific collaboration (see Box 2.1). Figure 2.20 presents collaboration rates for selected regions during 2003-10. On average, Southeast Asia had the highest rates of international scientific collaborations. The Southeast Asian trend decreased only slightly from 47% in 2003 to 43% in 2010, mirroring the moderate downward trend globally. However, the use of co-authorship for comparing collaboration across countries and regions is limited, as it is very sensitive to scale: smaller countries tend to have a higher international collaboration rate than larger ones. Table 2.1 presents a size-adjusted index of international scientific collaboration. It shows that over the eleven-year period from 2000 to 2010, Viet Nam, Indonesia and Cambodia were the Southeast Asian countries with the highest propensity to collaborate. Scientists in Singapore, Malaysia and Thailand had a lower propensity to collaborate internationally, but still higher than their counterparts in Korea (0.70), Japan (0.69), Chinese Taipei (0.54) and China (0.44).

Figure 2.20. International collaboration of selected world regions, 2003-10



Source: Science-Metrix using the Scopus (Elsevier) database.

Table 2.1. Size-adjusted index of international scientific collaboration of Southeast Asian countries, 2000-10

Country	Collaborations	All papers	Collaboration rate	Collaboration index
Viet Nam	7.367	9.724	76%	1,44
Indonesia	8.094	10.970	74%	1,42
Cambodia	896	992	90%	1,38
Philippines	5.050	7.906	64%	1,19
Singapore	42.667	99.840	43%	1,01
Thailand	23.223	53.717	43%	0,97
Malaysia	17.360	52.242	33%	0,74

Source: Science-Metrix using the Scopus (Elsevier) database.

In addition, Tables 2.2 and 2.3 present the share of bilateral co-publications between a country and its peers in that country's total number of co-publications. The pairings of Cambodia and Thailand, the Philippines and Thailand, Malaysia and Singapore, and Viet Nam and Cambodia are especially strong. The figures highlight the unequal weight that links have for different countries: the link accounts for a greater percentage of Cambodia's international collaboration total (14.6%) than it does of Thailand's (0.6%). Indeed, Cambodia's international collaborations are more likely to be with one of its Southeast Asian neighbours than those of any other country in the group. On the other end, Southeast Asian partners account for a very small share of Singapore's total international collaborations.

Table 2.3 presents the same indicator for Southeast Asian countries and a selection of other countries with developed or rapidly developing innovation systems. In general, the strength of intra-regional co-authorship linkages is weaker than linkages with other countries. The United States, Japan, Australia and the United Kingdom were the leading collaboration partners. About a quarter of Singapore's international collaboration involved a partner from China, while about a fifth of Thailand's international collaborations involved a partner from Japan. Cambodia and Indonesia share notable links with Australia.

Table 2.2. Bilateral co-publications between Southeast Asian countries as a share of total international co-publications, 2000-10

Country	Cambodia	Indonesia	Malaysia	Philippines	Singapore	Thailand	Viet Nam
Cambodia		3.5	4.6	5.7	1.8	14.6	9.3
Indonesia	0.4		10.7	2.6	2.7	4.3	1.9
Malaysia	0.2	5.0		1.4	5.1	4.5	0.8
Philippines	1.0	4.2	4.9		4.6	6.7	3.1
Singapore	0.0	0.5	2.1	0.5		1.1	0.4
Thailand	0.6	1.5	3.4	1.4	1.9		1.9
Viet Nam	1.1	2.1	1.8	2.1	2.2	6.0	

Source: OECD and Science-Metrix using the Scopus (Elsevier) database.

Table 2.3. Bilateral co-publications between Southeast Asian and selected economies as a share of total international co-publications of Southeast Asian economies, 2000-10

Economy	Australia	Brazil	Canada	China	France	Germany	Japan	Korea	Chinese Taipei	United Kingdom	United States
Cambodia	13.3	0.8	2.8	4.5	17.6	2.9	14.0	2.0	1.8	12.5	25.6
Indonesia	15.1	1.1	3.3	3.2	5.4	8.0	27.0	3.2	1.7	8.2	18.7
Malaysia	8.9	1.0	2.9	7.9	2.4	3.0	10.2	2.4	1.4	15.8	11.7
Philippines	12.4	2.0	4.2	9.2	5.5	7.2	24.5	4.6	4.4	8.7	32.1
Singapore	10.5	0.5	4.9	24.1	3.2	4.6	4.9	2.5	2.7	10.2	29.3
Thailand	9.4	0.9	4.1	4.4	5.2	4.9	21.4	2.5	1.8	12.2	33.4
Viet Nam	9.3	1.1	2.5	4.6	14.4	7.0	18.5	11.0	2.9	9.4	15.1

Source: OECD and Science-Metrix using the Scopus (Elsevier) database.

Scientific collaboration is a complex phenomenon with multifaceted motivations. For example, scientists may be motivated by a desire to advance knowledge and learning, enhance research productivity, access expertise, create a network, or access funding streams (Beaver, 2001). In addition, geographical proximity (as in the case of Cambodia and Viet Nam) and similar scientific and/or technological specialisation profiles may help explain the extent of scientific collaboration. Social and cultural commonalities and a shared language may mitigate barriers for collaboration (as in the case of Singapore and China).

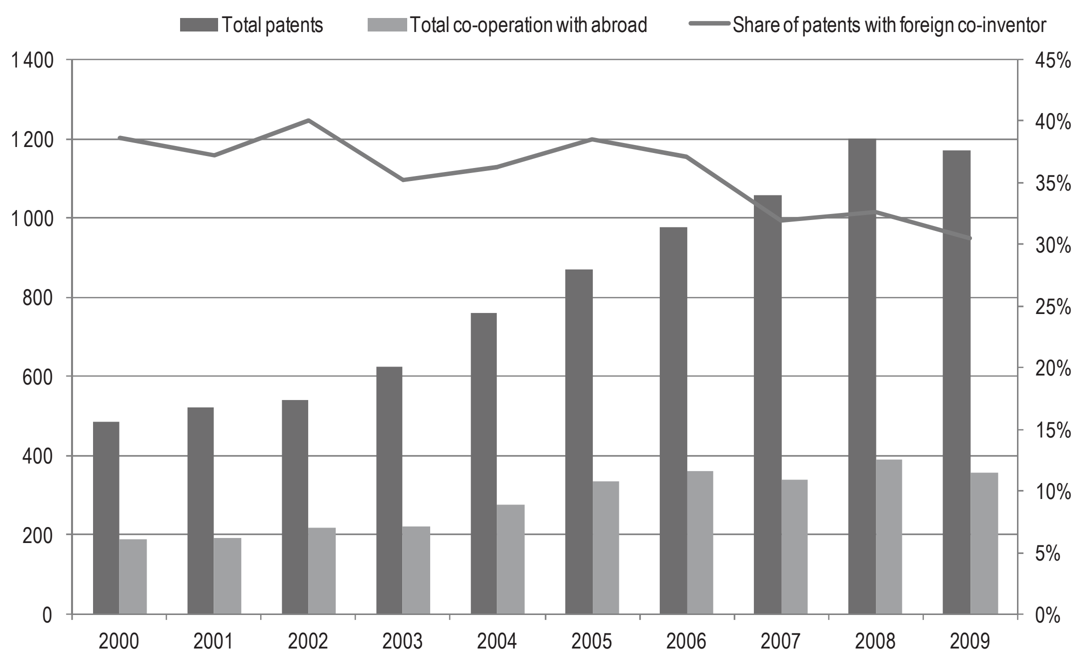
Co-inventions

Patent documents contain names and addresses of inventors and applicants (i.e. the holders of the patent rights). Information on the location of inventors can be used to trace the process of international collaboration in the production of technology. Co-inventions are measured as the share of patent applications with at least one co-inventor located abroad in total patents invented domestically. To the extent that international co-patenting corresponds to meaningful research collaboration it can signal cross-border knowledge flows that are essential to the development of a country's national innovative capacities. However, a non-negligible part of such co-inventions may reflect the activities of multinational enterprises, and in particular intra-firm research collaboration between affiliates, involving little or no knowledge transfer to the domestic economy. This shows the need for caution in the interpretation of this indicator in countries with substantial foreign direct investment.

In principle, co-invention rates can be affected by many things: formal R&D co-operation and knowledge exchange among inventors located in different countries, a country' skills endowment, intellectual property rights regimes, joint research ventures between firms and institutes of various types (*e.g.* universities, public research institutes), research collaboration by foreign multinational subsidiaries (*e.g.* strong US-Japanese link), technological and geographical proximity, language, and the international / inter-sectoral mobility of scientists (*e.g.* United States and possibly European countries).

As the total number of patents increased in Southeast Asia over 2000-09, so did the share of patenting involving at least one foreign inventor (Figure 2.21). International collaboration in the production of technology leading to co-inventions grew at 6.6% a year, while the number of total patent applications grew by 9.2% a year. As a result, the share of patents with a foreign co-inventor in the region decreased from 38.6% in 2000 to 30.5% in 2009. Co-invention shares usually decrease with the rise in the level of GDP and R&D intensity (Guellec and van Pottelsberghe, 2001), which may explain the recent decline in co-inventions in Southeast Asia. In OECD countries, instead, the share of patents with a foreign co-inventor remained stable at 7.5%.

Figure 2.21. Patents with foreign co-inventor in Southeast Asia, 2000-2009



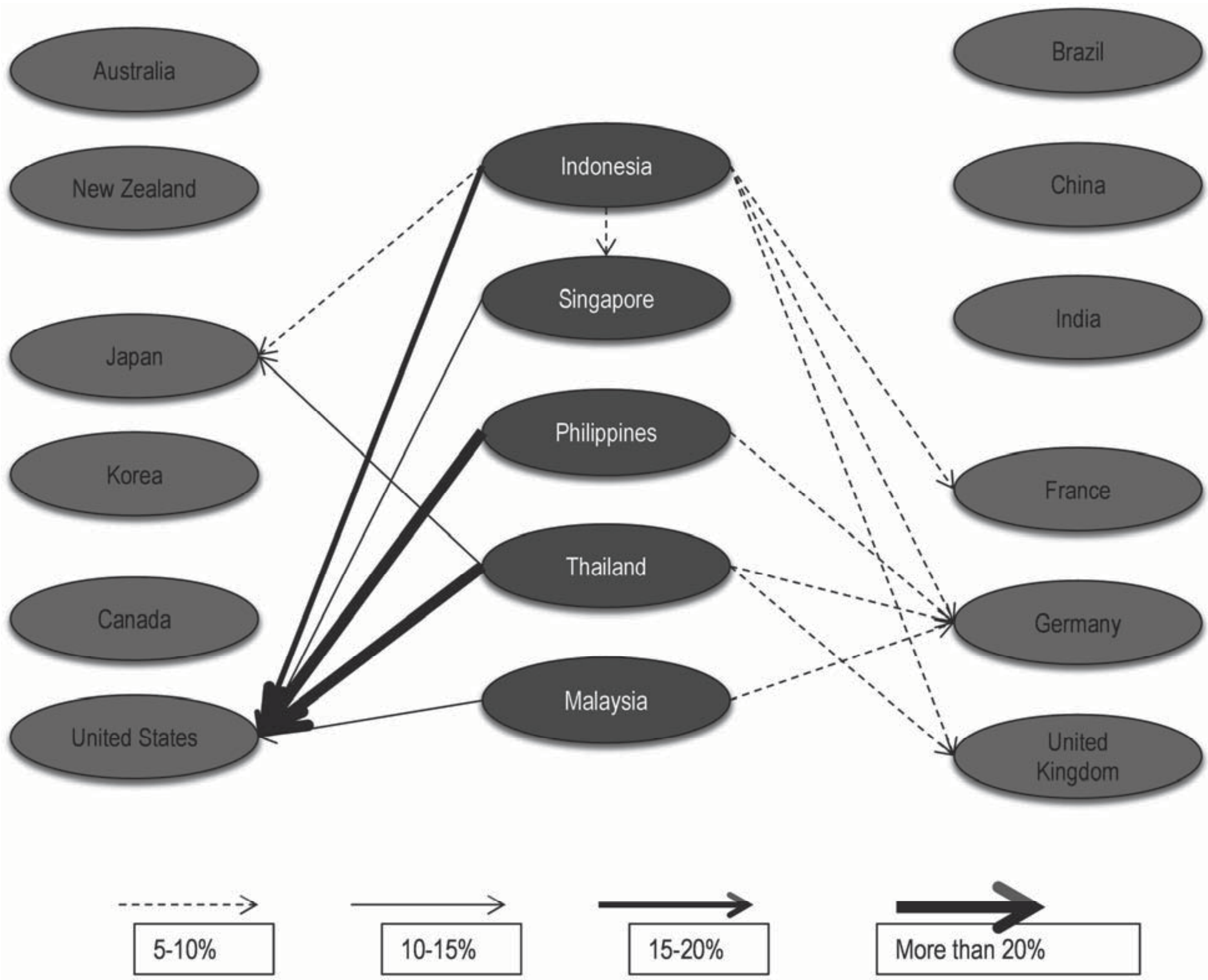
Note: Data refer only to Indonesia, Thailand, Philippines, Singapore and Malaysia.

Source: OECD Patent Database.

Figure 2.22 presents a summary view of the main international links between the Southeast Asian region and the rest of the world, in terms of the share of bilateral co-inventions in a country's total patenting. There are large differences in the extent of co-invention linkages across countries. Among Southeast Asian countries, only Indonesia has a notable patent co-invention link to a Southeast Asian counterpart: 6% of Indonesian patent applications had at least a co-inventor from Singapore. The picture looks different when one considers links to countries outside the Southeast Asia region. A significant share of co-inventors from the United States can be found in all Southeast Asian patent applications. The weakest links are with Malaysia (11.5%), Singapore (12%) and Indonesia (18%), while the Philippines (24%) and Thailand (30%) show strong co-invention links with the United States. The propensity to co-invent with Japan is somewhat lower, with only Thailand (11%) and Indonesia (6%) showing notable co-invention linkages. European countries such as Germany, France and the United Kingdom have also notable but comparatively weak (in a range of 5-10%) co-invention linkages to all Southeast Asian countries except Singapore.

Figure 2.22. PCT patent applications with co-inventor(s) in Southeast Asia and other countries, 2000-09

As a percentage of total patents



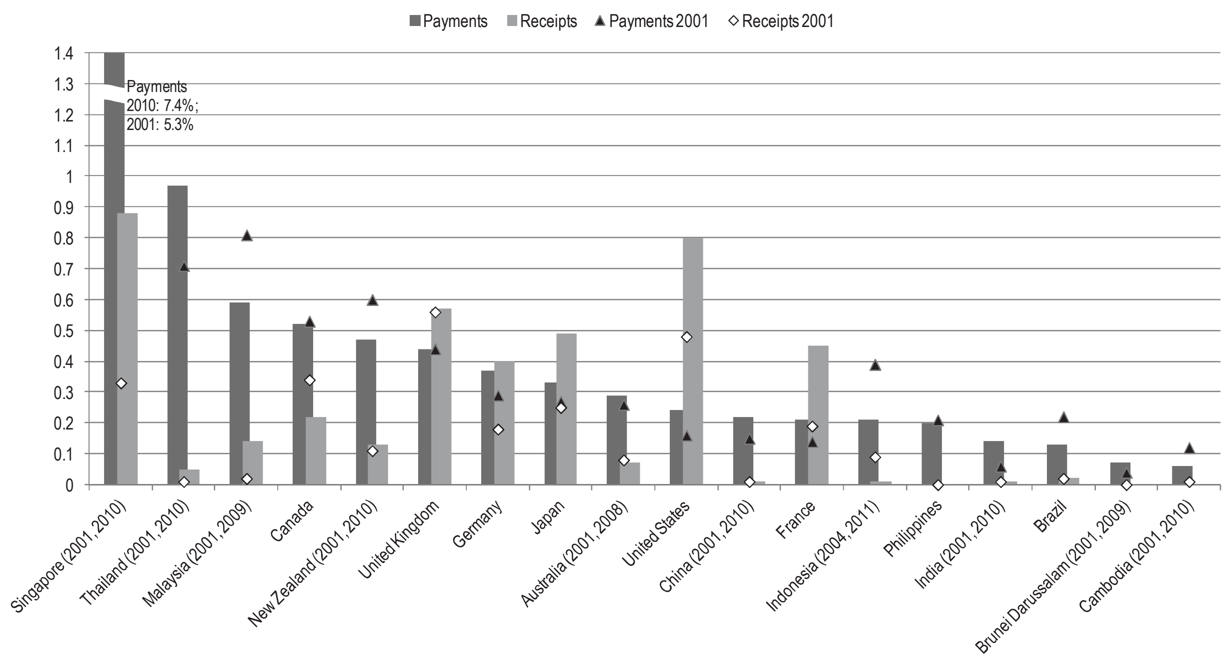
Source: OECD Patent Database.

Technology flows

The way technology is traded reflects the nature of technology as an economic asset. Over the years, trade in (disembodied) technology has grown, showing that knowledge generated in one country is increasingly used in another. Licence fees and royalties are payments and receipts between residents and non-residents for the authorised use of intangible, non-produced, non-financial assets and proprietary rights (such as patents, copyrights, trademarks, industrial processes and franchises) and for the use, through licensing agreements, of produced originals or prototypes (such as manuscripts, cinematographic works and sound recordings). For many economies transactions involving licence fees and royalties represent a notable share of GDP (Figure 2.23).

Figure 2.23. Licence fees and royalties in Southeast Asian and selected OECD and non-OECD countries, 2011 or latest available year

As a percentage of GDP



Source: World Bank Development Indicators.

As illustrated in Figure 2.23, the extent and growth of licence fees and royalties has been uneven across countries. OECD members such as the United Kingdom, Germany, the United States and France have positive trade balances. Singapore and Thailand have increased their propensity both to license in and to license out technologies. By 2010, payments in Singapore comprised 7.4% of GDP, while receipts stood at 0.9%. The trend for Malaysia indicates a considerable increase in the ratio of receipts to GDP (albeit from a very low level in 2001); over the same period, the ratio of payments decreased notably. For Indonesia and the Philippines, technology payments are in a range of 0.2% of GDP. The technology payments of Brunei and Cambodia are below 0.1% of GDP.

The current market for technology may have been conditioned by several factors (see Arora and Gambardella, 2010, for further discussion). First, robust economic growth over this period, particularly in ICTs, has contributed to the growth of technology markets in several Southeast Asian economies. Second, technology flows to and from Southeast Asia may be largely explained by the strong presence of foreign affiliates.

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Chapter 3

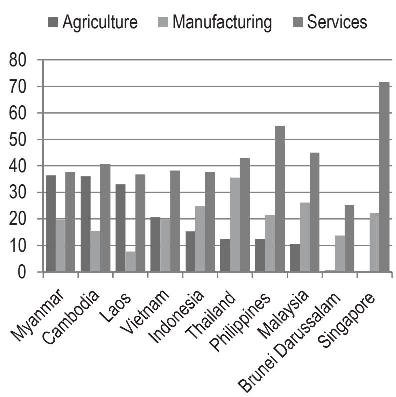
Business sector innovation

The effectiveness of innovation systems depends on the depth and diversity of innovation capabilities that are accumulated by, and deployed in, business enterprises. This chapter provides a brief introduction to the business landscape of Southeast Asian countries and explores the reasons for their diverse performance in R&D and patenting. Next, it discusses the role of foreign firms and subsidiaries, which are a defining feature of the industrial landscape in the region and are a central pillar of government strategies to upgrade national innovation systems. The role of large indigenous firms is then discussed, with a final section covering entrepreneurship and investment financing.

3.1. Business landscape

Southeast Asian economies are extremely diverse and not just in terms of the GDP they generate. As Figure 3.1 shows, the agricultural sector continues to constitute a sizeable proportion of GDP in several less-developed countries while services is by far the most dominant sector in Singapore, Philippines and Malaysia. Table 3.1 shows that there is also significant variability in the size of firms in Southeast Asian economies; for example, more than half of manufacturing employment in Malaysia is accounted for by large firms compared to much lower shares in Philippines and Indonesia where smaller firms are more dominant.

Figure 3.1. Value added by economic sector (% of GDP), 2010



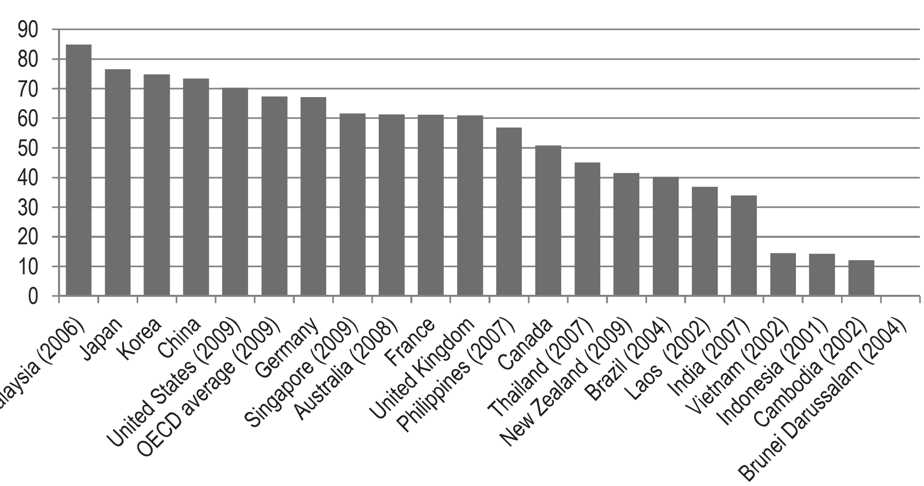
Source: World Bank.

Table 3.1. Share of manufacturing employment by enterprise size (%), selected economies

	No. of employees		
	1-49	50-199	>200
Philippines (2005)	69.6	7.5	22.8
Indonesia (2006)	64.7	6.3	29.0
Thailand (2007)	45.7	12.7	41.6
Malaysia (2005)	27.5	19.7	52.8

Source: Asian Development Bank (2009).

Figure 3.2. Proportion of GERD performed by the business sector, 2010 or latest available year



Source: UNESCO; OECD Main Science and Technology Indicators 2012/1.

This variability has implications for the locus and dynamics of innovation activities in the countries of the region. For example, the innovation literature shows that innovation processes in low and medium technology (LMT) industries are often less formal and more related to modification and incremental change, design and process optimisation, while the innovative activities of small firms often stress the practical application of tacit knowledge. Service sector firms also tend to innovate in an incremental way (Arundel et al, 2008). In such settings, by far the largest innovation expenditures tend to be devoted to the acquisition of machinery, equipment and software, with little formal expenditure on R&D (Box 3.1). Given that many South East Asian economies are dominated by LMT sectors and by small enterprises, it should come as no surprise that levels of BERD are so low (Figure 3.2).

Box 3.1. Non-R&D performing innovators

How do firms that do not perform R&D innovate? The innovation literature points to four main methods:

1. *Technology adoption*: Firms can acquire innovative products and processes from sources external to the firm, with little or no further work required. For example, a computer assembler can purchase faster hard drives or wireless cards from specialist firms for inclusion in a notebook computer, or a food processing firm can purchase improved packaging equipment. CIS data used by Evangelista and Mastrostefano (2006) show that the acquisition of new machinery and equipment is one of the most common innovation activities across firms. Similarly, firms can acquire ideas for organisational innovations from other firms.
2. *Minor modifications or incremental changes* to products and processes, including the use of engineering knowledge (Kline and Rosenberg, 1986). Modifications can be made to both purchased products and processes or to technologies previously developed by the firm itself. These innovation activities are particularly common for process innovation (Evangelista et al., 2002; Nascia and Perani, 2002). Lhuillery and Bogers (2006) estimate that 15% of overall cost reductions are from incremental innovations made by employees to production processes. Incremental change can depend on learning by doing, as a firm gets better at what it already does (Cohen and Levinthal, 1989).
3. *Imitation, including reverse engineering*: Many activities to replicate products or processes that are already available, including some solutions to circumvent a patent (Kim and Nelson, 2000), do not require R&D. This method of innovating may be especially common in less developed countries or for innovations that are not patentable.
4. *Combining existing knowledge in new ways*: This can include some types of industrial design and engineering projects (Grimpe and Sofka, 2007; Huston and Sakkab, 2006). The Italian “informal learning systems” are used by SMEs in traditional industries and mechanical and electrical/electronics sectors to create new products (Evangelista et al., 2002). These systems build on tacit knowledge, engineering skills and cumulative learning processes that are located in the system rather than in a specific firm (Gottardi, 1996). Informal contacts and highly skilled and mobile personnel move tacit knowledge from firm to firm.

There are also situations in which a firm adopts solutions developed by users (with users possibly doing some unreported R&D work). Von Hippel (2005) argues that user innovation is much more widespread than earlier thought. It thrives when there are methods for sharing information and breaking down a problem into components (*e.g.* innovation toolkits). These enable users to innovate without new R&D and improve the ability of users to combine and co-ordinate their efforts (*e.g.* over the Internet). User innovation can also serve as an important source of solutions for firms. Von Hippel calls users’ ability to develop what they need instead of buying what is available the “democratisation of innovation”.

Source: Arundel et al. (2008).

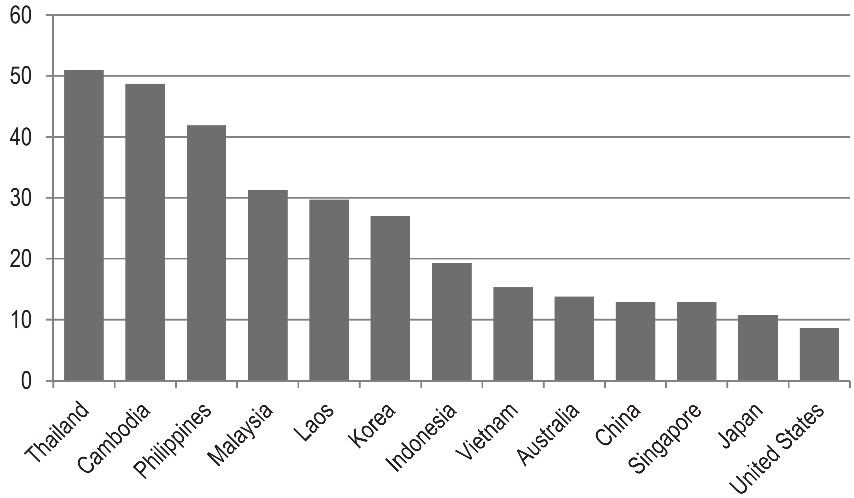
In line with the innovation studies literature, Thee Kian Wie (2005) finds that the vast majority of Indonesian firms do not invest in R&D but instead rely on technologies developed elsewhere. He identified four major channels of international technology transfer to the Indonesian manufacturing sector: foreign direct investment, technical licensing agreements by foreign licensors, imports of capital goods, and technical assistance from foreign buyers. Private-sector investment in R&D is very low, although some firms, especially in high-technology sectors with export potential, are increasingly interested in raising R&D competence levels and have started to co-operate with foreign research institutes.

Thus, technological innovation activities in enterprises draw upon a mix of inputs, with R&D just one of these, and often not used at all. This has important implications for supply-side innovation policy that seeks to build-up the public research base in the hope that it will create a kind of domino effect on the enterprise sector. While this is not without value, it should be complemented by other more demand-side measures that address relationships with consumers and even competitors.

Furthermore, non-technological innovation is increasingly recognised as an important driver of transformative change in enterprises. According to the *Oslo Manual* (OECD/ Eurostat, 2005), it can be broken down into two main components, *i.e.* organisational innovation, which refers to important changes in the organisational structure or the administration of an enterprise; and marketing innovations, which covers important changes in the design or the packaging of products or important changes in sales or distribution methods. It is also interesting to note that non-technological innovation is most commonly reported among high-tech sectors (*e.g.* technical testing and analysis; computer and related activities) and knowledge-intensive business services (*e.g.* architectural and engineering activities; financial intermediation). This points to the often close relationship between both types of innovation.

A final point on the characteristics of the business landscape concerns the "informal" economy. This is defined as activities that involve the provision of goods and services for remuneration but which are not (entirely) covered by formal arrangements. As Figure 3.3 shows, it is a prominent feature of many Southeast Asian economies. A number of factors affect the scale of the informal economy, including tax burdens, labour market regulations, the quality of public goods and services, and the state of the "official" economy (Schneider, 2010). The informal economy is far from homogenous and different informal activities can differ markedly with regard to the nature of and scope for innovation. However, it is typically marked by low entry requirements, small scale operations, skills that are often acquired outside formal education, and labour-intensive methods of production (OECD, 2010). Innovations in the informal economy are, for the most part, likely to remain localised and small-scale. A major policy question around innovation activities in the informal economy is whether they represent an as yet unrecognised core dimension of innovation systems that deserve greater policy attention or whether they are merely marginal activities that occur in the absence of a well-developed innovation system that should ultimately be formalised as innovation systems develop.

Figure 3.3. Size of the shadow economy of selected countries (% GDP), average 1999-2006



Source: Schneider et al. (2010).

Table 3.2. Intellectual property protection filing by patent office, broken down by resident and non-resident (2010 unless otherwise stated)

Patent office	Utility models		Patents		Industrial designs		Trademarks	
	Resident	Non-resident	Resident	Non-resident	Resident	Non-resident	Resident	Non-resident
Thailand	1 293	35	1 025	4 832	3 276	338	24 781	12 875
Philippines	589	32	166	3 223	435	410	8 855	7 983
Indonesia	247	42	516	5 122	2 987	1 079	33 555	14 051
Viet Nam	215	40	306	3 276	1 206	511	21 214	11 075
Malaysia	33	63	1 233	5 230	737	940	13 099	13 271
Singapore	-	-	895	8 878	542	1 384	4 431	13 173

Note: Resident filing refers to an application filed at an Office of or acting for the State in which the first-named applicant in the application concerned has residence. Non-resident filing refers to an application filed at an Office of or acting for the State in which the first-named applicant in the application concerned does not have residence. Utility models data for Malaysia (2008) and Indonesia (2009); Trademarks data for Indonesia (2008); and Patents data for Thailand (2009).

Source: WIPO Statistics Database, December 2011.

These characteristics of the business landscape and its innovation activities have implications for the appropriability mechanisms used by firms. As Table 3.2 shows, utility models are a prominent type of intellectual property protection used by residents in Thailand, Philippines, Indonesia and Vietnam: for example, this type of protection is utilised more extensively than patents in Thailand and Philippines, which probably reflects the less onerous filing procedures involved (see Box 3.2). By contrast, in the more economically advanced countries, *i.e.* Singapore and Malaysia, this type of protection is far less common. It is also rarely used by non-residents in any country. Instead, non-residents account for very large proportions of patent applications: for example, in Singapore, where patenting is most utilised, there are around 10 patent applications from non-residents for every resident application. Similar ratios are found in Indonesia and Vietnam. In Thailand and Malaysia, the ratio is less stark and is closer to four to one. Domestic patents correspond for the most part to new-to-the-country technological innovations and reflect the efforts of country-based applicants. Patents filed by foreign applicants though have a different purpose. The intention is to protect a foreign invention from imitation and production in and for the local market. Patents filed by foreign applicants can be seen as much as an indicator of international technology diffusion (in the sense that an international invention is disclosed to the community of a give country's inventors) as an indicator of barriers put in place to prevent the appropriation of global knowledge by local actors.

Box 3.2. Main types of intellectual property protection

A *patent* is an exclusive right granted for an invention, which is a product or a process that provides, in general, a new way of doing something, or offers a new technical solution to a problem. An invention must, in general, fulfill the following conditions to be protected by a patent. It must be of practical use; it must show an element of novelty, that is, some new characteristic which is not known in the body of existing knowledge in its technical field.

An *industrial design* is the ornamental or aesthetic aspect of an article. To be protected under most national laws, an industrial design must be new and/or original. Novelty or originality is determined with respect to the existing design corpus. An industrial design is primarily of an aesthetic nature, and does not protect any technical features of the article to which it is applied.

A *trademark* is a distinctive sign which identifies certain goods or services as those produced or provided by a specific person or enterprise. Trademarks may be one or a combination of words, letters, and numerals. They may consist of drawings, symbols, three- dimensional signs such as the shape and packaging of goods, audible signs such as music or vocal sounds, fragrances, or colours used as distinguishing features.

A *utility model* is an exclusive right granted for an invention, which allows the right holder to prevent others from commercially using the protected invention, without his authorisation, for a limited period of time. A utility model is similar to a patent, but with some important differences. First, the requirements for acquiring a utility model are less stringent than for patents. While the requirement of 'novelty' is always to be met, that of 'inventive step' or 'non-obviousness' may be much lower or absent altogether. In practice, protection for utility models is often sought for innovations of a rather incremental character which may not meet the patentability criteria. Second, the term of protection for utility models is shorter than for patents and varies from country to country (usually between 7 and 10 years without the possibility of extension or renewal). Third, In most countries where utility model protection is available, patent offices do not examine applications as to substance prior to registration. This means that the registration process is often significantly simpler and faster, taking, on average, six months. Finally, utility models are much cheaper to obtain and to maintain. They are considered particularly suited for SMEs that make "minor" improvements to, and adaptations of, existing products, and are primarily used for mechanical innovations.

Source: WIPO web site (*www.wipo.org*), last accessed August 2012.

3.2. Foreign firms and subsidiaries

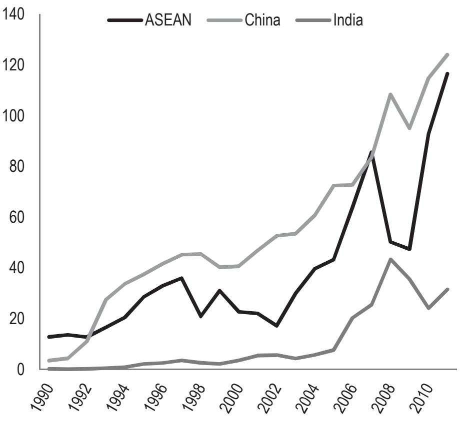
Foreign direct investment (FDI) has provided Southeast Asian countries an alternative route to technology acquisition and opened the way for their participation in global value chains. Large foreign firms and their subsidiaries dominate the economies of Singapore, Malaysia and Thailand, accounting for large parts of high technology exports and constituting the main patents filers (Table 3.3). FDI also plays important roles in other parts of the region, particularly in Vietnam, the Philippines and Indonesia. Taking the region as a whole, after a sharp dip in 2008-09, FDI inflows have rebounded strongly and are at similar levels to FDI inflows into China (Figure 3.4). ASEAN's share of inward stock of FDI in developing countries has remained at around 16% over the last decade (Figure 3.5). Singapore has been the main recipient of FDI inflows into the region, followed by Thailand and Malaysia (Figure 3.6). Moreover, Singapore continues to receive remarkably high levels of FDI as a percentage of GDP (Figure 3.7) and now hosts more than 11 000 foreign affiliates (Figure 3.8).

Table 3.3. Top patenting firms and organisations in Malaysia, Philippines, Singapore and Thailand, 2002-11

	Country of origin	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
Malaysia												
Avago Technologies ECBU IP Pte. Ltd.	Singapore	0	0	0	0	12	50	43	45	46	29	225
Intel Corporation	United States	0	5	4	11	11	27	28	20	30	12	148
Altera Corporation	United States	1	1	1	2	7	13	6	8	11	12	62
Avago Technologies General IP Pte. Ltd.	Singapore	0	0	0	0	4	8	14	12	15	7	60
Agilent Technologies, Inc.	United States	0	2	11	22	3	1	3	1	1	1	45
Philippines												
Fairchild Semiconductor Corporation	United States	1	5	4	5	7	5	3	5	10	7	52
Texas Instruments, Incorporated	United States	2	3	7	4	7	3	4	5	0	2	37
Astec International, Ltd.	United States	2	3	3	1	5	3	1	4	3	1	26
Intel Corporation	United States	0	2	3	3	5	3	1	2	1	0	20
Lexmark International, Inc.	United States	0	0	0	0	0	0	0	0	6	4	10
Singapore												
Chartered Semiconductor Manufacturing Ltd.	Singapore	125	92	73	45	56	36	25	22	34	19	527
Stats Chippac Ltd.	Singapore	0	0	0	3	3	6	20	30	85	125	272
Seagate Technology, LLC	United States	12	40	65	28	27	22	20	22	20	15	271
Micron Technology, Inc.	United States	6	21	34	32	35	37	26	24	33	23	271
Agency for Science, Technology and Research	Singapore	0	1	3	14	26	38	27	31	44	54	238
Thailand												
Advanced Micro Devices, Inc.	United States	26	8	2	2	0	0	0	0	0	0	38
Delta Electronics Inc.	Taiwan	0	1	0	3	6	2	1	2	0	0	15

Source: USPTO, Patenting By Geographic Region (State and Country), Breakdown by Organisation.

Figure 3.4. FDI inflows to ASEAN, China and India from all investors (USD millions)

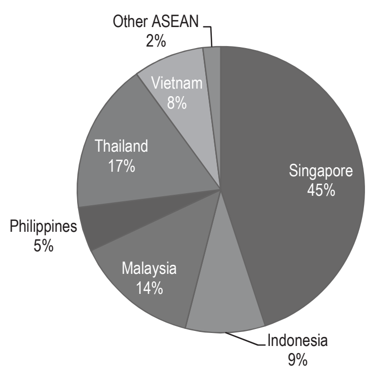


Source: UNCTAD.

Figure 3.5. ASEAN share of inward stock of FDI in developing countries

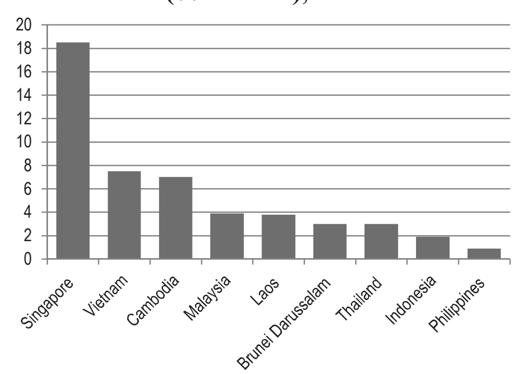
Source: UNCTAD.

Figure 3.6. Cumulative FDI inflows in ASEAN 1999-2009



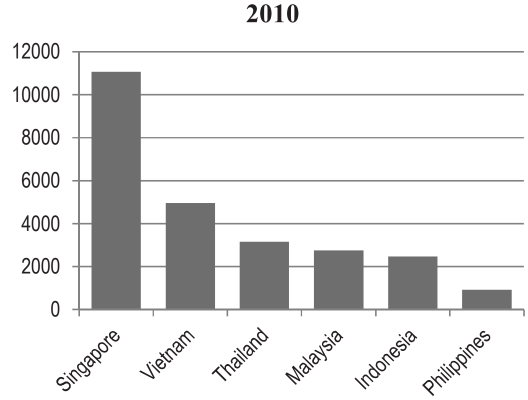
Source: World Bank.

Figure 3.7. Net private foreign direct investment (% of GDP), 2010



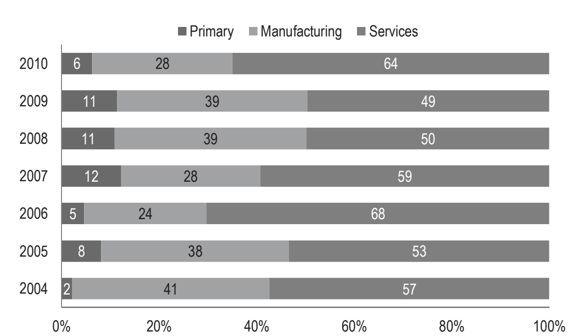
Source: World Bank.

Figure 3.8. Number of foreign affiliates by country, 2010



Source: UNCTAD.

Figure 3.9. Composition of FDI by sector



Source: ASEAN.

The rationales for foreign investment by multinational enterprises vary, depending on firm-level strategies and conditions in the host country (Box 3.3). As Figure 3.9 shows, more than 90% of FDI into the region is in the manufacturing and services sector, with the latter accounting for almost two-thirds of investment in 2010. Thus, much FDI is efficiency-seeking (especially in the case of manufacturing) or market seeking (more in the case of services).

Box 3.3. Rationales for foreign investment by multinational enterprises

In a widely-used categorisation of the rationales for foreign investment by multinational enterprises (MNEs), Dunning (1993) distinguishes between four main categories:

- *Natural resource seekers*: enterprises that are prompted to invest abroad to acquire particular resources, perhaps of a higher quality and/or of a lower cost than could be obtained, if at all, in their home country. Most of the outputs of this type of production tends to be exported, typically to more developed industrialized countries.
- *Market seekers*: enterprises that invest in a particular country or region with the aim of supplying goods and services to them and/or to adjacent territories.
- *Efficiency seekers*: enterprises that rationalise the structure of established resource-based or market-seeking investment by concentrating production in a limited number of locations to supply multiple markets. Such investments aim to take advantage of different factor endowments offered by different locations as part of their coordinated global operations.
- *Strategic asset seekers*: enterprises that seek to promote their long-term strategic objectives, often by acquiring the assets of foreign firms. The motive is therefore less to exploit cost or marketing advantages and more to augment portfolios of physical assets and human competences.

It should be noted that many of the larger MNEs are pursuing multiple objectives that entail two or more of the above categories of rationale for foreign investment. Furthermore, the motives for foreign investment may also change over time, often shifting from natural resource and market seeking through to efficiency and strategic asset seeking. The categorisation obviously applies to both inward and outward FDI and can be used to explore the rationales of foreign firms investing in SE Asia and of SE Asian firms investing abroad.

Source: Based on Dunning (1993).

FDI is one of the most important channels through which technology is transferred across countries and by encouraging MNEs to establish local facilities, governments hope to generate the transfer of technology to local firms (OECD, 2011). Typical mechanisms include backward linkages to suppliers, human capital accumulation and mobility, and training effects. Of particular interest are backward linkages, which are widely lauded by proponents of FDI as the most important mechanism for knowledge spillovers. These tend to occur in two ways: either customer firms establish supportive linkages to supplier firms, increasing their capabilities directly; and/or customers put pressure on their suppliers to produce inputs that satisfy requirements of quality, quantity, delivery time and price, a mechanism that forces suppliers to improve quality and efficiency (Jordaan, 2005).

While spillovers from MNEs to the host economy might be expected from a theoretical point of view, they do not occur automatically and might not materialise in reality. The empirical literature on the presence of spillovers is mixed but has demonstrated that they will only arise if local firms invest and learn to absorb foreign knowledge and skills (OECD, 2011). Evidence, particularly from developing countries, has shown that local firms often lack the necessary absorptive capacity for the advanced technology and skills of MNEs (see Blomstrom and Kokko, 2003 for an overview). At the same time, MNEs develop different protection mechanisms to prevent their knowledge from spilling over to local competitors.

Singapore has been the most successful country in the region in generating spillovers from MNEs to local firms, followed by Malaysia and Thailand. In the case of the latter two, backward linkages to indigenous firms are often between tier 1 and tier 2 suppliers rather than with final assemblers. In efforts to attract more high-value activities, the more economically advanced countries in the region are investing in various knowledge infrastructures in the hope of attracting more high-tech and high-skilled dependent FDI, including R&D facilities. Box 3.4 highlights some of the many "location factors" that influence the attractiveness of a country for international investments of this kind.

Box 3.4. "Location factors" in attracting high-tech industries and R&D investments

The attractiveness of a country for international investment is directly determined by the advantageous character of its location factors. Location factors for vertical MNEs relate to differences in endowments between countries, e.g. unskilled labour-intensive production activities are typically located in countries with relatively abundant unskilled labour (Helpman, 1984 and 1985; Horstman and Markusen, 1987 and 1992; Markusen, 1997 and 2002). For high-tech industries, the size of the market, the availability of high-quality resources like scientific infrastructure (especially in specialised fields of research) and the supply of skilled labour are reported to be important location factors. Cost considerations, including labour costs, appear more secondary than in other industries; instead, the quality of the location factors in the host country is much more important.

In addition, empirical studies also show the role of spatial proximity and agglomeration effects (at the regional or local level) as a location factor in high-tech industries. Agglomeration effects arise as proximate economic activity might benefit (domestic and foreign) companies because of the access to skilled labour, access to specialized suppliers and inter-firm knowledge spillovers. Several empirical papers have shown that a large presence of firms active in the same industry and/or foreign affiliates originating in the same home country attracts international investments by MNEs (Head et al., 1999; Mayer et Mucchielli, 1999; Head and Mayer, 2004; Crozet et al., 2004; Py and Hatem, 2009). It is clear that agglomeration effects may be especially important in technology and knowledge-intensive industries; strategic asset-seeking (*i.e.* knowledge-seeking) MNEs try to maximise knowledge spillovers through their choice of location and will favour locations with rich sources of knowledge. As such, they will locate in localities / regions with a high-quality scientific infrastructure (*e.g.* top universities and public research organisations) and will co-locate with other knowledge-intensive firms.

Location determinants for R&D have been extensively discussed in recent years (see OECD, 2008a for an overview). R&D has long been one of the least mobile activities of MNEs, but it has become increasingly internationalised over the past decade. Technological knowledge is often tacit and embodied in persons and therefore not easily transferable; furthermore, a company's competitive advantage is often directly related to that of its home country. As such, it is strongly shaped by that country's industrial specialisations and national innovation systems, including its accumulated research and labour force skills (Patel and Pavitt, 1999). While corporate R&D activities are still predominately carried out in the home country, MNEs are changing how they innovate and building globally distributed R&D and innovation networks. Following the fragmentation of the value chain and the resulting internationalisation of manufacturing, MNEs now increasingly establish R&D facilities at many locations worldwide (OECD, 2008b).

Market size is found to be a major determinant for international investments in R&D, reflecting the importance of R&D activities abroad for adapting products and processes to local conditions in the foreign country (Kumar, 2001; Doh et al., 2005; Shimizutani and Todo, 2008). Likewise, the adaptive and demand-led strategy of R&D subsidiaries abroad is also underscored by the importance of the presence of foreign affiliates as this type of R&D is closely related to production (Hakanson and Nobel, 1993; Kuemmerle, 1997). Also, the availability of highly skilled human resources appeared as an important location factor for adaptive as well as innovative R&D investments abroad (Florida, 1997; Kumar, 2001, Jones and Teegen, 2003).

Source: OECD (2011).

3.3. Large domestic firms and innovation

In addition to multinational enterprises, two other classes of large firms are present in Southeast Asian economies. The first of these is state-owned enterprises (SoEs) – better known as government-linked companies (GLCs) in Singapore and Malaysia – which operate in a variety of sectors, but are particularly dominant in utilities (including telecoms), transportation, and oil and gas, where they often occupy monopoly positions. For the most part, these firms perform little R&D for their size, even in the most advanced economy in the region, Singapore. In the latter case, government innovation policy places far greater emphasis on promoting entrepreneurship and nurturing new technology-based firms (NTBFs) than on promoting innovation in GLCs. The second class of large firms is domestic and privately-owned. Many of these are family-based business groups (FBGs) and are predominantly owned and operated by ethnic Chinese families. The largest are conglomerates operating in a wide variety of sectors across the region and beyond. Generally speaking, like their SoE counterparts, they perform little R&D for their size, but some are quite innovative and several have emerged as multinational enterprises (see Tables 3.4 and 3.5). The region's top corporate R&D spenders are shown in Table 3.6, which illustrates the dominance of ICT firms, most of which are Singaporean.

Table 3.4. Top non-financial MNE in South East Asia, ranked by total number of foreign assets, 2009

No.	Firm	Sector of activity	Country	Foreign assets (%)	Foreign sales (%)	Employment: Total (in 1 000)	Employment: Foreign (%)
1	Petronas - Petroliam Nasional Bhd	Petroleum expl./ref./distr.	Malaysia	27	42	39	20
2	Singtel Ltd.	Telecommunications	Singapore	79	65	20	45
3	Capitaland Limited	Construction and real estate	Singapore	57	70	10.5	57
4	Axiata Group Bhd	Telecommunications	Malaysia	76	51	25	76
5	YTL Corp. Berhad	Utilities (electricity, gas and water)	Malaysia	63	49	6	31
6	Flextronics International Ltd.	Electrical & electronic equipment	Singapore	47	51	160	98
7	Genting Berhad	Other consumer services	Malaysia	58	24	27.5	61
8	Sime Darby Berhad	Diversified	Malaysia	43	69	100	25
9	Keppel Corporation Limited	Diversified	Singapore	33	31	35.5	52
10	San Miguel Corporation	Food, beverages and tobacco	Philippines	37	12	15.5	16
11	Neptune Orient Lines Ltd.	Transport and storage	Singapore	48	77	11	31
12	PTT Public Company Limited	Petroleum expl./ref./distr.	Thailand	10	10	8	10
13	Tanjong Public Limited Company	Pharmaceuticals	Malaysia	71	41	2.5	36

Source: UNCTAD.

Table 3.5. Outward FDI by ASEAN MNEs, 2005-09

Company name Country	Industry	Overseas activity	Specific targets
Temasek Holdings (Singapore)	Sovereign Wealth Fund	Extensive global investments	– Merrill Lynch (US; banking): USD 4.9 billion for 9% stake (2007) – Standard Chartered Bank (UK; banking): 18.8% stake worth USD 357 million – Chennai branch office of the DBS bank (India; banking) (2009) – Shin Corporation (Thailand; telecom): 49.6% share for USD 1.88 billion (2006)
Petronas (Malaysia)	Oil and gas operations	Extensive overseas (recently focusing on Africa, Asia)	– FL Selenia (EU; lubricant blend and marketing): USD 1.4 billion – Cairn India Limited (India; oil): stake purchased from Cairn UK
Maybank (Malaysia)	Financial services	Embracing Islamic finance	– PT Bank International Indonesia (Indonesia; banking): USD 1.1 billion for 55.6% stake (2008) – MNC Bank (Pakistan; banking): USD 687 million for 15% stake
Bangkok Bank (Thailand)	Financial services	21 overseas activities mainly in Asia, but also US/UK	– People Insurance of China (China; insurance): 10% share (2005)
Charoen Pokphand (Thailand)	Agro-business and food industry/ diversified (e.g. restaurants in China)	Extensive overseas activities (mainly in Asia)	– Marine business (Philippines) – Restaurant chain (China) – Marine and animal feed business (UK and Turkey)
Salim Group (Indonesia)	Conglomerate	Mainly in Asia (China/India)	– New Kolkata International Development (India; real estate): 50% stake increase – LAB Plant (China; chemical): USD 97 million via a joint venture with Korean Great Orient Chemical Pte. Ltd (2008)
Lippo Group (Indonesia)	Conglomerate	Global network mainly in Singapore/ Malaysia	– Robinson and Company Ltd. (Singapore; retail): EUR 100 million for 29.9% stake – Overseas Union Enterprise (Singapore; hotel and real estate): stake raised by 88.5% worth USD 957 million – First REIT (Singapore; hospital and real estate): USD 111 million
San Miguel (Philippines)	Food and beverages	Mainly ASEAN countries/ China for market seeking and cost reduction	– Brewery operations (China and ASEAN) – Packaging facilities (China, Viet Nam and Malaysia) – Meat processing plants (Indonesia and Viet Nam) – Feed mill and hog farm (Viet Nam)
Petrovietnam (Viet Nam)	Mining and quarrying	20 projects in 17 countries mainly in Russia and Venezuela	– Rusvietpetro Joint Venture (Russia): 49% stake in 2008 – Joint venture with Petroleos de Venezuela – Projects in Algeria and Malaysia

Source: Thomsen et al. (2011).

Table 3.6. Top corporate R&D spenders in Southeast Asia, ranked by R&D investments, 2011

No.	Firm	Sector of activity	Country	R&D investment (in million USD)	Employment (in 1 000)
1	Avago Technologies	Semiconductors (9576)	Singapore	209	3.5
2	Verigy	Semiconductors (9576)	Singapore	72	1,5
3	Proton	Automobiles & parts (335)	Malaysia	65	12
4	Singapore Technologies Engineering	Aerospace & defence (271)	Singapore	59	21.5
5	Hong Leong Asia	Construction & materials (235)	Singapore	50	n.a
6	Creative Technology	Computer hardware (9572)	Singapore	44	n.a
7	Delta Electronics (Thailand)	Computer hardware (9572)	Thailand	43	n.a
8	Stats ChipPAC	Semiconductors (9576)	Singapore	35	n.a

Source: European Commission (2011), *Monitoring industrial research: the 2011 EU Industrial R&D investment Scoreboard*, European Commission, Luxembourg.

Through their activities in creating, accumulating and dispersing knowledge, large firms can play critically important roles as vehicles for building up knowledge capital for innovation across wide areas of the economy in which they are embedded (Box 3.5). However, this picture of the positive role of large firms in the development of national innovation systems does not imply that such a role will automatically arise from the mere existence of large firms. On the contrary, their existence creates only the basis for a potential role, and the extent to which it has been played in industrialising economies has been shaped by very specific institutional factors: particular types of social contract between the state and private business; particular forms of relationship between the policy bureaucracy and private enterprise; particular forms of state-facilitated collaboration among firms; and specific forms of relationship between public and private technological organisations (OECD, 2007). Another factor is the presence of large foreign firms, which is particularly pertinent to Southeast Asia, as discussed in the previous section. Singapore appears to have been largely successful in managing these various relations, the other countries in the region less so, and there remains considerable scope for indigenous large firms to play more positive roles in innovation systems, along the lines of those set out in Box 3.5.

Box 3.5. The potentially positive roles of large firms in innovation systems

In considering the positive roles of large firms in the development of the economy, one can distinguish between creating and accumulating knowledge resources for innovation (*e.g.* by training, research, technological development, and acquisition of experience), and using and applying these knowledge resources in production (*e.g.* in starting, operating or improving production activities). Large firms can be particularly effective in creating and accumulating knowledge resources in a wide range of industrial development contexts. They are particularly well placed to accumulate knowledge resources, to invest in training and to achieve effective scale in implementation. Their scale also increases their incentives to undertake such activities, since it typically enables them to capture a relatively larger fraction of the benefits. For example, the expected returns to investment in training process design engineers depends on how frequently the firm's future projects will draw on design engineering skills, and large firms can usually expect much greater use of them than smaller firms. This was strikingly illustrated, for instance, in the intensive efforts of large Korean firms in the 1960s and 1970s to acquire and accumulate engineering capabilities for use in a rapid succession of investment projects. In both developed and developing economies large firms are also the major players in accumulating knowledge resources through R&D.

Beyond training and R&D, large firms are typically very effective accumulators of experience, a rarely discussed but critically important form of knowledge for innovation. They are usually better able than smaller firms to invest explicitly in experience-accumulation activities, e.g. by secondment of engineering and management personnel to other organisations where they can acquire it, and also by actively managing the rotation of personnel through successions of experience-enhancing activities and projects. There is, however, another side to this story of intra-corporate accumulation of knowledge-resources via training, R&D and experience acquisition. Large firms rarely appropriate the full returns from their investments in accumulating knowledge resources, and large fractions of these resources typically leak into the rest of the economy. They flow to suppliers and customers and also more widely through a variety of channels, among which the movement of highly skilled people is often particularly important. In effect, as well as being important accumulators of knowledge resources, large firms also act as substantial diffusers of those resources into their economic environments. An important part of this knowledge-diffusing role is concerned with SMEs because large firms frequently act as sources of knowledge for the smaller firms that are their suppliers and customers, and as sources of knowledge assets for the establishment of new small firms (spin-outs). This last role runs counter to the more common emphasis on small firms as knowledge creators in the modern economy. It is indeed the case that in recent years the organisation of innovation in advanced economies has shifted, such that, in some industries and some areas of technology, small firms have come to play a larger role in more organisationally distributed forms of innovation. Even here, however, large firms, and not just the more commonly discussed spin-offs from universities and other public research organisations, play an important role in the emergence of new small firms. They do so both deliberately via relatively formal spin-off arrangements, but also passively or involuntarily as people leave larger firms, taking with them their accumulated know-how and experience to set up new small firms.

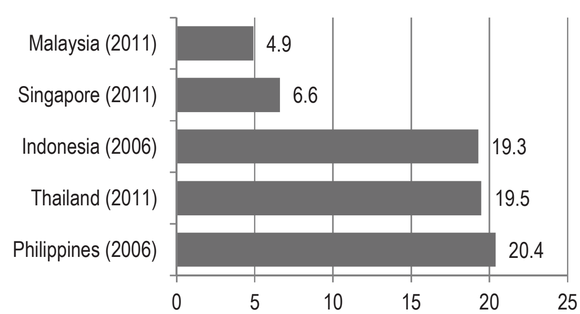
Source: OECD (2007), *OECD Reviews of Innovation Policy: South Africa*, OECD, Paris.

3.4. Entrepreneurship and investment finance

New business ventures can play important roles in upgrading the aggregate productivity of economies. They can displace firms with lower productivity and place incumbents under competitive threat. And they can enable the exploitation of knowledge that might otherwise remain unexploited in large firms, universities and research organizations, which makes them especially important in breakthrough innovations. However, the vast majority of start-ups innovate very little compared to large firms, and there is just a small group of highly innovative and high-growth-potential firms with important individual impacts on jobs and productivity (OECD, 2010).

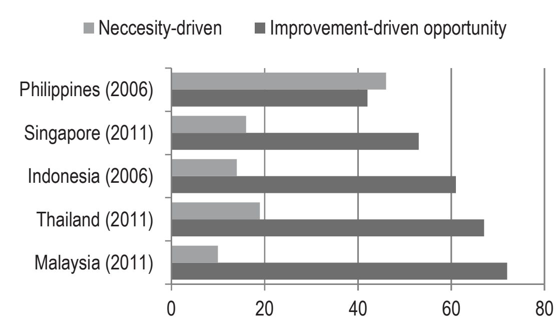
The Philippines, Thailand and Indonesia have among the highest levels of entrepreneurship in the world, as measured by the Global Entrepreneurship Monitor Total Entrepreneurial Activity indicator (GEM TEA), which measures the proportion of adults (18-64 years) engaged in starting up a business in the previous 42 months (Figure 3.10)[1]. The GEM survey distinguishes entrepreneurs who start a business as a result of an opportunity ("opportunity entrepreneurs": those who seek to exploit a perceived business opportunity to generate income or wealth or gain independence in their life) from those who start it from necessity ("necessity entrepreneurs": those who start a business because they lack other realistic options for generating income and wealth). Figure 3.11 shows relatively high levels of necessity-driven entrepreneurship across the region, particularly in the Philippines. High levels of necessity entrepreneurship reflect a lack of job opportunities.

Figure 3.10. Total early-stage entrepreneurial activity (TEA) in selected South East Asia countries, various years



Source: Global Entrepreneurship Monitor.

Figure 3.11. Relative prevalence of improvement-driven opportunity entrepreneurial activity and necessity-driven entrepreneurial activity in selected South East Asia countries, various years



Source: Global Entrepreneurship Monitor.

Table 3.7. Sources of investment finance in selected Southeast Asian countries

	CAM 2007	IND 2009	LAO 2009	MAL 2007	PHP 2009	THD 2006	VIE 2009	*Group avg.*
Percentage of firms using banks to finance investments (%)	11.3	11.7	0.0	48.6	21.9	74.4	21.5	*27.1*
Proportion of investments financed internally (%)	44.3	85.8	97.2	46.1	73.3	28.2	74.7	*64.2*
Proportion of investments financed by banks (%)	6.1	6.0	0.0	32.8	11.5	53.0	12.0	*17.3*
Proportion of investments financed by equity or stock sales (%)	0.0	3.0	2.8	3.2	3.5	9.7	3.8	*3.7*

Source: Enterprise Surveys (www.enterprisesurveys.org), World Bank.

1 GEM sample sizes: 2 000 for all Southeast Asian countries, except for Singapore, 4 000.

Across all countries, there are significant barriers to SME innovation performance, including access to internal and external financing. Table 3.7 shows the popularity of various sources of finance for investment in a selection of countries in the Southeast Asian region. Internal finance is by far the most common source of investment finance in the group. There are, however, some encouraging signs of the development of a formal financial system. About one out of four firms are using banks to finance investments and banks finance just under a fifth of investment in the region. The proportion of investments that is financed by equity or stock sales is low, as these options appeal to a segment of firms that is still largely underdeveloped in most countries. Among the group (which excludes Singapore), Thailand appears to have the most developed formal financial sector, as a majority of firms use banks, just over half of investment is bank financed and a notable proportion of investments (about 10%) is financed by equity or stock sales. Malaysia also has a developed banking sector, but unlike Thailand, its proportion of investments financed by equity or stock sales is at around the group average.

The development of bank finance in the region was historically affected by the Asian crisis. For example, Indonesia's banking sector has not fully recovered since. The development of bank finance is also hampered among other factors by the lack of managerial skills to mobilise credit, the high degree of informality in the business sector and in some cases by the geographic dispersion of economic activity in the form of an urban-rural divide. As a response, it is common for companies in Thailand to resort to the informal sector for financing. Efforts directed at the expansion of the banking sector in Malaysia have not yet yielded the expected results.

Venture capital is even less developed in the region. Only Singapore has had a notable venture capital community dating back to the 1990s and even there the success record is mixed and the role of the sector still peripheral. Whereas noteworthy attempts have been made for the establishment of venture capital in Malaysia and Thailand, the development of the sector there remains at an early stage and only caters for the needs of a very small subset of firms. Reasons for the stunted development of the sector can be identified on both the supply and demand side. In Singapore, an important limiting factor has been the lack of business angels investing at the seed stage, i.e. before they are fundable by venture capitalists. In Malaysia, there is a lack of skilled personnel to manage the funds and a considerable share of finance continues to be channelled to government-linked firms and even recent efforts to strengthen risk finance cater to government-back firms. At the same time, two-fifths of respondents to a firm-level survey suggested that their demands for venture capital finance had been unmet (Thiruchelvam et al., 2011a). The lack of plentiful investment opportunities, liquid and well developed capital markets, and talented venture capitalists have been identified as limiting factors in Indonesia, Thailand and Malaysia (Kenney et al., 2002).

Government-backed initiatives to offer supplementary finance for start-ups and risky business activities are common, and though there are examples of success, such initiatives have not yet had a notable impact at the level of any one country. The most significant such initiative existed in Singapore, and was known as the Technopreneurship Investment Fund (TIF). TIF and other government efforts were instrumental in establishing Singapore as a regional hub for venture capital activity, and a sizable portion of venture capital funds managed in Singapore appears to have been directed overseas. TIF was closed in the late 2000s with only moderate success. In Thailand, industrial development banks set up by the government have been largely ineffective in providing venture finance owing to overly bureaucratic procedures and the fact that loans on offer tend to be small and not on particularly attractive terms (Intarakumnerd, 2010).

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Chapter 4

Innovation and the role of government

Governments play a range of important roles in innovation systems. For example, the so-called "framework conditions" for innovation tend to be heavily framed by regulation, taxation, trade policies and physical infrastructure, among other things. Innovation depends to a large extent on workforce skills that are largely determined by public education systems. And public sector research is a critical source of new knowledge upon which innovation can draw.

This chapter briefly examines how governments in Southeast Asian countries support innovation. It begins with an account of countries' economic development strategies and the extent to which they emphasise the role of innovation. It then turns to the framework conditions for innovation, paying particular attention to the regulatory framework and its friendliness to innovative start-ups. The chapter then covers the role of education for innovation and presents various educational statistics. In a final section, a brief overview of public sector research systems is provided.

4.1. Economic development strategies

Southeast Asian governments play significant roles in guiding economic activity in their countries, typically through five-year macroeconomic development plans. Following examples of successful economic development in East Asia, they have implemented export-led growth strategies that place considerable emphasis on attracting foreign direct investment (FDI). Countries continue to adapt their development strategies to reflect the changing growth dynamism in the region and international market conditions. Although different countries have different policy challenges, Table 4.1 shows that, overall, the priority areas identified in the national plans focus largely on human capital development, infrastructure investment, and regulatory and taxation reforms (OECD, 2012).

Table 4.1. Summary of medium-term policy challenges and responses

Indonesia	Infrastructure	Speed up transport infrastructure development by improving the regulatory environment
	Human capital development	Improve the outcome of higher education and reduce urban-rural disparities in access to educational infrastructure
	Labour market	Reform labour market regulation to increase employment
Malaysia	SME development	Enhance SME development with special attention to capacity building and innovation
	Human capital development	Strengthen the link between industries and academic institutions to improve labour force skills and to enhance research and development
	Taxation and fiscal system	Reform the tax regime and improve efficiency of public spending to bolster the sustainability of public finances
Philippines	Infrastructure	Increase funding for infrastructure development and attract more private participation
	Human capital development	Improve the access to and the quality of basic education and strengthen technical education and vocational training
	Taxation	Reform the tax system by enhancing tax collection and widening the tax base
Singapore	Human capital development	Strengthen life-long learning by enhancing pre-school education
	Innovation	Raise the efficiency of innovation policy through well co-ordinated policy evaluation system
	SME development	Enhance SME development by improving assistance programmes
Thailand	Health	Reform health care schemes to provide a higher quality of and equal access to services
	Human capital development	Improve outcomes in education and reduce urban-rural disparities
	Agriculture	Enhance agricultural productivity and improve jobs in the farm sector
Viet Nam	Enterprise development and reform of SOEs	Speed-up the reform of state-owned enterprises, particularly by improving the governance and management
	Macroeconomic management	Establish an adequate monetary policy framework to control inflation
	Human capital development	Increase skilled labour by education reform

Source: OECD (2012).

Policies affecting the development of national innovation systems have been formulated and implemented, though mostly as part of broader sets of policies designed to improve the business environment or promote trade. A coherent policy focus on innovation appears to be absent in most countries in the region, though several have developed science and technology plans that seek to promote innovation, but from an R&D-centric perspective. These are briefly covered in section 4.4. The main exceptions in this regard are Singapore and Malaysia, which feature innovation prominently in their national development strategies. Both have set up dedicated organisational structures to elaborate and coordinate innovation policy. For example, in Malaysia's case, Unit Inovasi Khas (UNIK), the Special Innovation Unit under the Prime Minister's Office, was recently created to oversee an integrated innovation policy, while a statutory organisation, the Malaysian Innovation Agency (AIM), has been established to drive the national innovation agenda.

Attracting FDI has been a particularly important policy goal for countries in the region and is viewed today as a means for upgrading domestic technological capabilities via various types of spillovers to local economies. Singapore is arguably the most successful in pursuing this policy goal, identifying new market trends early on and quickly devising policy incentives to attract global players to locate part of their activities in Singapore. Parallel investment in supporting infrastructures and resources then allows Singapore to reap an "early-entry" advantage. Malaysia has also pursued an aggressive strategy of attracting strategic FDI to spur its industrialisation. Through the use of generous incentives, tax relief and subsidised investment loans, it has succeeded in attracting a number of multinational enterprises (MNEs) to Malaysia. Thailand's industrial policy also placed considerable emphasis on attracting FDI. Less-developed economies in the region are now following similar strategies. For example, Cambodia has enacted various regulations and offered tax incentives to raise FDI and has set up the Council for the Development of Cambodia, an investment promotion agency, to provide an "open door" to foreign investors.

Countries have taken a mix of approaches to nurturing spillovers with varying levels of success. For example, Singapore has been quite effective in facilitating the innovation links between MNEs and their local supporting industries, through schemes such as the Local Industry Upgrading Programme (LIUP). More recently, through the strategy of developing industry clusters, the Economic Development Board (EDB) has facilitated the formation of joint ventures and technology strategic alliances between Singaporean firms and major foreign MNEs in a number of high-technology industries, including semi-conductor wafer fabrication and chemicals (Wong, 2003). The experience of Thailand has been rather different, where until recently, relatively little emphasis was placed on explicit links between promoting foreign investment and upgrading the abilities of local firms (Vongpivat, 2003). A significant exception here is the automobile industry where technological upgrading targets and local content requirements have had the effect of raising the local content of passenger vehicles to over 54% by 2008 (Lauridsen, 2008). More recently, the cluster concept has become the main plank of industrial and innovation policy. This has seen the Thai Board of Investment (BOI) extend investment packages for strategic clusters, such as hard disk drives and semiconductors, and provide Thai firms incentives to participate in global value chains. Among the less developed economies, Cambodia has established the Cambodian Special Economic Zone Board, which, among other tasks, is charged with promoting industrial linkages and technology transfer via cluster development and inter-firm spillovers.

The drive for increased trade has been a core target of Southeast Asian countries' export-led strategies and has spurred economic integration efforts across the region. ASEAN has been moving towards economic integration since its creation in 1967. However, the benefits of many aspects of integration are yet to be experienced. More recently ASEAN member countries have agreed to the ASEAN Economic Community (AEC) Blueprint which lays the foundation for realising the goal of ASEAN as an integrated economic region by 2015 (Box 4.1).

Box 4.1. The ASEAN Economic Community (AEC)

The AEC is an extension of major integration initiatives that have been undertaken since the early 1990s such as the ASEAN Free Trade Area, ASEAN Framework Agreement on Services and the ASEAN Investment Area. The AEC has the aim of being a single market and product base characterised by the free flow of five core elements: goods, services, investment, financial capital and skilled labour. The measures to be implemented fall into three types of policy actions: elimination of border measures applying to imports into one member country from another member country, full national treatment by behind the border measures applying to imports into one member country from another member country, and harmonisation of domestic regulations across member countries by way of mutual recognition.

The AEC is organised by four pillars, as follows:

1. Single market and production base: this pillar incorporates the free flow of goods, the free flow of services and skilled labour, free flow of investment, freer flow of capital, and food, agriculture and forestry. It incorporates twelve 'priority integration sectors', as follows: agro-based goods, air transport, automotive products, e-ASEAN, electronics and electrical goods, fisheries, health care services, rubber-based goods, textiles and clothing, tourism, logistics services and wood-based products. In its evaluation of AEC progress, the ASEAN Secretariat (2012) estimates that around two-thirds of all agreed measures have been implemented, with significant achievements in the free flow of skilled labour and capital, and in the integration of priority sectors. There is still further work to be done in the free flow of goods. In May 2010 the ASEAN Free Trade Council endorsed the ASEAN Trade in Goods Agreement Full Tariff Reduction Schedule that will guide tariff liberalisation until 2015. It has also decreased the average intra-tariff rate for the ASEAN-6 (Brunei Darussalam, Malaysia, Singapore, Thailand, Indonesia and Philippines) from 3.64% in 2000 to 0.05% in 2011; however there are still a number of remaining measures not fully implemented.
2. Highly competitive economic region: this pillar incorporates competition policy, consumer protection, intellectual property rights and infrastructure development. Infrastructure development is particularly important in this context as it aims to improve transport infrastructure and information and communication technology. Both of these are required for equal development across the region and increased competitiveness for exports coming from countries with little access to external markets. The ASEAN Secretariat (2012) estimates that around two-thirds of the intended measures have been implemented.
3. Creation of a region with equitable economic development: within this pillar, ASEAN strives to encourage the development of small and medium enterprises and to meet the objectives of the 'Initiative for ASEAN Integration' (IAI). IAI is the process of developing new modalities and approaches to ensure that benefits of the AEC trickle down to the smaller ASEAN economies and sub-regions to ensure that they are not left behind if the AEC brings the intended increase in growth. The ASEAN Secretariat (2012) estimates that around two-thirds of all agreed measures have been implemented.
4. Integration of ASEAN into the global economy: this pillar focuses on external economic relations. ASEAN has ratified five free trade agreements in recent years with Australia and New Zealand, China, India, Japan and Korea. The ASEAN Secretariat (2012) estimates that around 85% of the intended measures have been implemented.

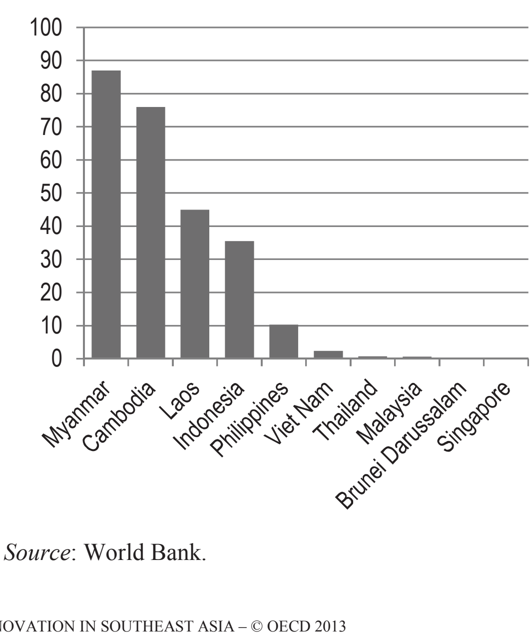
4.2. Improving the framework conditions for innovation

The existence of favourable framework conditions is a major factor in enabling and facilitating innovation throughout an economy. Innovation policy is not likely to compensate for seriously flawed framework conditions. The macroeconomic framework, the general business environment, the intensity of competition, product and labour market regulations, as well as the degree and quality of entrepreneurship – which is shaped by institutional and cultural factors – are all of key importance for a country's innovative performance.

The state of development of infrastructure is also an important factor, particularly in less-developed countries, where even access to electricity can be a significant issue. This is the case in Myanmar, Cambodia and, to a lesser extent, Laos, where access to electricity is largely confined to urban areas (Figure 4.1). Even in middle-income Indonesia, around one-third of the population does not have access to electricity. Roads, seaports, and power generation are generally considered poor in the less developed economies of the region, though there has been significant development of local infrastructure in certain industrial and export zones aimed at reducing costs and improving the competitiveness of firms located there. Compared to the region's less developed economies, Thailand has comparatively good infrastructure but this has become increasingly strained during the period of sustained economic growth. By contrast, Malaysia has made large investments in infrastructure development, including telecommunications, transport and power generation, to meet the bottlenecks caused by rapid industrialisation. Singapore is arguably in a class of its own, having developed one of the best air and sea transport infrastructures and logistic support industries in the world.

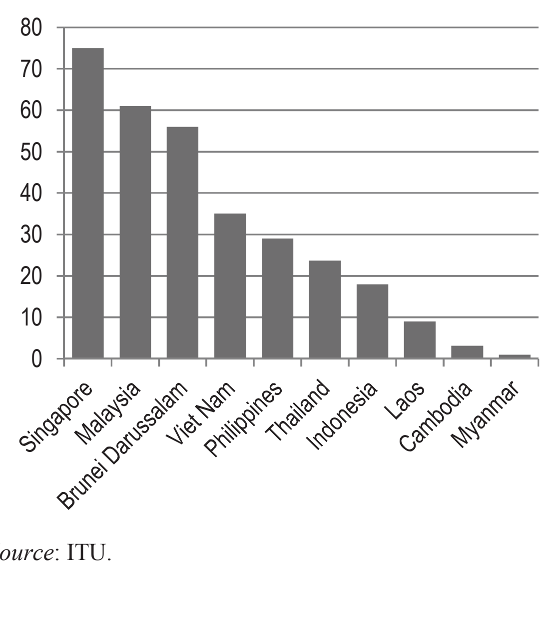
Several countries have liberalised and reformed their telecommunication markets, which has led to steep rises in the use of mobile communications and internet penetration, though often from very low starting points in less developed economies (Figure 4.2). However, there is evidence of digital divides in many countries. For example, in Indonesia, two-thirds of personal computer owners and 70% of households with Internet access are concentrated in Java and Bali alone (Kominfo, 2010).

Figure 4.1. Percentage of population without electricity, 2009



Source: World Bank.

Figure 4.2. Internet users as a percentage of the population, 2011



Source: ITU.

Notwithstanding physical infrastructure constraints, outmoded regulatory and legal systems in many parts of the region create barriers to innovation. For example, in Cambodia, legislation is often inconsistent or is not implemented, while unclear property rights constitute a major problem for dispute resolution mechanisms (World Bank, 2010a). In Indonesia, a lack of transparency and weak implementation of tax regulations hinder investment in innovation. In Thailand, political instability coupled with concerns about corruption and bureaucratic inefficiency has had a major impact on the contemporary business climate. In many countries, bureaucratic hurdles to the setting-up of new businesses remain steep. Table 4.2 shows results from the World Bank's "Doing Business" surveys conducted ten years apart. While hurdles have been lowered in all countries, many Southeast Asian countries continue to perform relatively poorly.

Table 4.2. "Doing Business" indicators for business start-ups

Comparison of "Doing Business" indicators, 2004 and 2013 editions

	2013 Rank	Procedures (number)		Time (days)		Cost (% of income per capita)		Paid-in min. capital (% of income per capita)	
		2004	2013	2004	2013	2004	2013	2004	2013
Singapore	**4**	**7**	**3**	**8**	**3**	**1**	**0.6**	**0**	**0**
Hong Kong, China	6	5	3	11	3	2.4	1.9	0	0
Chinese Taipei	16	8	3	48	10	5.9	2.4	210.8	0
Korea	24	10	5	17	7	18.4	14.6	347.7	0
Malaysia	**54**	**10**	**3**	**37**	**6**	**33.1**	**15.1**	**0**	**0**
Laos	**81**	**7**	**6**	**153**	**92**	**23.9**	**7.1**	**32.1**	**0**
Thailand	**85**	**8**	**4**	**33**	**29**	**8**	**6.7**	**0.4**	**0**
Viet Nam	**108**	**12**	**10**	**59**	**34**	**31.9**	**8.7**	**0**	**0**
Japan	114	11	8	31	23	10.7	7.5	74.9	0
China	151	13	13	48	33	17.8	2.1	1 236.50	85.7
Philippines	**161**	**17**	**16**	**49**	**36**	**28.6**	**18.1**	**2.3**	**4.8**
Indonesia	**166**	**12**	**9**	**168**	**47**	**136.7**	**22.7**	**69.1**	**42**
India	173	11	12	89	27	53.4	49.8	428	140.1
Cambodia	**175**	**11**	**9**	**94**	**85**	**534.8**	**100.5**	**438.9**	**28.5**

Source: World Bank/IFC (2012).

In several countries, business owners point to an uneven playing field where some firms receive preferential treatment in terms of finance and market access. In Malaysia, for example, while the MNE-led manufacturing sector is exposed to intense external competition, competitive pressures in other parts of the economy are weak. In some cases this is due to the presence of large conglomerates and government-linked corporations that crowd the economic landscape; in others it is because the goods and services are not tradable (World Bank, 2010b). These factors point to limited dynamism in the business environment, which can inhibit innovative activities.

Several countries have in place policies to support SME development, and as Table 4.1 shows, this is a major pillar of medium-term strategies in Malaysia and Singapore. On account of their size and agility, innovative SMEs often possess some distinct advantages over larger incumbents in innovation and may have significant potential to grow. However, SMEs also face many well-known challenges, including problems accessing finance, skills and markets. These challenges can be at least partly overcome through policy interventions and Box 4.2 highlights some OECD countries' policy experiences in supporting innovation activities in SMEs.

Box 4.2. Supporting innovation in SMEs – OECD policy experiences

When placing greater emphasis on innovation in their SME policies, governments face two challenges. First, given the variety of factors that influence firms' capabilities and incentives to innovate, they need to co-ordinate their actions in a variety of areas of government policy on the basis of a clear-cut strategy. Second, the heterogeneity of the population of small firms precludes any "one-size-fits-all" approach. In some sectors the bulk of innovations are due to new entrants or start-ups that challenge incumbents' market shares. But in most industries, SMEs contribute to the innovative process in a very different way. They operate in medium- to low-technology environments and innovate without engaging in formal R&D activities. They focus on improving production processes through the use of codified knowledge embedded in up-to-date equipment and on improving product design and marketing techniques through the use of tacit knowledge embedded in human resources.

OECD countries' experience demonstrates the importance of finding the right balance between measures addressing generic problems related to firms' size or newness and more targeted actions to solve problems that are specific to particular types of firms. Best practice policies include the following main components:

- *Conducive framework conditions*. The first responsibility of government is to provide a favourable climate in which entrepreneurs can easily create firms, have incentives to innovate and grow, and can access the necessary resources at a reasonable and predictable cost.
- *Measures to build innovation capacities*. Up to the early 1990s government promotion of innovation in SMEs was almost equated with support to technology diffusion. It focused on supply-led technology transfer and was biased in favour of manufacturing. However, mixed experience with supply-driven programmes, improved understanding of the role of new firms in increasingly interactive innovation processes, as well as growing evidence that the obstacles to innovation in most SMEs were internal to the firm and stemmed from deficiencies in labour skills and in organizational and managerial capacities prompted the emergence of a new generation of policies that put more emphasis on: *i*) fostering an entrepreneurial culture; *ii*) building the "innovative and absorptive capacity" of firms through skills development and improved management; and *iii*) promoting e-business and developing other business infrastructure for small innovative firms.
- *Measures to facilitate financing of innovation*. Insufficient access to financing is a persistent obstacle to the creation, survival and growth of innovative SMEs. Policies to reduce financing gaps broadly fall into three categories: *i*) subsidised loans and loan guarantees; *ii*) provision of seed financing and support for the development of venture capital; and *iii*) tax incentives and/or grants to correct market failures that lead to under-investment in R&D.
- *Measures to promote networking and partnerships*. Even more than larger firms, SMEs depend on external sources of information, knowledge, know-how and technologies in order to build their own innovative capability and to reach their markets. For complementary knowledge and know-how, innovative firms increasingly rely on collaborative arrangements in addition to market-mediated relations (*e.g.* purchase of equipment, licensing of technology). Inter-firm collaboration within networks is now an important channel for the sharing and exchange of knowledge. Interactions are also intensifying between firms and a number of other institutions involved in the innovation process: universities and other institutions of higher education, private and public research labs, providers of consultancy and technical services, regulatory bodies, etc. In OECD countries, public programmes and initiatives that explicitly address networking are commonplace. They address market failures at different stages of the networking process through SME-specific or less targeted measures: *i*) raising awareness of networking opportunities and helping search for partners; *ii*) organising, financing and operating networks; iii) interfacing scientific and innovation networks through public-private partnerships (PP/Ps); and iv) creating international linkages and building global networks.

Source: Based on OECD (2007), *OECD Reviews of Innovation Policy: Chile*, OECD, Paris.

Finally, the existence of a strong and effective intellectual property rights (IPR) regime is also a crucial component of a supportive innovation environment. International IPR agreements mean that IPR legislation is generally in line with international practice across the region. But while IPR legislation is generally adequate, the region's less developed economies often lack the institutional capacity to manage and provide legal support to IPR cases. As a consequence, intellectual property piracy remains a major concern and a lack of company confidence in enforcement mechanisms deters them from accessing the system in the first place. It is costly to monitor potential infringement of IPRs, and the threat of litigation by more resourceful firms can sometimes intimidate SMEs.

4.3. Human capital development

Human resources are a main pillar of knowledge-based economies and as such are a major concern of innovation policy. Box 4.3 highlights the many ways in which human resources spur innovation and points to the importance of a broad set of knowledge and skills beyond science and engineering. Various kinds of design, engineering and associated management activities are critically important, and in many firms it is these resources alone that support innovation.

Box 4.3. How does human capital spur innovation?

Generating new knowledge

Skilled people generate knowledge that can be used to create and introduce an innovation. For instance, Carlino and Hunt (2009) found that the presence of an educated workforce is the decisive factor in the inventive output of American cities, with a 10% increase in the share of the workforce with at least a college degree raising (quality adjusted) patenting per capita by about 10%. Data on Spanish regions also found a positive relationship between levels of human capital and the number of patent applications (Gumbau-Albert and Maudos, 2009). In an alternative approach, using "new work" (*i.e.* new statistical occupational categories) as an indicator of innovation, Lin (2009) found that locations with a high share of college graduates have more jobs requiring new combinations of activities or techniques. Such jobs appeared in the labour market along with the application of new technologies and knowledge.

Adopting and adapting existing ideas

For many countries, incremental innovations involving modifications and improvements to existing products, processes and systems can form the bulk of innovation activity and can have great significance for productivity and the quality of goods or services. Higher skill levels raise economies' absorptive capacities and ability to perform incremental innovation by enabling people to better understand how things work and how ideas or technologies can be improved or applied to other areas. Importantly, skills for adoption and adaptation are beneficial across the wider workforce and population, not just within R&D teams. Toner (2007) argued that the production workforce plays a particularly strong role in incremental innovation, assisted by management that encourages and acts on suggestions for improvement. Skills and absorptive capacity are also required in functions and activities such as marketing. At the same time, more skilled users and consumers of products and services can also contribute to the adaptation of existing offerings by providing the supplier with ideas for improvement.

Enabling innovation through a capacity to learn

Skilled people have a greater ability to learn new skills, to adapt to changing circumstances and to do things differently. In the workplace, educated workers have a better set of tools and a more solid base for further "learning", thus enhancing their ability to contribute to innovation. Leiponen (2000) found that, in contrast to non-innovating firms, innovators' profitability was significantly influenced by the amount of higher education, higher technical skills and research skills possessed by employees. …/…

Box 4.3. How does human capital spur innovation? *(continued)*

Complementing other inputs to innovation

By interacting with other inputs to the innovation process, such as capital investment, people with better skills can spur innovation. For instance, Australian research has shown that human capital complements investment in information and communication technologies (ICT), with the uptake and productive use of ICTs significantly influenced by management and employee skills (Gretton et al., 2004). A Canadian study found that a firm's human resource strategy, as well as its innovation strategy and business practices, influenced the extent to which it adopted new advanced technologies (Baldwin et al., 2004). Equally, because of its complementary nature, a firm's lack of human capital is likely to exacerbate other constraints on innovation. Mohnen and Röller (2001) concluded that measures aimed at removing barriers to innovation may be more effective if also explicitly directed at increasing levels of internal human capital.

Generating spillovers

Human capital can contribute indirectly to innovation through the "spillovers" generated by skilled people. For instance, not only do skilled workers diffuse their knowledge throughout their workplace and the wider environment, they may also, through their interactions and their explicit or implicit actions as role models, spur faster human capital accumulation by other workers. Both of these factors can spur innovation through the spread of ideas and the upgrading of competencies. A recent idea suggests that entrepreneurs also "spill" knowledge by commercialising ideas that would otherwise not be pursued within the organisational structure of an existing firm (Acs et al., 2009).

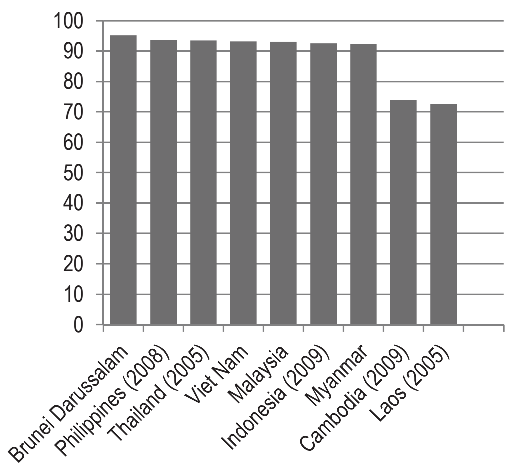
Adding to social capital

Higher levels of human capital enhance social capital, and social capital can support innovation in several ways, predominantly through its effect on trust, shared norms and networking, which improve the efficiency and exchange of knowledge. Some studies suggest that improved levels of trust can promote venture capital financing of risky projects, owing to factors such as reduced monitoring costs (Akçomak and ter Weel, 2009). Closer relationships between actors can lead to the exchange of proprietary information and underpin more formal ties (Powell and Grodal, 2005), while social networks may also enable firms to work through problems and get feedback more easily, thereby increasing learning and the discovery of new combinations (Uzzi, 1997). Firms with higher levels of social capital are more likely to engage specialist knowledge providers, such as the public science base, to complement their internal innovation activities (Tether and Tajar, 2008). Social capital is also a feature of "invisible colleges" that bind researchers across geographic space in pursuit of common research interests.

Source : OECD (2011) *Skills for Innovation and Research*, OECD, Paris.

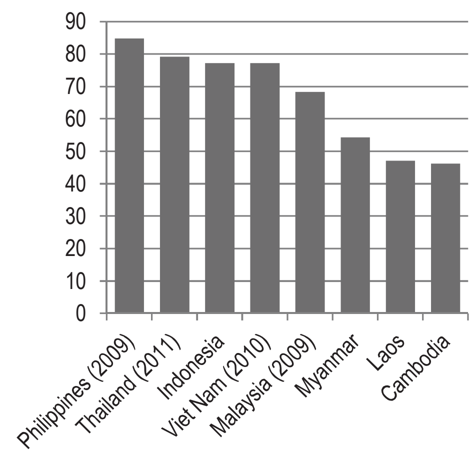
Adult literacy rates are high across the region, with the exception of Laos and Cambodia (Figure 4.3). Moreover, secondary gross enrolment rates have risen sharply over the last two decades, though are still below 50% in Laos and Cambodia (Figure 4.4). Some countries in the region participate in comparative international assessments of student performance, which can shed some light on the comparative quality of their education systems. Among such assessments is TIMSS (Trends in International Mathematics and Science Study), which measures trends in mathematics and science achievement at the fourth and eighth grades. The surveys have been conducted on a regular 4-year cycle since 1995 and the latest available results, from the 2007 survey, are shown in Figure 4.5 for selected countries. Singapore is among the highest ranked countries in the world, while Malaysia and Thailand perform just below the TIMMS scale average score (set at 500). Indonesia is among the lowest ranked countries. This result would seem to mirror countries' level of economic development. Another well-known comparative international assessment programme is the OECD's Programme of International Student Assessment (PISA). Through tests and surveys of 15 year-olds, this examines how well individual national education systems are doing in equipping their young people with essential skills. Unlike many traditional assessments of student performance in science, PISA is not limited to measuring students' mastery of specific science content. Instead, it measures the capacity of students to identify scientific issues, explain phenomena scientifically and use scientific evidence as they encounter, interpret, solve and make decisions in life situations involving science and technology. This is important, since if students learn merely to memorise and reproduce scientific knowledge and skills, they risk being prepared mainly for jobs that are disappearing from labour markets in many countries. For today's global economy, students need to be able to solve problems for which there are no clear rule-based solutions and to communicate complex scientific ideas clearly and persuasively (OECD, 2007b). As with TIMMS, Singapore's performance is ranked among the highest in the world, while the other two Southeast Asian countries that participate in PISA, Thailand and Indonesia, perform some way below the OECD average score (set at 500) (Figure 4.6).

Figure 4.3. Adult (15+) literacy rate (%), 2010



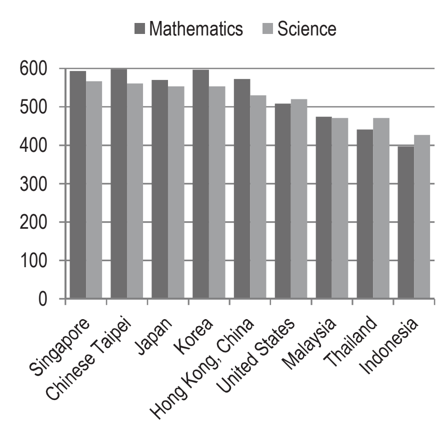
Source: UNESCO.

Figure 4.4. Secondary gross enrolment rates, 2010 or nearest year



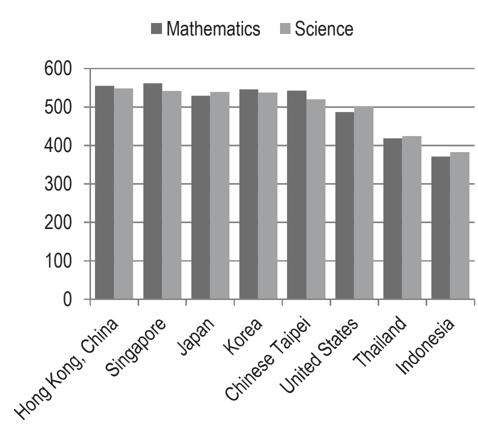
Source: World Bank.

Figure 4.5. TIMSS science and mathematics scores of eighth-grade students, 2007



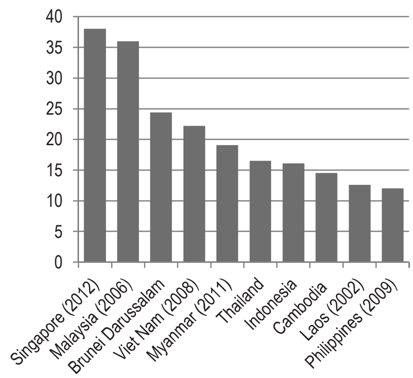
Source: TIMMS International Data Explorer.

Figure 4.6. PISA educational attainment of 15-year olds, 2009



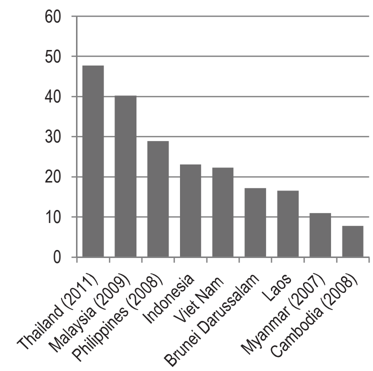
Source: OECD (2011).

Figure 4.7. Percentage of public expenditure on education devoted to the tertiary level, 2010 or nearest year



Source: UNESCO.

Figure 4.8. Tertiary gross enrolment rates, 2010 or nearest year



Source: World Bank.

Education is a major priority for countries in the region – as indicated in Table 4.1. For example, in Singapore, expansion of education at all levels has been a priority public expenditure focus of the government throughout the years, with a shift in emphasis over time with evolving demands for skills. Education is one of the main instruments used by the Malaysian government to improve the socioeconomic status of its population and fuel overall development. The Tenth Malaysia Plan specifically addresses the human capital deficiency and the need to train qualified students and develop a skilled workforce.

Nevertheless, building appropriate human resource competencies is a major challenge for the region. In Singapore, which has been particularly successful in building human resource competencies geared to absorbing and assimilating new technologies, there are insufficient numbers of highly skilled knowledge professionals to meet the critical mass of science and technology manpower needed for its high-technology industrial drive, especially in the life sciences (Wong and Singh, 2008). Problems in Malaysia's education system – particularly at the secondary level, which fails to sufficiently prepare its students for university education – are often blamed for its difficulties in fostering domestic technological development. Realising Malaysia's ambition to move from a focus on assembly in the manufacturing sector towards higher-value, front-end aspects such as design will also depend on increasing the pool of engineers and technical personnel. Thailand faces similar problems. University teaching is academic and does not emphasise creativity and the self-learning abilities that would allow graduates to acquire further knowledge and problem-solving skills. Even in less developed Viet Nam, an insufficient supply of higher education graduates and a very limited science and technology work-force impedes development.

As shown in Figure 4.7, the percentage of public expenditure on education devoted to the tertiary level is still relatively low in most Southeast Asian countries, where capacity development in primary and secondary education provision takes precedence. The exceptions are in more economically advanced Singapore and Malaysia, where the tertiary level accounts for more than one-third of public expenditures on education. Tertiary gross enrolment rates vary considerably across the region (Figure 4.8), with the ranking of countries more or less mirroring their GDP per capita levels.

Raising the quality and relevance of tertiary education is a major policy preoccupation across the region. In Malaysia, the Ministry of Higher Education has put in place the Higher Education Strategic Plan to revamp tertiary education to better meet labour market needs. A rating system for Malaysian higher education institutes (SETARA) has also been introduced to enhance quality and promote best practices in public universities. The Thai government has approved a 15-year Tertiary Education Framework (2008-22) focused on knowledge and innovation. Among other things, it seeks to improve cooperation between industry and educational institutes on curricula design. In Viet Nam, reforms are still needed to enable the higher education system to meet demands for trained science and technology workers in an expanding economy. Debates continue on what constitutes a useful education, as currently skills needed by employers are often at odds with the focus of Viet Nam's higher education on theoretical learning.

Meeting the skills demands of industry is perhaps nowhere more important than in the provision of vocational education and training. Singapore has been particularly effective in promoting industrially relevant workforce development through a network of institutes for technical education (ITEs) with a host of industrially relevant vocational training programmes. Many of these programmes are collaborative ventures between the government and reputable overseas partners, such as MNEs and highly regarded foreign industrial training institutes. Other countries in the region continue to trail Singapore in this regard. One major issue is the perceived inferior status of vocational training vis-à-vis university qualifications. The government in Malaysia has tried to tackle this problem by incorporating some vocational training programmes into tertiary education, for example, by setting up several new university colleges to revamp the science, technology and engineering education system. A national dual training system has also been incorporated into existing vocational education to address technical labour shortages. In Thailand, a Science-Based Technology School (SBTS) has recently been established whose objective is to increase the number of qualified vocational students. Work-integrated learning is being expanded through the Practice Engineering School approach to meet industry demand for engineers. The programme provides work and research experience at industrial sites to students who study for one year and work on industrial projects for the second year at the company (Intarakumnerd, 2010). In the less economically developed countries of the region, significant deficits of skilled technicians and workers with vocational qualifications remain, despite a desperate need for people with such skills in industry. For example, in Cambodia, much technical and vocational education and training is of relatively low quality, while little information is given to secondary students on potential careers and job opportunities for skilled technicians. In Viet Nam, no dual vocational education system exists whereby students combine theoretical training with practical training at a company. In summary, improving the availability, access and quality of the technical track is as important as upgrading the academic track, yet most countries in the region need to do considerably more in this regard.

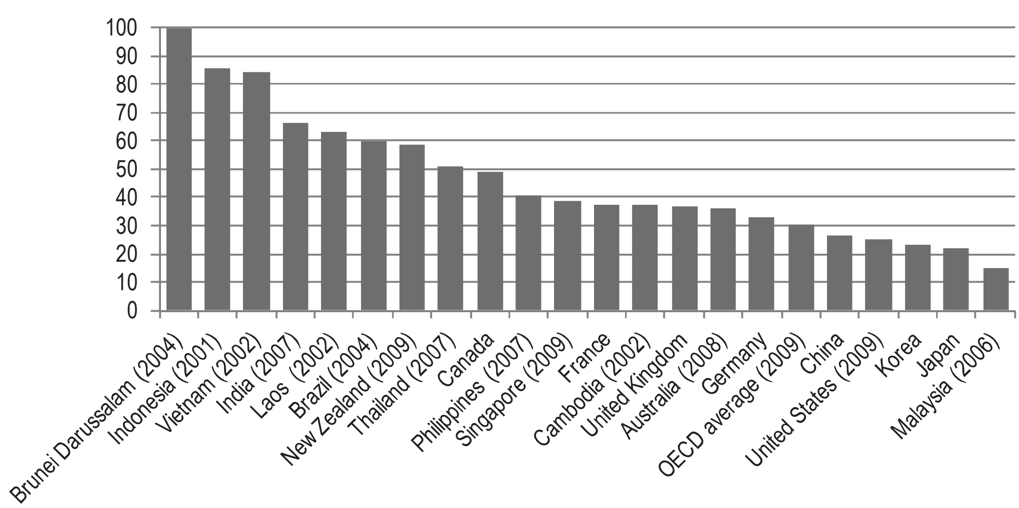
The school and further/higher education system are not the sole organisational mechanism for creating required human capital. Business firms are also important creators of human capital for the innovation system and are not simply employers of human resources. For example, many of the skills associated with various kinds of design, engineering and associated management activities are often acquired in firms. Yet, there are serious deficiencies in the training of workers by firms in the region, especially among SMEs, which limits knowledge upgrading and undermines progress towards activities with higher value added and higher productivity.

Finally, the international mobility of skilled workers is an important issue for the region. For example, a key aspect of Singapore's competence-building policy is its policy towards attracting foreign talent. To supplement the local supply of skilled labour, the government has consistently adopted a liberal immigration policy to attract overseas skills. China and the Indian sub-continent have provided the bulk of the foreign technical professionals working in Singapore since the mid-1990s (Wong and Singh, 2008). Other countries in the region tend to suffer from net outward mobility of the highly-skilled and many have considerable overseas knowledge diasporas as a result. For the most part, these diasporas have not been a source of local entrepreneurship or technical improvements, although governments are looking to change this with new programmes offering incentives to nationals living abroad to return to work in the country.

4.4. Public sector science and technology

Government also plays a significant innovation role via the public research system. The two main actors in the public research system are universities and public research institutions (PRIs), where PRIs include government research laboratories and establishments engaged in activities such as administration, health, defence and cultural services, public hospitals and clinics, technology centres and science parks (OECD, 2011). All Southeast Asian countries have public sector science and technology systems of varying scope and scale. In some countries, such as Indonesia and Vietnam, the public sector performs more than 80% of gross expenditure on R&D. In others, such as Malaysia and Singapore, it is a much lower proportion, on account of the relatively strong performance of firms (Figure 4.9). Several countries have formulated dedicated science and technology plans or strategies in place that seek to strategically steer their research systems (Box 4.4). These typically include various targets and also tend to outline thematic priorities.

Figure 4.9. Proportion of GERD performed in public research institutes and universities, 2010 or latest available year



Source: UNESCO; OECD Main Science and Technology Indicators 2012/1.

Box 4.4. Recent science and technology plans in selected countries

Indonesia: The National Research Council (DRN) suggests research priorities which feed into broader-based planning activities. Within the context of the production of a long-term National Development Plan covering the period 2005-2025 (the RPJPN), Indonesia has been producing a series of medium-term five-year plans (RPJMNs), each of which comprises five annual plans (RKPs). The first, covering 2005-2009, prioritised the establishment of a stable, prosperous democratic nation; the second (2010-2014) focused on human resource development and improved S&T capability. It was envisaged that the third (2015-2019) would have a similar focus, and that the fourth (2020-2024) would prioritise the establishment of a solid economic structure based on local competitive advantage, quality and strong human resources (Sulaeman and Pawennei, 2010). The vision outlined in the second RPJMN for 2010-2014 emphasises the two main strands that constitute the Science and Technology National Strategic Policy. The first is strengthening the national innovation system via efforts designed to strengthen institutions, S&T resources and networking. The second focuses on R&D and the application of S&T in the priority research areas suggested by the National Research Council and detailed in the National Research Agenda.

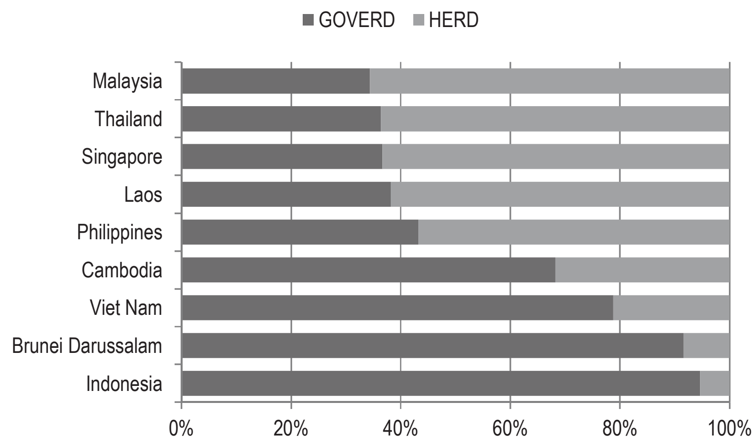
Malaysia: The current initiatives of the government are the New Economic Model (NEM) and the Tenth Malaysia Plan (2011-15), both of which emphasise, among other priorities, improving innovation capability and human capital development as well as institutional efficiency. The NEM has identified growth drivers in the electrical and electronics industry, information technology (IT), nanotechnology, biotechnology and life sciences, palm oil downstream industries, high-end commercial agriculture, the oil and gas industry, medical and bio-tourism services, green technology industries and services, and integrated Islamic finance involving banking, capital markets and insurance. Specific incentives are being used to encourage MNEs to locate their research and development (R&D) centres as well as advanced production and assembly operations in Malaysia (Felker and Jomo, 2007).

Singapore: Singapore places a strong emphasis on building long-term basic research capabilities. This emphasis was confirmed in the National Science & Technology Plan 2010 (STP 2010) and the establishment of the National Research Foundation (NRF) (Wong, 2011). The current 2011-15 R&D budget of SGD 16.1 billion represents a 20% increase over STP 2010; moreover, greater emphasis will be placed on technology commercialisation to recoup some of the cost of R&D, by encouraging public-private R&D partnerships and the establishment of technology transfer offices and enterprise incubators (Teh, 2010). . SGD 1.55 billion has been allocated to the NRF for the development of three strategic sectors in which Singapore is seen to have a competitive advantage and which are critical for future economic growth: biomedical sciences; environmental and water technologies, including clean energy; and interactive and digital media.

Viet Nam: The Government aims to improve the S&T system through the 2011-2020 Science and Technology Development Strategy signed by the Prime Minister in 2012. The Strategy has three main targets; *i*) to raise the value of high-tech and applied science products to about 45% of GDP by 2020 and to ensure a 15-17% annual growth rate of the science and technology market; *ii*) to increase the ratio of scientific researchers and professional staff in ICT to 9 or 10 people per 10 000 employees, while up to 5 000 highly skilled engineers will be trained to operate in Vietnam's priority fields by 2015; and *iii*) to develop 60 basic and applied science research centres of international standing by 2020. The government has identified a number of priority sectors within the Strategy: petroleum, metallurgy, machinery, basic chemicals, fertilizers and construction materials.

Higher education research plays a particularly significant role in the development of national innovation and R&D capabilities in OECD countries, but probably more through its contribution to human capital formation than through its contribution to new knowledge. This is a main reason for expanding the research capacity of higher education to meet the growing needs of the economy. Figure 4.10 shows that countries fall into two broad categories on the balance between where public R&D is performed. The more technologically advanced economies of Singapore, Malaysia and Thailand are clearly more university-centric, whereas a majority of the less developed countries rely more heavily on public research institutes. In some of these countries, there is a clear need for reform of many of these institutes, many of which are small and lack adequate funding.

Figure 4.10. Balance in R&D expenditures between government labs and universities, 2007 or nearest year



Source: UNESCO database.

To make higher education research a useful component of the innovation system it is important for universities not only to have a significant amount of fundamental research capacity but also to devote much attention to strategic and applied research in areas of social and industrial relevance. Programmes that link higher education to industry can be important focusing devices that signal where the higher education system should increase its activities and are also useful sources of information for the universities.

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Part II

NATIONAL INNOVATION PROFILES

Chapter 5

Cambodia innovation profile

Cambodia lags behind many of its regional neighbours in terms of overall development, but growth has been rapid over the past decade because of increases in trade, tourism and foreign direct investment (FDI). It is still dominated by agriculture and garment manufacture, and employment growth has helped to reduce poverty. There is little technological sophistication and innovation has played an insignificant part in economic development, as many factors conspire to undermine firms' capacity to become competitive and innovate. The country's fragile infrastructure is a deterrent to inward investment, its information and telecommunications infrastructure is expanding but still at an early stage of development, and its legal and financial institutions are not geared towards innovative entrepreneurial activity. As a consequence, Cambodia's innovation performance is weak. There is very little expenditure on R&D, the number of researchers is low, publication levels are modest, albeit growing, and patenting is extremely rare.

Current policies focus on product diversification, trade expansion and efforts to increase FDI. There is no explicit focus on science or innovation policy, though general improvements to the business environment are likely to improve framework conditions for innovation. The establishment of an Accreditation Committee for degrees awarded by higher education institutions (HEIs) and a National Training Board to oversee the development and implementation of a national plan for vocational education and training should also improve the quality of educational provision and strengthen the human resource base.

The relative immaturity of the country's innovation system suggests that it is too early for innovation to be at the heart of its short-term plans for development. Continued expansion via trade and inward investment and efforts to upgrade the general business and educational environments must take priority. But there is tremendous scope for short-term plans to be informed by long-term visions that prioritise actions likely to facilitate the country's eventual transition to a modern, innovation-oriented economy. This will call for an approach to policy formulation that emphasises the co-ordination of seemingly disparate policies towards a common goal. In particular, the further development of the educational sector will need to prioritise science, engineering and entrepreneurship; industrial policy will need to prioritise cluster developments, spillovers and product diversification that involves the manufacture of higher value-added goods; and science and innovation policies will need to move towards centre stage if a suitable infrastructure for scientific and innovative activities is to emerge.

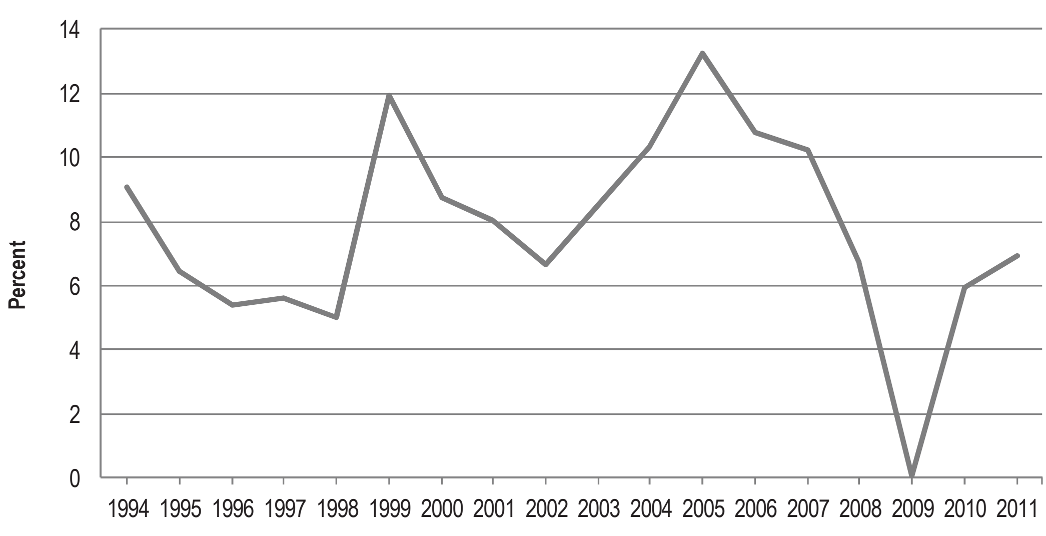
5.1. Macroeconomic performance and framework conditions for innovation

5.1.1. Performance and structure of the economy

In the decade preceding the global financial crisis of 2008, Cambodia's gross domestic product (GDP) grew in real terms at an average annual rate of 9.5% (1999-2008) (Figure 5.1), with real GDP per capita increasing from USD 969 in 1999 to USD 1 898 in 2008, both at constant 2005 PPP prices. Although starting from a very low base, this placed Cambodia among the world's 15 fastest-growing economies, with continued growth in exports as well as foreign direct investment (FDI). Over the period 2004-07, the incidence of poverty in Cambodia fell by around one percentage point a year, from 34.8% in 2004 to 30.1% (Figure 5.2) as a result of rapid economic growth. Most of the growth occurred in four sectors – tourism, construction, the garment industry and agriculture – with exports to international markets and employment expansion in the latter two playing a particularly important role in poverty reduction. Labour productivity also grew steadily after a dip in the growth rate during 1995-2000 (Figure 5.3), but in absolute terms it remains at a low level (approximately 4% of the US level in 2010) and made only a modest contribution to economic growth (APO, 2012).

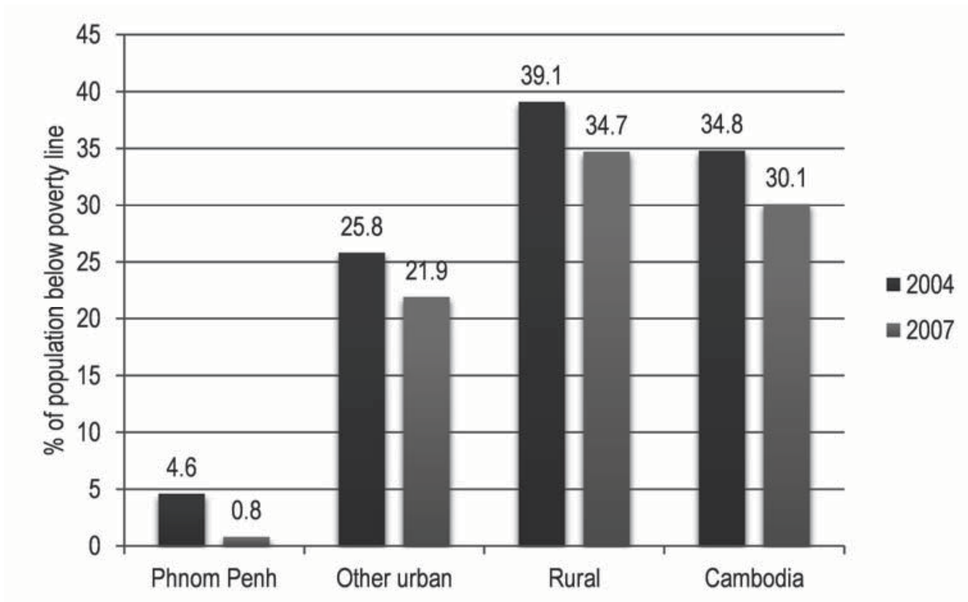
Cambodia's efforts to catch up with some of the more developed countries in South-east Asia were temporarily interrupted by the global economic crisis. The ensuing downturn affected several of Cambodia's primary engines of growth – garment exports, tourism, construction and FDI. Overall GDP growth was only 0.1% in 2009. In the short run, budgetary consolidation measures have been introduced, with cuts in public expenditure affecting some public services and investment in infrastructure. Fiscal consolidation should provide a solid base for long-term economic growth. The economy recovered somewhat with growth of 6% in 2010 and 6.8% in 2011 with a growth in 2012 expected to be 6.6% (World Bank, 2012a).

Figure 5.1. GDP growth rates, 1994-2011



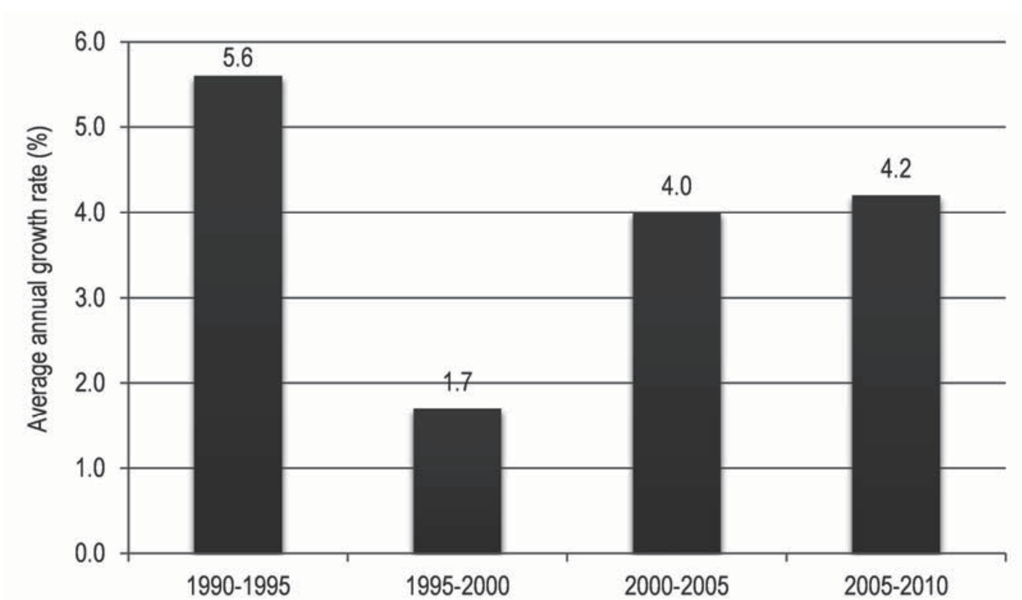
Source: World Bank World Development Indicators.

Figure 5.2. Changes in the incidence of poverty, 2004 and 2007



Source: Khov (2010), "Review of Innovation in Southeast Asia – Country Note: Cambodia", Draft prepared by the Institute of Technology of Cambodia (ITC). Based on Cambodia Socio-Economics Survey (CSES) results for 2004 and 2007; see NIS, 2011), "Cambodia Socio-Economics Survey Results, 2004 and 2007", National Institute of Statistics, *www.nis.gov.kh/*; and Knowles (2008), "Poverty Estimates for Cambodia, 2007", Report to the EAS Country Unit of the World Bank.

Figure 5.3. Trends in labour productivity growth, Cambodia, 1990-2010



N.B. Average annual growth of GDP at constant basic prices per hour, using 2005 PPPs.

Source: APO (2012).

Table 5.1 shows the distribution of GDP by sector in 2008. Textiles and crop production constituted the largest individual sub-sectors, with agriculture and industry each accounting for just over a quarter of total GDP and the services sector accounting for nearly 40%. Growth rates in 2008 were highest in the services sector (9%), followed by agriculture (5.7%) and industry (4.0%).

For a small and open economy such as Cambodia, international trade and FDI are of key importance for economic growth and development. Aspects of the evolution of the world economy – notably globalisation and the emergence of new economic players on the global stage – provide fresh opportunities, but they also require continuous adaptation if a country is to remain competitive. International linkages through trade and FDI are also important for a country's innovation performance, since they are channels of knowledge flows both directly and indirectly through the transfer of knowledge via spillovers.

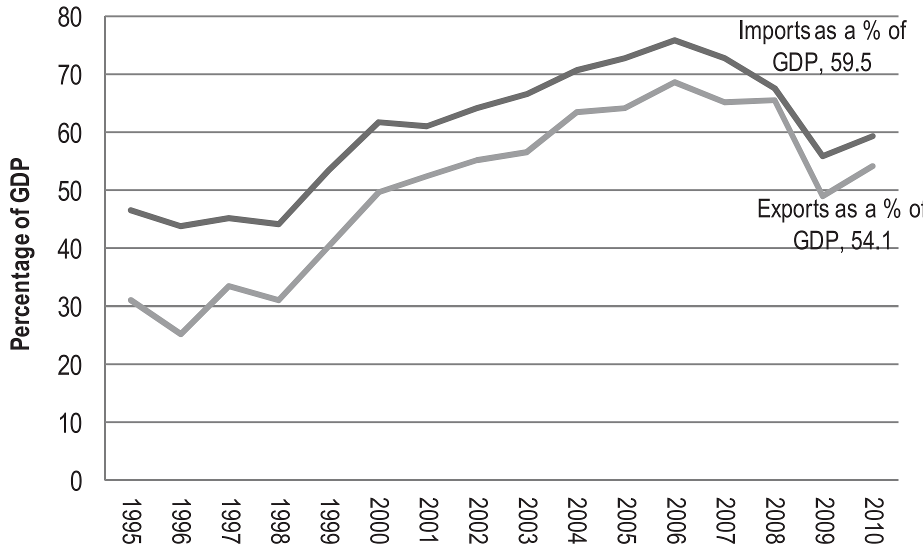
Table 5.1. GDP and GDP growth distribution by sector, Cambodia, 2008

Sector	Value added (KHR millions, constant 2000 prices)	Distribution (% constant 2000 prices)	Growth rate (% constant 2000 prices)
Agriculture, fisheries & forestry	7 583 772	26.5%	5.7%
Crops	4 000 119	14.0%	6.6%
Paddy	2 116 451	7.4%	4.1%
Other crops	1 883 668	6.6%	9.5%
Livestock & poultry	1 162 907	4.1%	3.8%
Fisheries	1 900 098	6.6%	1.5%
Forestry & logging	520 648	1.8%	0.9%
Industry	7 869 800	27.5%	4.0%
Mining	125 892	0.4%	15.8%
Manufacturing	5 681 074	19.8%	3.1%
Food, beverages & tobacco	547 791	1.9%	5.9%
Textile, wearing apparel & footwear	4 354 584	15.2%	2.2%
Wood, paper & publishing	110 077	0.4%	5.0%
Rubber manufacturing	64 163	0.2%	9.2%
Other manufacturing	604 458	2.1%	6.5%
Non-metallic manufacturing	175 053	0.6%	9.1%
Basic metal & metal products	65 566	0.2%	7.0%
Other manufacturing	363 839	1.3%	5.2%
Electricity, gas & water	164 050	0.6%	8.5%
Construction	1 898 784	6.6%	5.8%
Services	11 217 428	39.1%	9.0%
Trade	2 454 883	8.6%	9.4%
Hotel & restaurants	1 311 632	4.6%	9.8%
Transport & communications	1 748 649	6.1%	7.1%
Finance	454 033	1.6%	19.2%
Public administration	348 597	1.2%	4.5%
Real estate & business	2 157 868	7.5%	5.0%
Other services	2 741 767	9.6%	12.0%
Taxes on products & services	2 338 291	8.2%	6.7%
Taxes on products	2 374 405	8.3%	9.0%
Less: Subsidies	36 114	0.1%	1.5%
Less: FISIM	341 774	1.2%	14.0%
Gross domestic product (GDP)	28 667 518	100.0%	6.7%

Source: National Institute of Statistics, Cambodia.

Cambodia opened its economy and its trade regime in the 1990s. It joined the Association of Southeast Asian Nations (ASEAN) in 1999 and was among the first of the least developed countries to join the World Trade Organization (WTO) in 2004. Over the decade prior to 2008, garment exports and tourism were the key drivers of economic growth, and this in turn led to the development of the agriculture and construction sectors. Total exports increased from around 34% in 1997 to 68.6% of GDP in 2006 but fell back strongly in 2009 before reaching 54.1% of GDP in 2010 (Figure 5.4). The major products exported in 2009 were clothing, timber, rubber, rice, fish, tobacco and footwear (CIA, 2011). Between 2000 and 2010 the United States and China remained the predominant destinations for exports from Cambodia (Table 5.2) although the combined share of exports to those two countries fell over the period.

Figure 5.4. Imports and exports, 1995-2010



Source: World Bank World Development Indicators.

The current intention is to diversify the range of products available for export. In 2007, the government's Diagnostic Trade Integration Strategy (DTIS) identified 19 products with good export potential. These included products from the agricultural sector (beer, cashew nuts, cassava, maize, fish, livestock, rice, rubber, silk, soybeans, fruit and vegetables – including organic mango, palm and pepper, and wood products); the industrial sector (footwear, garments and light manufacturing assembly); and the services sector (tourism, labour services such as construction and domestic services, transport and business services, including information technology).

Total imports also increased from around 47% in 1995 to 76% of GDP in 2006 before falling back to 59.5% by 2010 (Figure 5.4). To some extent this growth over time highlights Cambodia's limited capacity to capture a larger share of value chains. In the garment sector, for example, fabrics continue to be almost entirely imported. The major products imported are petroleum products, cigarettes, gold, construction materials, machinery, motor vehicles and pharmaceutical products (CIA, 2011). Between 2000 and 2010 China grew to become the biggest importer to Cambodia whilst the share of imports from Hong Kong and Thailand has fallen, although they still represent major partners (Table 5.2).

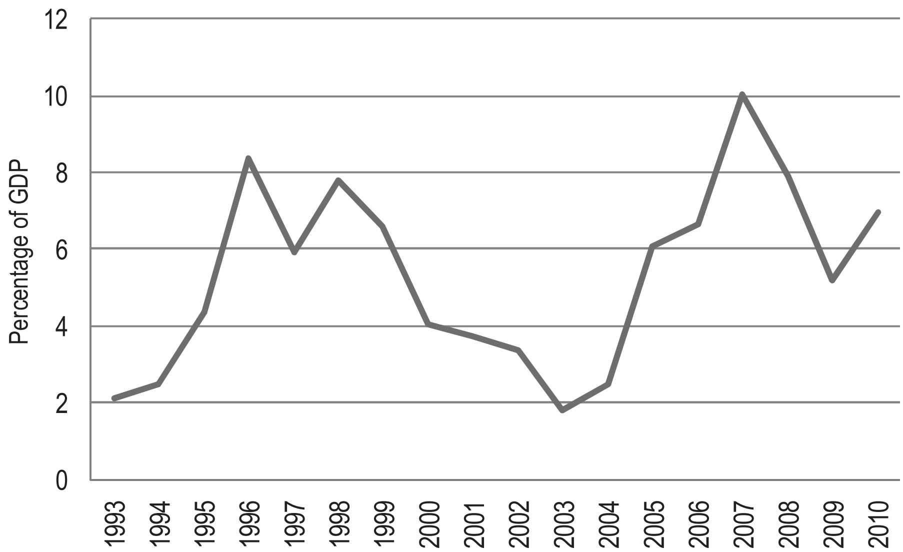
Table 5.2. Cambodia's top trading partners, 2000-10

Rank	Cambodia's top 10 export partners in 2000	USD million	Cambodia's top 10 export partners in 2010	USD million
1	United States	751	United States	1 906
2	Hong Kong, China	266	Hong Kong, China	1 386
3	United Kingdom	83	Singapore	430
4	Germany	67	Canada	274
5	France	28	Netherlands	236
6	China	24	United Kingdom	235
7	Thailand	23	Thailand	150
8	Netherlands	21	Germany	112
9	Viet Nam	20	Spain	101
10	Singapore	18	Viet Nam	96
Rank	Cambodia's top 10 import partners in 2000	USD million	Cambodia's top 10 import partners in 2010	USD million
1	Hong Kong, China	258	China	1 186
2	Thailand	225	Thailand	691
3	Chinese Taipei	178	Hong Kong, China	553
4	China	115	Viet Nam	487
5	Singapore	108	Chinese Taipei	477
6	Viet Nam	93	Korea	248
7	Korea	78	Indonesia	175
8	Indonesia	69	Switzerland	171
9	Malaysia	65	Malaysia	166
10	Japan	59	Japan	157

Source: UN Commodity Trade (Comtrade) Statistics Database.

When it opened to the world economy, Cambodia attracted considerable inward flows of FDI. After the first election in 1993, FDI increased from 2.8% of GDP to 8.4% of GDP in 1996 (Figure 5.5). Growth was interrupted temporarily by political instability in 1997-98 and by the Asian financial crisis of 1997, which led to a decline in the growth rate that reached a nadir of 1.6% in 2003, but political and macroeconomic stability and the 2003 amendment to the *Investment Law*, which offered tax incentives and ensured equality of treatment for domestic and foreign investors, helped to raise FDI to a new peak of 10% of GDP in 2008, with growth especially strong in the garment sector, tourism and real estate, although the most recent figures for 2010 are lower at 7% of GDP. There is also significant investor interest in mining, as opportunities exist for mining bauxite, gold, iron and gems. China has made substantial investments in mineral resources and hydro-energy; Korea has invested in the construction sector; and Viet Nam has invested in the fertiliser industry (Shin, 2011). By 2010, many multinational companies from Asia, Europe and the United States had become active in Cambodia, including 47 from Japan (NTT, 2011).

Figure 5.5. Foreign direct investment, net inflows as a percentage of GDP, 1993-2010



Source: World Bank World Development Indicators.

FDI has the potential to contribute to Cambodia's economic growth in various ways. It can act as a channel for knowledge flows by providing Cambodian firms opportunities to learn about advanced methods and skills in production, finance and marketing. It can also help domestic firms to establish innovative regional networks around or involving foreign-controlled companies, with spillovers having an indirect impact on economic performance. To date, however, such spillovers have been limited, and despite improved FDI and trade performance, Cambodia was only in 97th position on the World Economic Forum's Global Competitiveness Index in 2010. This compares with the higher rankings of its regional competitors, Singapore (3rd), Malaysia (26th), Thailand (38th), Indonesia (44th) and Viet Nam (59th), although the position was 12 places higher than the previous year.

5.1.2. Framework conditions for innovation

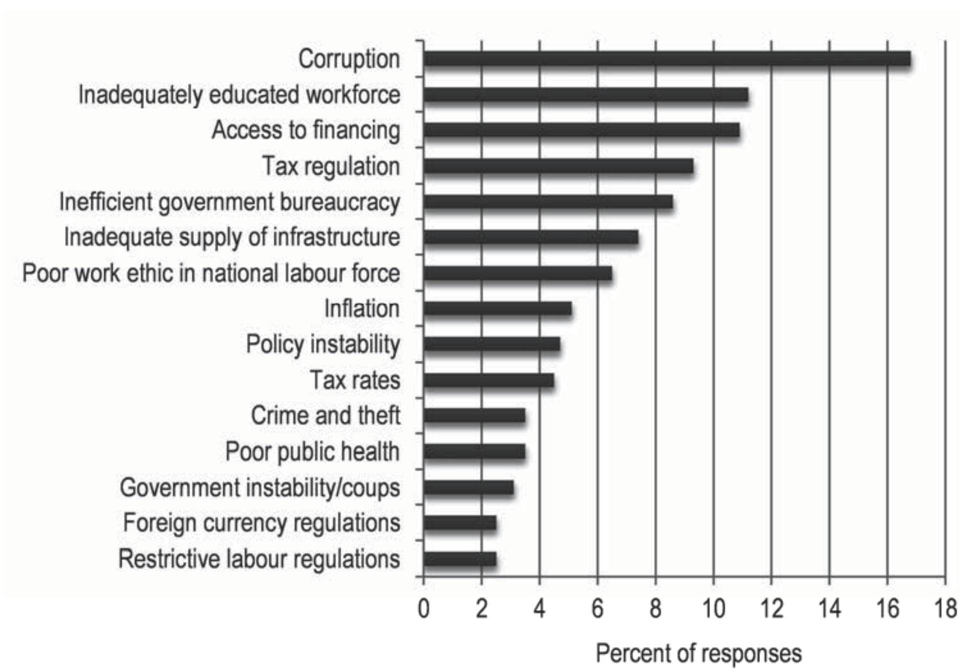
Any attempt to catch up with its regional neighbours will necessarily involve a strong focus on innovation in its broadest sense (*i.e.* the implementation of new or improved products, processes, services, marketing methods, business practices and models, etc.) and concerted efforts to establish suitable framework conditions. These include, for example, improvements to the overall macroeconomic framework, the general business environment, the country's logistics and information and communication technology (ICT) infrastructures, the degree and quality of entrepreneurship, the intensity of competition, and product and labour market regulations.

The opening of the economy has helped to create well-functioning product markets and an improved business environment. Accession to the World Trade Organization has helped firms to access global supply chains and new sources of know-how and finance. Product market competition is also now a strong driver of productivity growth and improved product and service provision. The introduction of local competition in the telecommunications sector, for example, has led to better telecommunication services, with the cost of mobile communications falling progressively and the number of subscribers rising to around 14 million by the end of 2011.

Political and macroeconomic stability and recent success in terms of trade expansion and FDI flows also constitute a good platform for the future development of a supportive environment for innovation, but innovation has played an insignificant part so far in economic development and many factors undermine the capacity of firms to become competitive and innovate. These include red tape and corruption, an underdeveloped infrastructure, a weak legal and regulatory system, and an inadequate set of innovation-related policies (World Bank, 2010).

According to the World Economic Forum, corruption and an inefficient government bureaucracy were the factors most cited as undermining successful business operations (Figure 5.6). In the Transparency International Perceptions Index of 2012, Cambodia ranked 164th out of 183 countries in terms of perceived levels of corruption. There is also evidence that administrative procedures continue to be a burden on the business community. The World Bank's Doing Business indicators for 2012 (World Bank/IFC, 2012), for example, ranked Cambodia 138th out of 183 countries in terms of the ease of doing business, and 171st in terms of the ease of starting up a business.

Figure 5.6. The most problematic factors for doing business in Cambodia

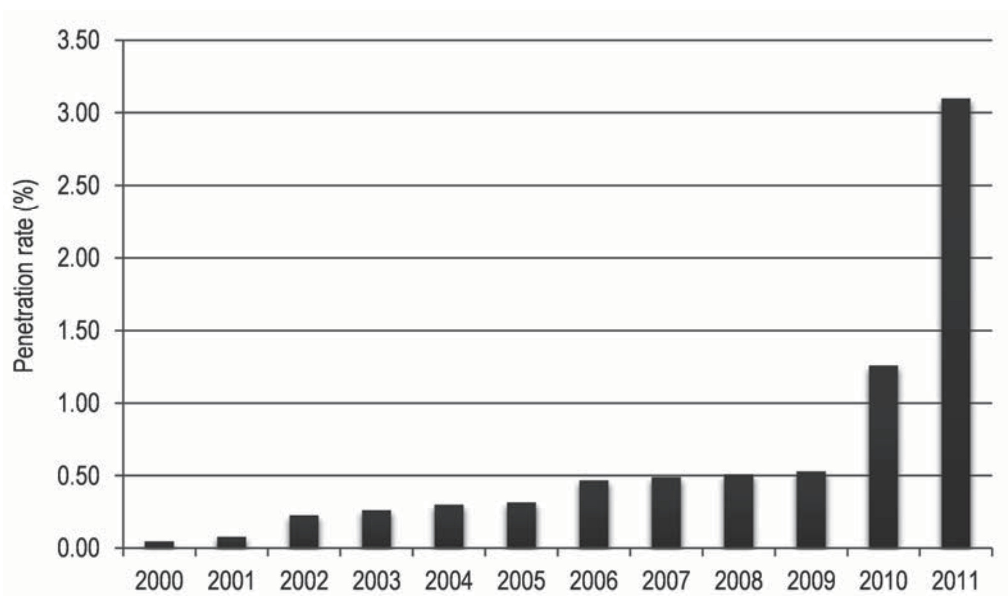


Source: World Economic Forum (2012). Percentages represent the weighted results of a ranking of the five most problematic factors from a list of 15 by respondents to the WEF survey.

Cambodia's weak overall infrastructure is also a deterrent to investment, growth and the conduct of business generally (Figure 5.6), especially for firms in the agribusiness sector. It takes rural firms, for example, an average of 2.6 hours to reach their most important markets, and around 3.5 hours to reach input suppliers and financial institutions. The electricity grid is also restricted to urban environments. Since liberalisation and the reform of the telecommunications market in 2007-08, however, the use of mobile communications has increased and Internet penetration has started to rise steeply (Figure 5.7), but in 2011 it was still at a very low level (3.1%) compared to other Southeast Asian countries, *e.g.* Singapore (75%), Malaysia (61%), Viet Nam (35%), Thailand (24%) and Indonesia (18%). Fixed broadband subscriptions were also very low in 2011 (0.15 per 100 inhabitants), a decrease on the previous year's figure. This compares with 25.5 subscriptions per 100 inhabitants in Singapore, 5.4 in Thailand and 4.3 in Viet Nam.

Entrepreneurs' access to finance is limited in Cambodia. The availability of bank credit is constrained by the low penetration of commercial banks in rural areas, as financial services are still largely an urban phenomenon. Most companies in Cambodia also still operate on an extremely informal level, so that banks demand high collateral and set high interest rates. Access to venture capital is an option, since there are many venture capital funds in Cambodia, but the overall amount of venture capital is rather small by international standards. Most of these funds also tend to be invested in non-innovative activities, especially in booming sectors such as real estate and service businesses. A limited fund established by the government and development partners is now available to encourage entrepreneurs in the agribusiness sector and to support R&D activity.

Figure 5.7. Internet users per 100 inhabitants, Cambodia, 2000-11



Source: ITU (2012), World Telecommunications and ICT Database, *www.itu.int/ITU-D/ict/statistics/*.

Deficiencies in Cambodia's legal and regulatory system constitute another barrier to the operation of an efficient business sector. Legislation is often inconsistent or is not implemented, and business owners point to an uneven playing field where some enterprises receive preferential treatment in terms of equity, credit and market access. Unclear property rights also constitute a major problem for agribusinesses and local producers, since weak dispute resolution mechanisms are incapable of dealing with the rising incidence of disputes (World Bank, 2010).

The existence of a strong and effective intellectual property rights (IPR) regime is a crucial component of a supportive innovation environment, and Cambodia has taken steps to establish one that is in line with international practice. A law covering patents, utility models and industrial designs was enacted in 2003 to comply with Cambodia's WTO obligations, and it was supplemented in 2006 by a decree detailing procedures. The current legislation provides, in particular, for international IPR agreements to which Cambodia is a party to take precedence over national legislation in case of conflict. Despite the adequacy of existing legislation, however, Cambodia lacks the institutional capacity to manage and provide legal support to IPR cases. This is currently not a major problem, since most Cambodian enterprises, especially small and medium-sized enterprises (SMEs), are untroubled by IPR concerns, but it could become one in the future as the importance of innovation is more fully recognised.

5.2. Innovation performance

Innovation has not played a significant role to date in Cambodia's economic development and innovation performance as a whole is weak by all standard measures. Cambodia ranked 132nd on the World Bank's Knowledge Economy Index in 2012 with an overall KEI figure of 1.56, and a score of 1.54 for the knowledge pillar (Table 5.3). Moreover, it has fallen sixteen places in the international ranking since 2000 suggesting slow progress in innovation performance compared to similar countries.

Table 5.3. Knowledge Economy Index and Knowledge Index, Cambodia, 2012

Indicator	Value
Knowledge Economy Index (KEI)[1]	1.71
Knowledge Index (KI)[2]	1.52
Economic incentive and institutional regime	*2.28*
Innovation	*2.13*
Education	*1.70*
ICT	*0.74*
Position in world rank	132
Change in rank from 2000	-16

1. The Knowledge Economy Index (KEI) is calculated on the average of the normalised scores of a country on all four pillars related to the knowledge economy: economic incentive and institutional regime; education; innovation; and ICT.

2. The Knowledge Index (KI) measures a country's ability to generate, adopt and use knowledge. The index is based on key variables in the three knowledge pillars: education; innovation; and ICT.

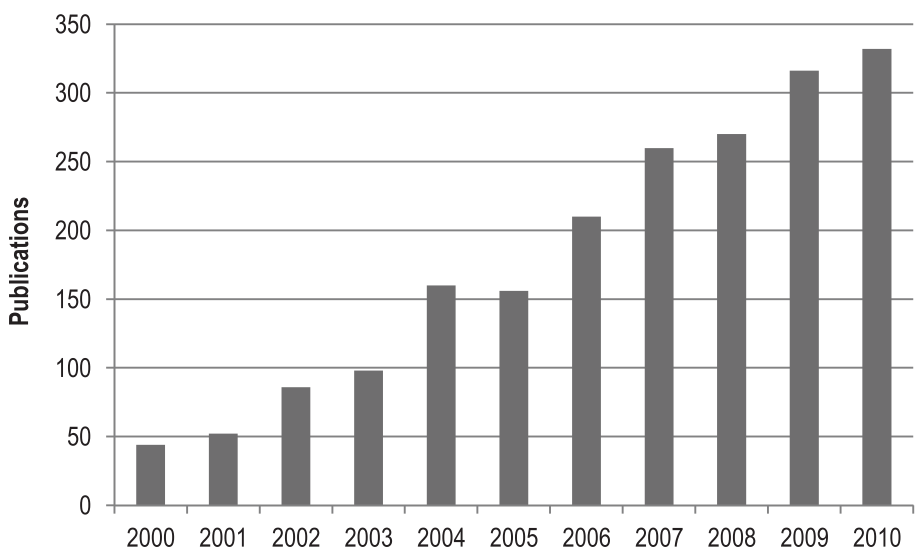
Source: World Bank (2012).

Cambodia's gross domestic expenditure on R&D (GERD) is very small. GERD as a percentage of GDP was 0.05% (according to 2002 UNESCO statistics), considerably below, for example, Thailand's more recent GERD/GDP ratio of 0.26% in 2007. Over 50% of R&D expenditure occurs in the private non-profit sector, 25% in the government sector and 12% in the business sector, with only 12% in the university sector (Turpin and Magpantay, 2009). Over 70% of R&D funding comes from either the NGO sector or abroad.

The human resources available to undertake R&D are also limited. In 2006, there were only 223 full-time equivalent researchers, or 16.85 persons per million inhabitants, less than a fifth of the equivalent number in Viet Nam (World Bank, 2011). Half were employed in the government sector, 21% in the private non-profit sector, 16% in industry and just 13% in universities.

Taking Cambodia's low spending on R&D and limited scientific resources into account, the fact that it produces only a small number of scientific publications annually should come as no surprise. The number of scientific journal publications (in the Scopus database) has increased progressively, however, from below 50 in 2000 to over 330 in 2010 (Figure 5.8), with English language publications growing commensurately. Data on scientific publications show that 90% of publications over 2000-2010 were with international co-authors (most commonly with from the United States, France and Japan). This reflects the limited resources available for science and technology in Cambodia and the importance of co-operation with foreign partners willing to cover many of the expenses involved in R&D projects.

Figure 5.8. Trends in scientific publications, Cambodia, 2000-10

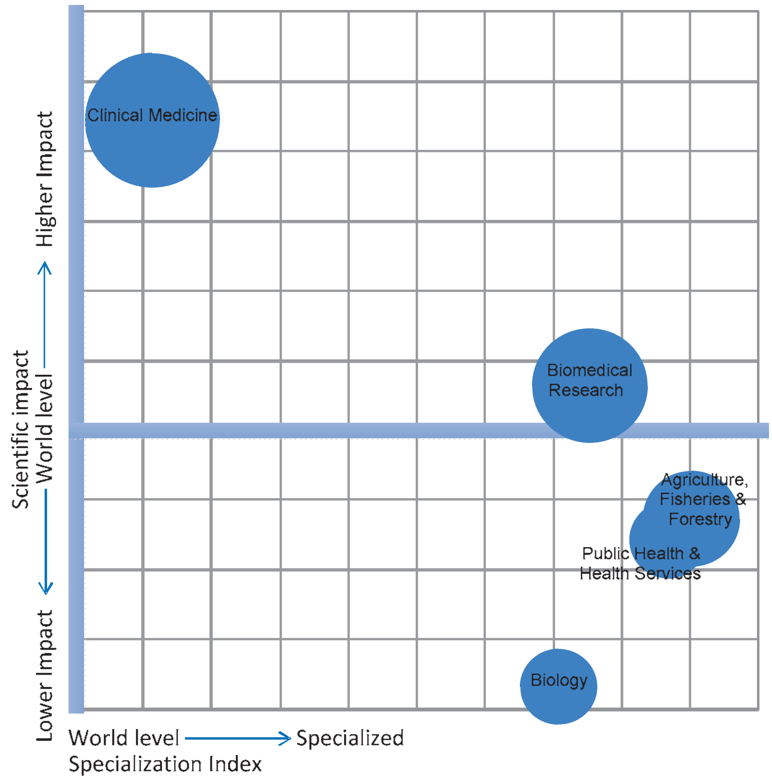


Source: Science Metrix analysis of Scopus (Elsevier) database.

Clinical medicine and biomedical research are the two largest areas of publication, with agriculture, biology and public health also areas of relative specialisation (Figure 5.9). The largest impact of scientific publications is in clinical medicine, with a higher relative citation impact when compared to the World average in the same field.

In terms of the other main indicator of scientific and innovative performance, *i.e.* the production of patents, the fact that only two USPTO patents were granted to Cambodia over the period 2000-07 (one in 2004 and the other in 2006) is indicative of the lack of emphasis to date on innovation *per se*. R&D and innovation activities are undertaken in relatively few public institutions and a small number of private sector organisations, typically foreign-owned enterprises with an export orientation and some parts of the services sector. In contrast, the majority of small and medium-sized enterprises (SMEs) are not involved – or only feebly involved – in innovation activity.

Figure 5.9. Positional analysis of Cambodia's scientific publications, 2000-10



Source: Analysis of Scopus (Elsevier) database by Science Metrix. This combines the number of publications by scientific field (area of circles), the specialisation index (a measure of relative intensity in a field compared to the World average) and the average of relative citations (citations relative to the World average controlling for age and field).

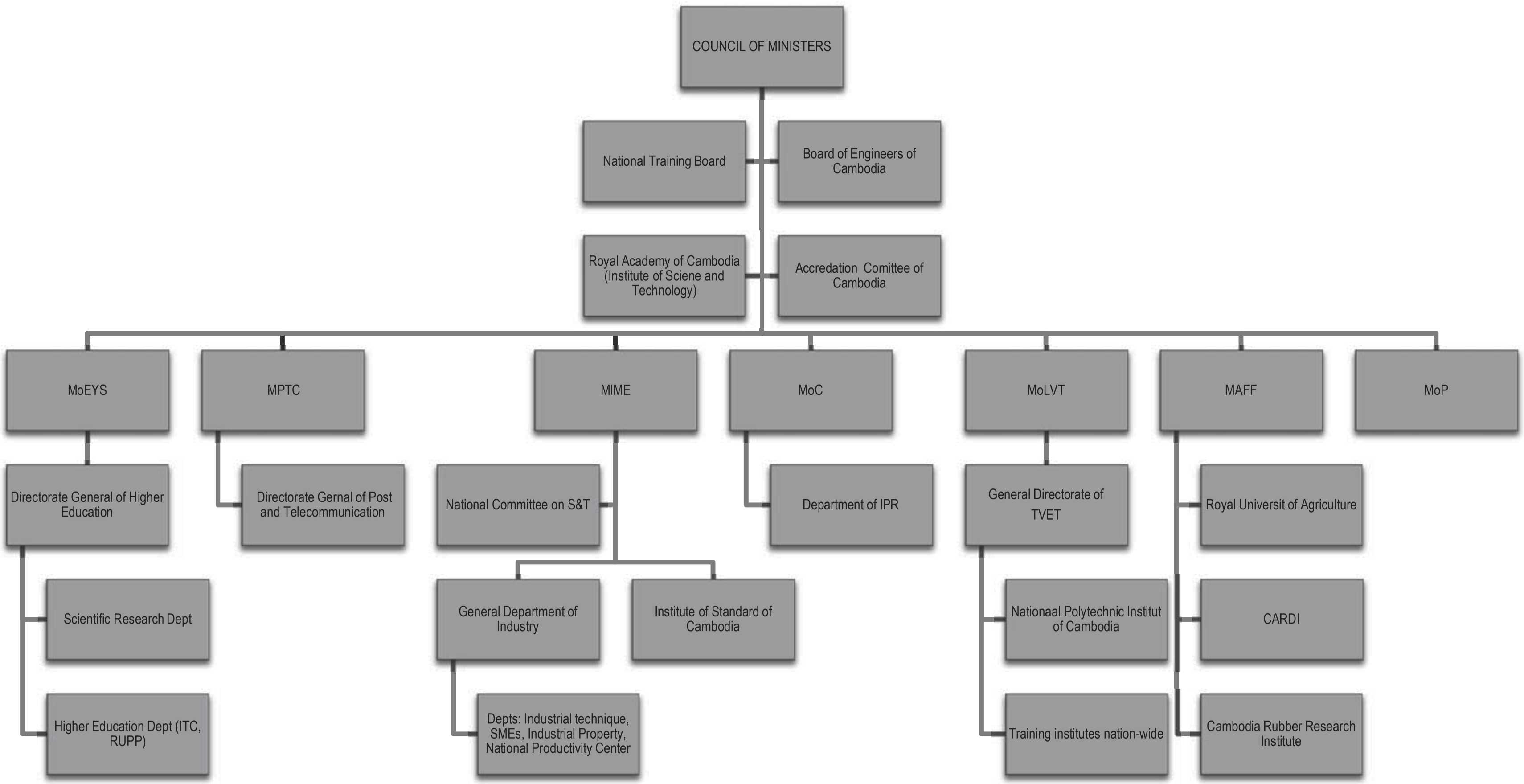
5.3. Innovation policy orientations and frameworks

Cambodia's National Strategic Development Plan (NSDP) for 2009-13 aims to establish a sound system of governance; to strengthen the agricultural sector; to attract FDI and generate employment through the development of the private sector; to develop the country's infrastructure; and to improve the human resource base. A highly visible role for innovation policy is missing, despite the notion that the development of the national innovation system (NIS) is arguably critical to the realisation of these aims.

A coherent focus on innovation has been – and continues to be – absent. Policies affecting the development of the NIS have been formulated and implemented, though only as part of broader sets of policies designed to improve the business environment or promote trade. During the last few years, for example, the government has made significant efforts to facilitate trade, support SMEs and ensure that technological spill-overs occur. Many of these have in fact improved the overall environment for future innovation. New trade mechanisms have been introduced, new business regulations imposed, and new laws adopted (Dutta, 2010). These include:

- The adoption of a law governing the behaviour of commercial enterprises (2005); laws on commercial arbitration (2006); a law concerning customs (2007) and related regulations; a law dealing with secured transactions (2007); a law governing the involvement of public-private partnerships in infrastructure development; a law on insolvency (2008); and other regulatory reforms dealing with streamlined business registration processes and the decentralisation of registration at a provincial level.
- The implementation in 2008 of an Automated System for Customs Data (ASYCUDA) at Port Sihanoukville and Phnom Penh airport.
- A Diagnostic for Trade Integration Strategy (DTIS), finalised in 2007, which reviewed developments in key trade policies and championed the development of the Trade Sector Wide Approach (Trade SWAp), which addresses issues in three strategic pillars: *i)* legal and institutional cross-cutting reform for trade development; *ii)* product and service export supply development; *iii)* capacity development for Trade SWAp management (ODI, 2009).
- The establishment of the Government-Private Sector Forum (G-PSF), which was set up to enhance the investment climate in Cambodia. The forum aims to improve the business environment, build trust and encourage private investment by fostering capacity building and developing a strong relationship between the government and private sector. It is a demand-driven process in which the private sector identifies issues and recommends solutions. Forum meetings, held twice a year and chaired by the Prime Minister, are the principal mechanism for direct government-to-private sector discussion. They are formal Cabinet meetings and decisions made in the Forum are binding. To ensure wide public exposure, the forums are telecast live on television and radio (Invest in Cambodia, 2011).
- The establishment of special economic zones (SEZs) designed to develop infrastructures, create jobs, nurture skills, enhance productivity and reduce poverty. To date, 21 SEZs have been identified, of which five have commenced operations and two are in the final stages of construction (Invest in Cambodia, 2011).
- The establishment of the Institute of Standards of Cambodia in 2008.
- The enactment of various government laws and regulations designed to encourage FDI and capture spillovers. Article 18 of the law relating to investment, for example, states that: “Investors shall be allowed to hire foreign employees provided that the qualifications and expertise are not available in the Kingdom of Cambodia among the Cambodian populace. Furthermore, investors shall perform the following obligations: *i*) provide adequate and consistent training to Cambodian staff; and *ii*) promotion of Cambodian staff to senior positions will be made over time.” Similarly, Article 11 of the decree relating to the establishment and management of the SEZs states that: “foreign managers, technicians or experts may be employed, provided that the number of foreign staff does not exceed 10% of the total number of its personnel”; while Article 12 on vocational training states that: “the Zone Developer has the duty to co-operate with the Ministry of Labour and Vocational Training in order to facilitate the training of Cambodian workers, employees and promote new knowledge and skills to workers and employees with specific and effective programmes” (Hay, 2010).

Figure 5.10. Organisational chart of innovation stakeholders in the public sector: Cambodia



Source: Hay (2010).

The historical absence of a specific focus on policies dealing with science and technology or an overarching innovation strategy that addresses the issues of technology development, diffusion, adoption, absorption and adaptation in a cross-cutting way has contributed to Cambodia's weak innovation performance. The national innovation system is fragmented and there is little co-ordination of the activities of key R&D institutions and private sector organisations. The public R&D institutions that do exist are distributed across the various ministries responsible for different areas of social and economic management and development, and their activities are primarily governed by the strategic roadmaps of the individual ministries.

The main public-sector actors involved in the governance of the Cambodian NIS and its operation are shown in Figure 5.10. A series of ministries and associated directorates and departments are overseen by the Council of Ministers, which is chaired by the Vice Prime Minister. These ministries include: the Ministry of Education, Youth and Sport (MoEYS); the Ministry of Labour and Vocational Training (MoLVT); the Ministry of Post and Telecommunications (MPTC); the Ministry of Industry, Mines and Energy (MIME); the Ministry of Commerce (MoC); the Ministry of Agriculture, Forestry and Fishery (MAFF); and the Ministry of Planning (MoP). Aside from these ministries, there are a number of national boards and committees concerned with different aspects of governance (*e.g.* NCOST, NTB, ACC and BEC – see below) and a set of public research organisations (*e.g.* NPC, TIC and the RAC-IST – see below).

The National Committee for Science and Technology (NCOST) has a mandate to devise a national strategy for the development of the NIS, though this has not been done to date (World Bank, 2010). It is chaired by the Ministry of Industry, Mines and Energy, since this body leads the government's efforts to develop the industrial sector in Cambodia, and has representatives from the other ministries concerned with science, technology and innovation. The committee was established in 1999 after Cambodia acceded to the ASEAN and has the same structure as the ASEAN COST, *i.e.* nine sub-committees, each responsible for a different field of science and technology. The committee's role in promoting R&D and innovation activity, however, has been limited by a lack of finance, employees and expertise.

The Cambodian Special Economic Zone Board (CSEZB) operates under the umbrella of the Council for the Development of Cambodia (CDC), an investment promotion agency established in December 2005 to provide an "open door" to foreign investors. CSEZB is in charge of the development, management and supervision of operations in the SEZs. Management and administration units in each SEZ are responsible for facilitating imports and exports, product quality control, compliance with labour standards and the provision of skills training for workers. The CSEZB is also charged with promoting industrial linkages and technology transfer via cluster development and inter-firm spillovers.

The National Training Board (NTB), established in October 2005, is tasked to prepare policies and produce a national training plan for technical and vocational education and training (TVET); to co-ordinate and orient the work of TVET to meet the demand-driven needs of the national economy, now and in the future; and to propose improvements to the TVET system.

The Accreditation Committee of Cambodia (ACC) was set up in 2003 and is responsible for the accreditation of bachelor and higher degrees delivered by higher education institutions (HEIs) in Cambodia and for quality assurance in line with international standards. By early 2010 it had successfully completed the assessment of the foundation year for the bachelor degree or the equivalent part-time study in over half of the country's many HEIs (Khov, 2010).

The Board of Engineers of Cambodia (BEC) was established in April 2009 and was initially funded by the government budget. As Cambodia's national engineering institution, it hopes to set up a professional association of engineers and to develop their professional qualifications to an internationally accepted standard. By October 2010, 1 317 engineers had been registered. Rather than relying solely on membership fees for income, the intention is to derive revenue by providing services such as training, publications, insurance and legal services to their membership, in a similar fashion to professional associations in other countries (World Bank/ADB, 2009).

5.4. National innovation system

5.4.1. Business sector

Cambodia's private sector is primarily composed of small enterprises. Out of 63 507 firms identified by the International Finance Corporation (IFC) and the Asia Foundation (AF) in 2009, 68.8% are run solely by their owners, 21.6% have between one and four employees, 5.7% have between five and nine employees, 2.2% have 10-19 employees, and 1.7% have more than 20 employees (IFC/AF, 2009). Phnom Penh accounts for 45% of all enterprises, Battambang is a distant second with 10%, and Kandal, Phnom Penh's neighbouring province, has 7%.

Overall, however, both the number and the average size of firms are growing. The number of firms grew by 52% from 2008 to 2009, with larger businesses in the sample included in the IFC/AF survey having the highest growth rate. The number of businesses with between 10 and 20 employees nearly doubled, while those with over 20 employees grew by almost 200%.

The vast majority of enterprises are concentrated in services (48.2%) or commerce (45.3%), with manufacturing and construction accounting for only 5.4% and natural resource exploitation for a further 1%. Nine out of ten businesses surveyed operated solely within their home province; only 10% exported goods or services. The private sector also has many features of an informal economy: limited tax compliance (78% of firms do not report all of their income); poor accounting practices (only 14% have audited financial statements); and limited use of the banking sector (only 10% use banks for investment purposes and 13% for general expenses) (Khov, 2010).

In Cambodia, the majority of micro, small-scale and even medium-sized enterprises use traditional techniques and technologies inherited from their ancestors for the processing of products such as fish sauce, soybean sauce, fish paste (*prahok*), tomato sauce, chilli sauce, canned meat, alcohol and vinegar, etc. Only a few of the more successful companies have acquired modern technology from abroad (from parent companies, equipment and machinery suppliers, overseas joint-venture partners, overseas distributors, etc.). This has allowed them to meet quality standards and compete successfully in indigenous and export markets for fruit juices, beer, condensed milk, wine, footwear and garments.

Given its industrial structure, it is not surprising that Cambodia ranked 82nd out of 133 countries in terms of company spending on R&D (see Table 5.3). Most companies are not in a position to invest in the R&D needed for new and improved products, and those that are suffer from human resource and capital constraints. The education system does not deliver sufficient numbers of skilled workers and capital markets are immature. In particular, the financial sector has not yet learned how to cope with uncertainties and manage the risks associated with the different stages of the innovation process in different business environments. Consequently, the risk and seed capital markets are too shallow to cater for the vast majority of entrepreneurs with no record of successful research and limited access to both internal and external financing.

5.4.2. Higher education institutes (HEIs)

According to Khov (2010), Cambodia has 91 tertiary institutions, 35 public and 56 private. The most prestigious public institutions are the Royal University of Phnom Penh (RUPP), the Institute of Technology of Cambodia, the Royal University of Agriculture, the Royal University of Fine Arts, the National University of Management, the Royal University of Law and Economics, and the Royal University of Health Science.

The Institute of Technology of Cambodia (ITC), established in 1964, is the most prestigious scientific institution. Its primary goal is to provide students with a quality education in the fields of engineering, science and technology and to impart the technical know-how and analytical skills they will need to compete successfully in the labour market. Over 4 000 students have graduated from ITC and work in a variety of technical fields in Cambodia and abroad.

ITC has numerous co-operative agreements with European, regional and local universities. The intention is to improve the quality of its educational programmes, create new degrees (postgraduate programmes), encourage the mobility of teachers and students, and conduct collaborative research projects. Some 40-50 professors are engaged in research work in about 15-20 projects, most of which depend on foreign sources of funding. ITC also enjoys privileged relations with a number of Cambodian companies and multinationals with branches throughout Cambodia.

The RUPP has limited facilities for both the teaching of science and the conduct of research. Only a handful of faculty members have higher degrees and the university has no research laboratories (Turpin and Magpantay, 2009).

5.4.3. Public research institutes (PRIs)

The National Productivity Centre of Cambodia (NPCC) was set up to improve productivity in industry, especially in the SME sector. It is responsible for formulating and implementing government policy and development strategy for productivity. Its main areas of responsibility include promoting productivity improvement and providing technical assistance to SMEs and industry. On the technical side, NPCC is tasked with the development and implementation of applied techniques and technology for enhancing efficiency, improving safety, encouraging environmental responsibility and increasing the value added of industrial products.

The Industrial Laboratory Centre of Cambodia (ILCC) is responsible for the testing and analysis of product quality. Its main areas of responsibility include the promotion of R&D in product quality and safety improvement.

The Technology Incubation Centre (TIC) was established in early 2008 with technical and financial support from the Asian Development Bank (ADB). It started operating in September 2009 with a mandate to drive innovative technology development by carrying out applied research for the private sector; developing and disseminating new technologies and know-how to private enterprises; and serving as a critical technology demonstration site and learning centre where SMEs can learn and exchange knowledge, skills and experience. By March 2010 it had ten technical staff (World Bank, 2010).

The Royal Academy of Cambodia (RAC) is placed under the Office of the Council of Ministers. It is composed of six institutes: the Institute of Biology, Medicine and Agriculture; the Institute of Culture and Fine Arts; the Institute of Humanities and Social Sciences; the Institute of National Language; the International Relations Institute; and the Institute of Science and Technology. Its roles are to: *i*) establish co-operative relations in research with ministries, institutions and national and international organisations that have the same goals; *ii*) organise scientific and educational forums; *iii*) train researchers for master's degrees and doctorates; *iv*) distribute documents and research findings in national and foreign languages; *v*) collect and preserve research findings relevant to Cambodia and to other countries in the region and the rest of the world; *vi*) co-operate on the examination and evaluation of higher education graduate and postgraduate candidates; *vii*) participate in and co-operate on the protection of intellectual property; *viii*) examine and evaluate scientific research findings; *ix*) co-operate on the establishment of research institutes within ministries.

The Institute of Science and Technology (IST) is one of the main institutes of the RAC. It has five departments: *i)* Mathematics and Statistics; *ii)* Chemistry and Food; *iii)* Physics and Energy; *iv)* Technology; and *v)* Informatics and Communications. Since 2007, it has operated a PhD programme for graduates of its internal master's programme, with the opportunity for some PhD graduates to be retained and work for the Royal Academy of Cambodia.

Although the RAC is one of the few educational institutions to provide postgraduate programmes in pure and applied sciences, it suffers from a lack of funds and facilities. To conduct or demonstrate experiments, for example, the RAC frequently has to take advantage of better facilities at the Royal University of Phnom Penh or the National Institute for Education. Concerning its links with industry, the IST had indicated its desire to conduct joint research with industry whenever possible, but to date there have been few overt approaches either to or by industry.

5.4.4. Linkages between innovation actors

The efficiency of a national innovation system typically depends on the degree and quality of the interaction between the different actors involved in the innovation process. These processes are increasingly open and involve a wide variety of actors with complementary assets and capabilities. In some national and sectoral contexts, intense relationships between universities and enterprises lie at the heart of the innovation process. In others, the realisation of innovative potential depends more on the existence of tightly knit networks of SMEs, or on the degree of interaction with large enterprises and the spillovers from them. Similarly, the degree of internationalisation and the positioning of enterprises in global production chains can strongly affect the beneficial impacts on innovation performance. The composition of an innovation system, in terms of sectors, types of enterprises and knowledge-producing actors, thus determines the structure of the interaction.

In Cambodia, the nature of its industrial structure and the relative absence of strong innovation actors in either the public or private sectors, or strong links between indigenous and foreign-based actors, means that the overall level of interaction – and hence the efficiency of the innovation system as a whole – is inevitably low. In recent years, however, there has been increasing policy emphasis on interactions between public-sector bodies and laboratories, non-profit organisations (NGOs), HEIs and the private sector to promote and support the diffusion and adoption of innovative techniques and technologies and the introduction of new processes and products. This has involved, for example, the setting up of an industrial research centre (the Industrial Laboratory of Cambodia), a technology incubation centre (the Technology Incubation Centre) and packages of incentives aimed at increasing companies' adoption of new technologies. These developments have mostly occurred in areas related to energy production, agro-processing and handicrafts and have typically involved the adoption of new methods of production, the use of cleaner technology, the introduction of improved products to the market and product diversification.

5.5. Human resources

There is a distinct lack of an innovation culture in Cambodian society and a shortage of specialised human capital. This is apparent in the dearth of people with science and engineering degrees and the limited demand for them in industry (Shin, 2011).

There has been a rapid rise in student enrolments over the last two decades, with student levels rising from about 10 000 in 1992 to 124 947 in 2008 (World Bank, 2011), a gross enrolment rate of 11.1%. However, the majority of universities and other degree-awarding bodies mainly offer programmes in social sciences, business and management, with very few offering science and engineering programmes. Indeed, over 80% of students are enrolled in business/management courses; the enrolment rate for science and engineering is just 12.24% of the total number of post-high school students in 2009 (World Bank KAM, 2012). The result is an under-supply of graduate and postgraduate scientists and engineers. To date this has not been a problem because of the relatively limited demand for them in industry, but in future it could act as a severe constraint on innovation-related growth.

Perhaps even more worrying, however, is the significant deficit of skilled technicians and workers with vocational qualifications, despite a desperate need for people with such skills in industry. According to the World Bank (2010), there are three main reasons for this. First, there is a common public perception that this type of training is "inferior"; second, much technical and vocational education and training is of relatively low quality; and third, little information is given to secondary students on potential careers and job opportunities for skilled technicians.

The overall conclusion at both graduate and vocational levels is that the tertiary education system is not responding adequately to evolving labour market needs.

5.6. SWOT analysis

Based on the material presented above, several strengths and weaknesses of Cambodia's NIS can be identified, along with future opportunities and threats. These are summarised in Table 5.4.

Table 5.4. Summary SWOT (strengths, weaknesses, opportunities, threats) analysis

Strengths	Weaknesses
• Momentum from recent growth in trade and FDI • Political stability • Attractiveness for FDI, especially in strong sectors (agriculture, tourism, garment manufacture and construction) and niche areas (mineral extraction) • Good endowment of natural resources • Small but increasing presence of globalised, internationally competitive firms • The accumulated experience of some public agencies for the promotion of science, technology and innovation (STI) and economic development	• Poor performance of the education system and low qualifications of the labour force • Lack of qualified scientists • Insufficient STI infrastructure • Low investment in R&D • Extremely weak innovation culture • Weak IPR culture, with low patenting and non-utilisation of IPR • Very low levels of public-private co-operation and overall interaction between different innovation actors • Low technological absorptive capacity in the vast majority of SMEs • Financial institutions ill adapted to innovation-related investment • Absence of strong political will concerning STI policy formulation and implementation • Absence of a strategic roadmap for STI • Lack of efficient co-ordination between public STI stakeholders
Opportunities	**Threats**
• A young population • Growth of science and engineering education capabilities • Growing demand for technicians and, increasingly, science and engineering graduates • Growing demand for high value-added, knowledge-intensive goods • Diversification of production and trade towards goods and services with higher knowledge content • Engagement of SMEs in more innovation-driven strategies • Greater interaction between multinationals and SMEs, and between all innovation actors generally • Insertion in global knowledge networks and technological platforms	• Continuing global economic crisis • Growing competition from emerging economies operating in similar markets • A short-term focus on trade expansion and neglect of the need to upgrade and diversify • Continued lack of a vision informing co-ordinated policies to build up the science base, encourage spillovers from FDI and support innovative entrepreneurs • Intensifying global competition for talent and an exodus of talented individuals • High economic and technological dependence on low-growth economies • Poor linkages with dynamic emerging regions experiencing rapid economic, scientific and technological development • Accelerated expansion of the scientific and technological frontier

Cambodia's most notable strength is the boost that recent expansion of trade and FDI has given to the economy as a whole, with momentum dimmed but not derailed by the recent global financial crisis and political stability an enticement for future FDI in strong sectors such as agriculture, garment manufacture, construction and tourism and in niche sectors such as mineral extraction. The country has a good endowment of natural resources and the still small but growing presence of multinationals is an appreciating asset. The experience gained by policy makers concerned with improving the business and educational environments also constitutes a sound basis for future policy development with an innovation orientation.

Cambodia's weaknesses, while considerable, are not overwhelming. The workforce lacks relevant skills and the education and training system is underdeveloped, producing inadequate supplies of graduates, postgraduates and people with vocational qualifications. Investment in R&D is almost non-existent and the overall infrastructure for research woefully deficient. Key elements of an innovation culture are also missing. The vast majority of firms are SMEs with no track record of innovation or experience of technology adoption, and financial institutions are not prepared to deal with innovative entrepreneurs. The absence of a strategic approach to the formulation, co-ordination and implementation of science, technology and innovation (STI) policies is also a weakness that could prove a severe handicap if not rectified.

There are nevertheless opportunities to build on the expansionary developments of the last decade. Cambodia has a young population that could drive growth if the education and training sector continues to improve and curricula are reoriented towards the changing, innovation-oriented needs of the labour market. The growing market demand for high-value-added, knowledge-intensive goods and services is also a stimulus for industry to prioritise product upgrading and diversification and to intensify its efforts to participate in global knowledge networks and technology platforms. The increased presence of multinationals also opens the door to increased interaction with innovative SMEs and to beneficial spillovers for the economy as a whole.

In the worst-case scenario, external threats to world trade due to the continuing global economic crisis could have a deleterious effect on continued expansion. Intense and increasing competition from other emerging economies operating in similar markets could be a threat in a more vibrant trade environment. A short-term focus on the expansion of trade in existing product areas and complacency concerning the need to diversify and upgrade could also trap Cambodia in trajectories with low growth potential. Continued lack of a vision to inform co-ordinated policies and build up the science base, encourage spillovers from FDI and nurture innovative entrepreneurs could leave Cambodia subject to an exodus of talented individuals, economically and technologically dependent on low-growth sectors, bereft of strong linkages with other emerging economies experiencing rapid economic, scientific and technological development and stranded a long way behind a rapidly expanding scientific and technological frontier.

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Chapter 6

Indonesia innovation profile

Indonesia has risen to become a middle-income economy through appreciable levels of economic growth which have relied to a large extent on exports of natural resources and good trade links with leading global economies. However, Indonesia's GDP per capita remains relatively low (poverty remains a social problem) and it has only attracted modest levels of foreign direct investment (FDI). It has not developed a technology-intensive industry structure and imports of high-technology products outweigh exports. Increases in total factor productivity (TFP) have contributed to economic growth, but TFP growth levels have been lower than in competitor countries. Similarly, FDI is flowing into high- and medium-technology sectors, but input levels are low compared to those elsewhere, and many of its regional neighbours appear to be modernising their economies more rapidly and effectively.

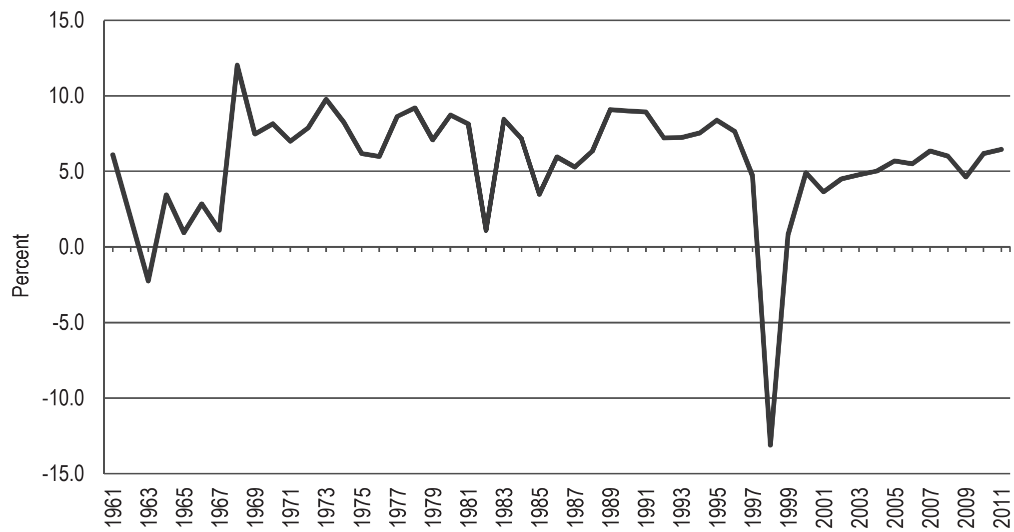
Until recently, government policies tended to neglect the development of an adequate scientific and technological base and framework conditions for innovation, but there is now a new emphasis on policies and mechanisms designed to stimulate innovation-led growth, with mechanisms freshly in place to oversee their co-ordination. Data capable of determining the effectiveness of these measures, however, are scarce. Significant improvements in infrastructure will be required to realise the government's growth ambitions – ICT infrastructure in particular is poor relative to much of the region – and other barriers to entrepreneurship and business risk holding back rapid knowledge-based economic development. The rapidly expanding higher education system is one means by which the innovation potential of Indonesia could be better harnessed, although the current momentum in this and other policy areas needs to be maintained in order for Indonesia to catch up with the capabilities of neighbouring countries and other competitors, and to continue its economic development.

6.1. Macroeconomic performance and framework conditions for innovation

6.1.1. Performance and structure of the economy

From the mid-1960s to the mid-1990s, Indonesia's GDP grew at an average rate of over 6% a year. The economy contracted sharply in the wake of the 1997-98 Asian financial crisis but economic growth rebounded to an average of over 5% over the decade 2000-2009 (Figure 6.1). Following a slight slowdown in 2009 due to reduced global demand, GDP growth returned to 6.2% in 2010 and 6.5% in 2011. However, GDP per capita remains low at USD 4 094 at 2005 PPP prices, while unemployment levels (7.1% of the total workforce in 2010), poverty levels (in 2010 18.1% of the population had a daily income less than USD 1.25 at PPP), and child labour (6.6% of children aged between 7 and 14 were economically active in 2009) are serious socio-economic problems confronting the country (World Bank 2012b).

Figure 6.1. Indonesia's GDP growth 1961-2011 (%)



Source: World Bank, World Development Indicators.

Indonesia's growth after a period of political instability in the early 1960s was based on exports of goods such as oil and gas, plywood, textiles and rubber, with a growing trade in manufactured goods such as electrical appliances and computer components. Japan and the United States became major export targets and have remained important export partners since 2000 (Table 6.1), though the relative share of exports to China, especially, as well as countries such as Singapore, Korea, India and Malaysia have increased over the period 2000-2010. Over the same period China has become the primary import partner, with Singapore remaining in second position whilst the share of imports from Japan and the United States have declined.

Products based on natural resources have dominated lists of the top ten exports, with exports of manufactured goods such as computer components dropping down the rankings over the period 2000-2007. The nature of manufactured goods exported has also altered since the Asian crisis. In the first instance, the crisis led to a short-term increase in the relative proportion of high-technology and medium-high technology manufactures at the expense of low-technology manufactures and agricultural products (Figure 6.2). Since 2000, however, exports of high-technology manufactures have declined to pre-crisis levels, though the proportions of medium-high and medium-low technology manufactures have grown slightly. The share of manufacturing exports accounted for by mining and quarrying grew from 25% to 32% between 2000 and 2010.

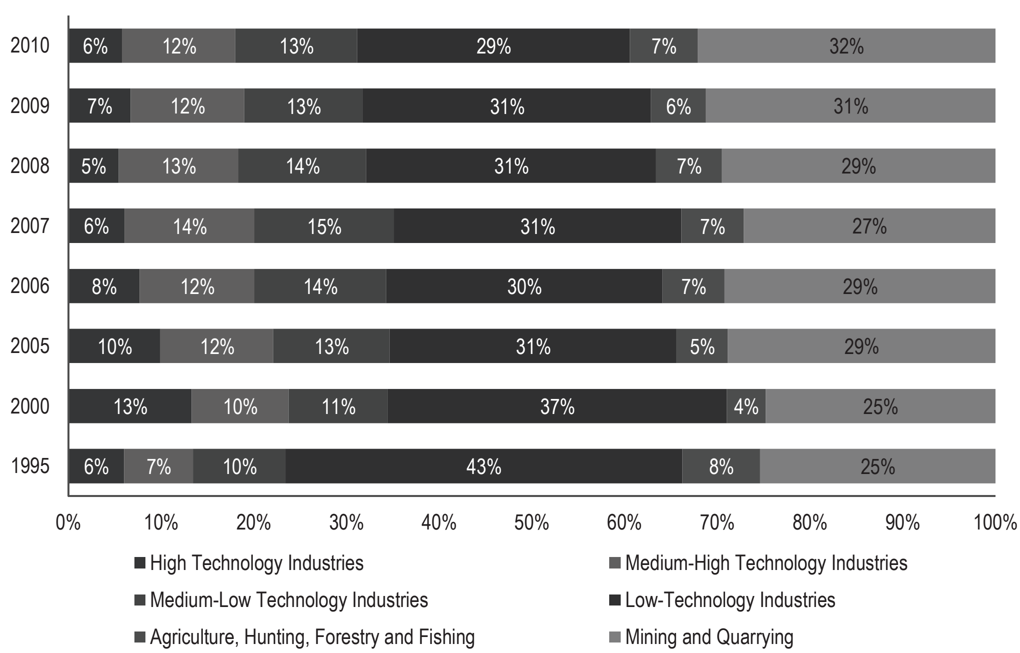
Table 6.1. Indonesia's top trading partners, 2000-10

Rank	Indonesia's top 10 export partners in 2000	USD million	Indonesia's top 10 export partners in 2010	USD million
1	Japan	14 415	Japan	25 782
2	United States	8 489	China	15 693
3	Singapore	6 562	United States	14 302
4	Korea	4 318	Singapore	13 723
5	China	2 768	Korea	12 575
6	Chinese Taipei	2 379	India	9 915
7	Malaysia	1 972	Malaysia	9 362
8	Netherlands	1 837	Chinese Taipei	4 838
9	Hong Kong, China	1 554	Thailand	4 567
10	Australia	1 519	Australia	4 244
	Indonesia's top 10 import partners in 2000	USD million	Indonesia's top 10 import partners in 2010	USD million
1	Japan	5 397	China	20 424
2	Singapore	3 789	Singapore	20 241
3	United States	3 393	Japan	16 966
4	Korea	2 083	United States	9 416
5	China	2 022	Malaysia	8 649
6	Australia	1 694	Korea	7 703
7	Saudi Arabia	1 598	Thailand	7 471
8	Chinese Taipei	1 271	Saudi Arabia	4 361
9	Germany	1 245	Australia	4 099
10	Malaysia	1 129	India	3 295

Source: UN Commodity Trade (Comtrade) Statistics Database.

Figure 6.2. Indonesia's manufacturing exports by technology intensity

% of total exports value

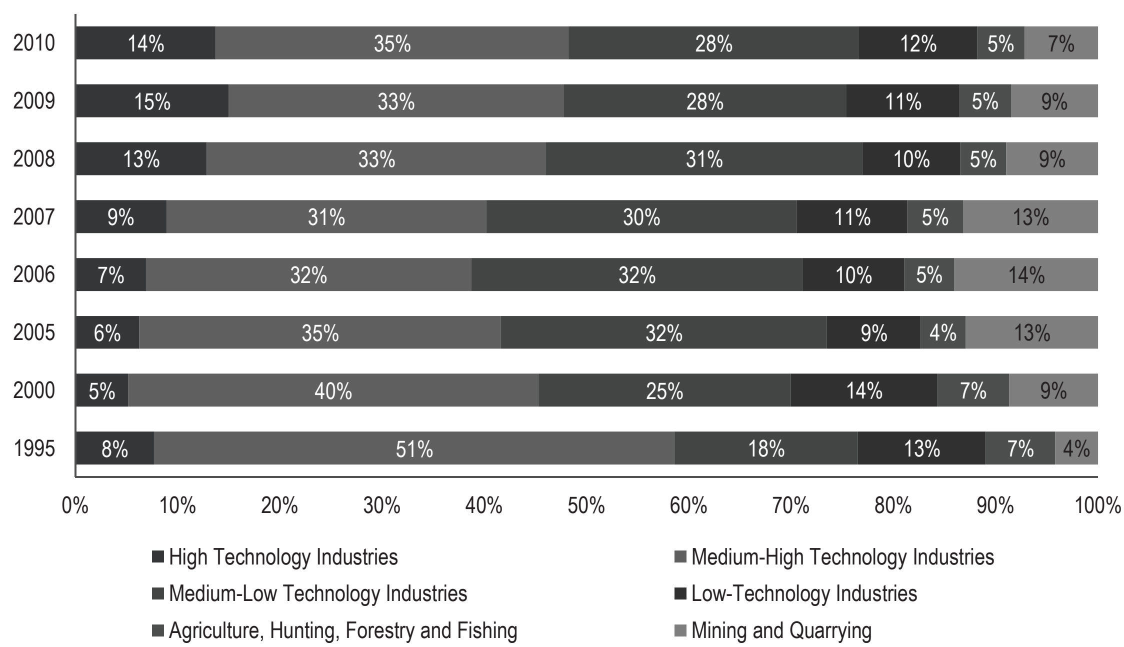


Source: OECD, STAN Bilateral Trade Database (BTD).

Changes have also occurred in the technological intensity of imports (Figure 6.3). Since 2000, Indonesia has increased its propensity to import high-technology manufactured goods from 5% of the total to 14% in 2010 with negative consequences for Indonesia's overall trade balance. Over the same time the proportion of medium-high technology imports has fallen. The share of medium-low technology imports was higher in 2010 than 2000 although it has been falling in the past five years.

Figure 6.3. Indonesia's manufacturing imports by technology intensity

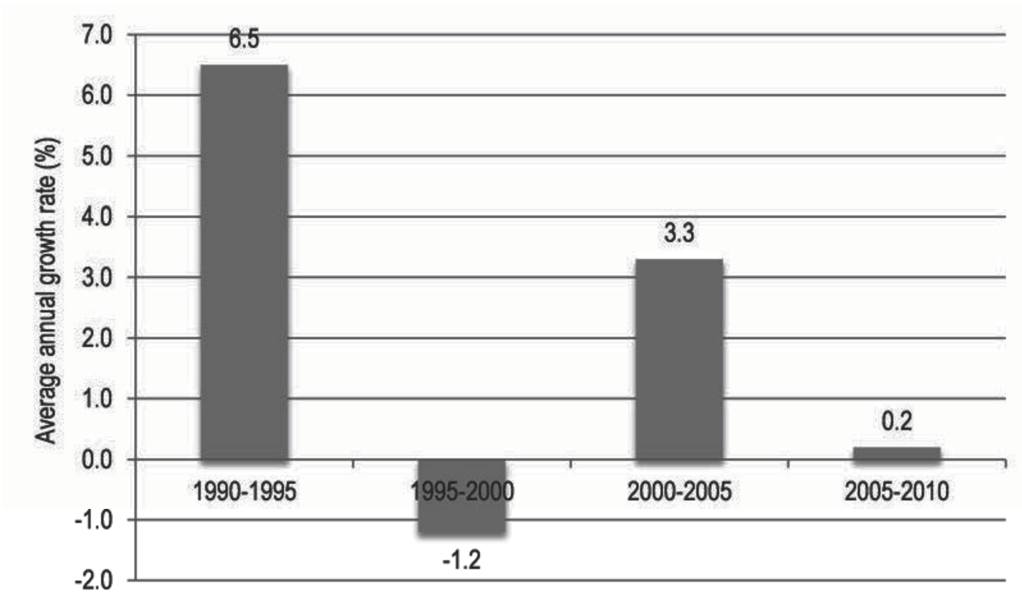
% of total imports value



Source: OECD, STAN Bilateral Trade Database (BTD).

Labour productivity levels in Indonesia remain low compared to other countries in the region and growth rates since the Asian financial crisis have lagged behind the rates achieved pre-crisis (Figure 6.4). Labour productivity growth over the period 2005-2010 (0.2%), especially, was considerably more sluggish than in countries such as Malaysia (3.0%), Viet Nam (3.2%) and Cambodia (4.2%). Growth in total factor productivity (TFP) since 1990 has also been much lower than levels established in Indonesia's early growth phase from 1970 to 1990 (Figure 6.5), with growth from 1990 to 2010 (0.5%) comparing poorly with growth levels in other countries over the same period, *e.g.* China (4.7%), Singapore (1.2%), United States (0.9%), Thailand (0.7%), and Viet Nam (1.8%) (APO, 2012).

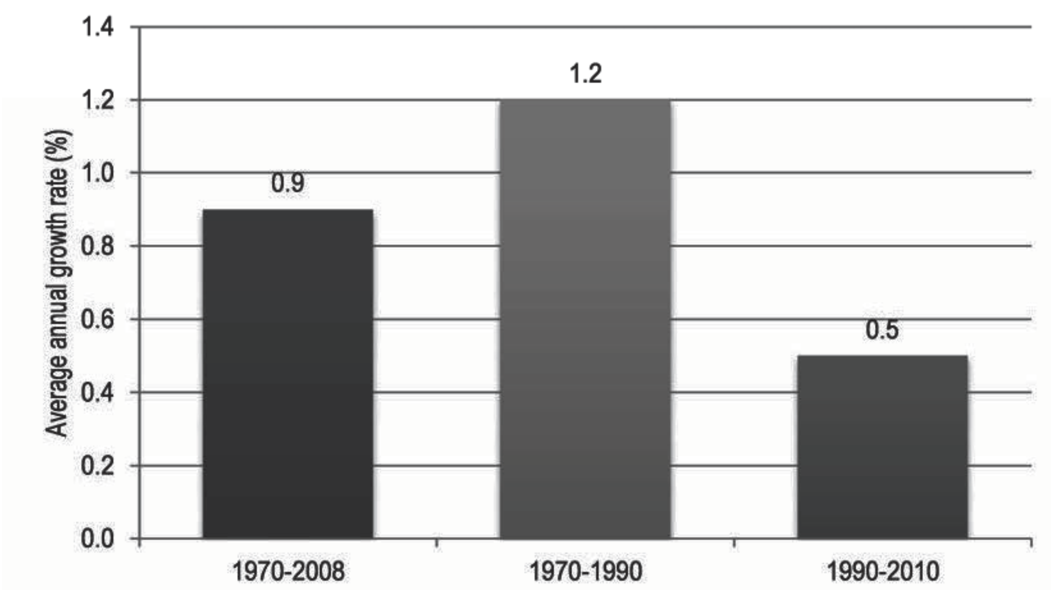
Figure 6.4. Trends in labour productivity growth, Indonesia, 1990-2010



Note. Average annual growth rate of GDP at constant basic prices per hour, using 2005 PPPs.

Source: APO Productivity Year Book (2012).

Figure 6.5. Trends in total factor productivity growth, Indonesia, 1970-2010



Source: APO Productivity Year Book (2012).

Nevertheless, apart from the severe blip associated with the Asian crisis of 1997-98, the contribution of TFP to overall output growth has been significant in recent years, with the contribution rising to 33% in the period following the crisis (2000-2005) before dropping to 21% in the period from 2005-2008 (Table 6.2). Another source, however, estimates that the TFP contribution to potential output growth over the period 2006-2009 could amount to approximately 40% (OECD, 2010a). Furthermore, a study by Alisjahbana (2009) supports the notion that the contribution of TFP to growth has increased significantly post-crisis, suggesting that excess capacity before the crisis employed production inputs more efficiently after the crisis.

Table 6.2. Contributions to output growth

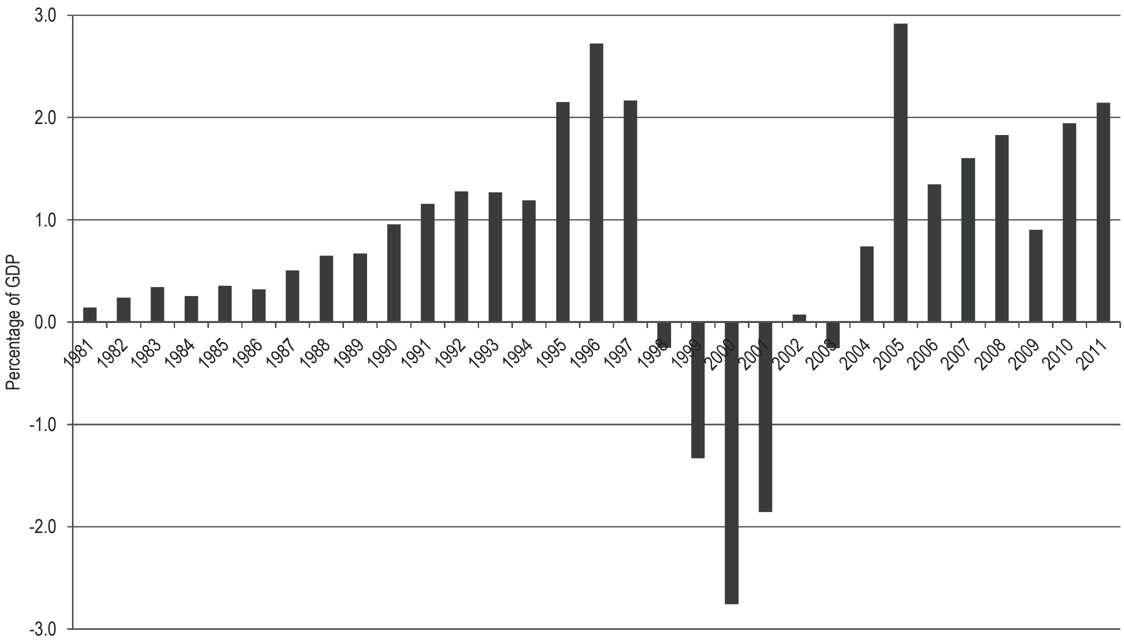
	1970-1975	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	2000-2005	2005-2008	1970-2008
Output growth (%)	8.28	7.79	4.66	7.49	7.57	0.76	4.65	5.80	5.88
Contribution from:									
Total factor productivity (%)	34	10	-53	22	32	-558	33	21	7
Non-IT capital (%)	55	71	112	48	57	500	48	46	69
IT capital (%)	1	2	4	2	4	26	5	5	3
Labour (%)	11	17	38	27	7	132	14	27	20

Source: APO (2011).

Historically, the largest contribution to growth has been made by non-IT capital, which accounted for 69% of all growth over the period 1970-2008 (Table 6.2), though the contribution from foreign direct investment (FDI) has been relatively small, especially since the Asian crisis (OECD, 2010c). Policy reforms favouring greater openness brought an increase of net FDI flows as a percentage of GDP in the mid-1980s, with Indonesia benefiting as currency appreciation pushed Japan and other newly-industrialising countries to relocate production in lower cost countries in Asia. Consequently, large amounts of FDI flowed into labour-intensive manufacturing sectors such as textiles. The Asian crisis, however, precipitated a severe decline in FDI, a net flight of capital for some years afterwards, and a relatively slow recovery compared to other Asian countries. Inward FDI flows finally rebounded in 2004 and averaged USD 7 billion per year over 2004-2009 (Bank Indonesia), a period characterised by political stability, favourable economic growth performance and the prospect of further trade integration in East Asia following the announcement of ASEAN-China Free Trade Area – CAFTA in 2002 and its subsequent implementation in 2010.

As a percentage of GDP, however, FDI inflows to Indonesia (1.9% of GDP in 2010; see Figure 6.6) have still been modest compared to inflows in other countries in Asia, *e.g.* Singapore (18.1% of GDP in 2010), Viet Nam 7.5%, Malaysia (3.9% of GDP), Thailand (3%) and China (3.1%). Capital inflows also show a considerable degree of volatility. During the global financial crisis of 2008-2009, inward FDI flows shrank by 48%, compared with decreases of 44% in Viet Nam, 30% in Thailand, 14% in India and 12% in China (UNCTAD, 2006; 2009; 2010).

Figure 6.6. Net FDI inflows in Indonesia, percentage of GDP (1981-2011)



Source: World Bank World Development Indicators.

Overall, Indonesia's economic performance can be summarised simply. It is a middle-income economy that has appreciable levels of economic growth and exports of natural resources, but only modest levels of foreign direct investment. It has not developed a technology-intensive industry structure and imports of high-technology products outweigh exports. Increases in TFP have contributed to economic growth, but TFP growth levels have been lower than in competitor countries. Similarly, FDI inflows have been modest and volatile relative to other ASEAN countries.

6.1.2. Framework conditions for innovation

Indonesia ranked 46th on the World Economic Forum's Global Competitiveness in 2011-2012, down two places from 2010-2011 but an improvement from 55th in 2008. However, it still trailed regional competitors like Singapore (2nd), Malaysia (21st) and Thailand (39th), though it was ahead of Viet Nam (65th) and Cambodia (97th).

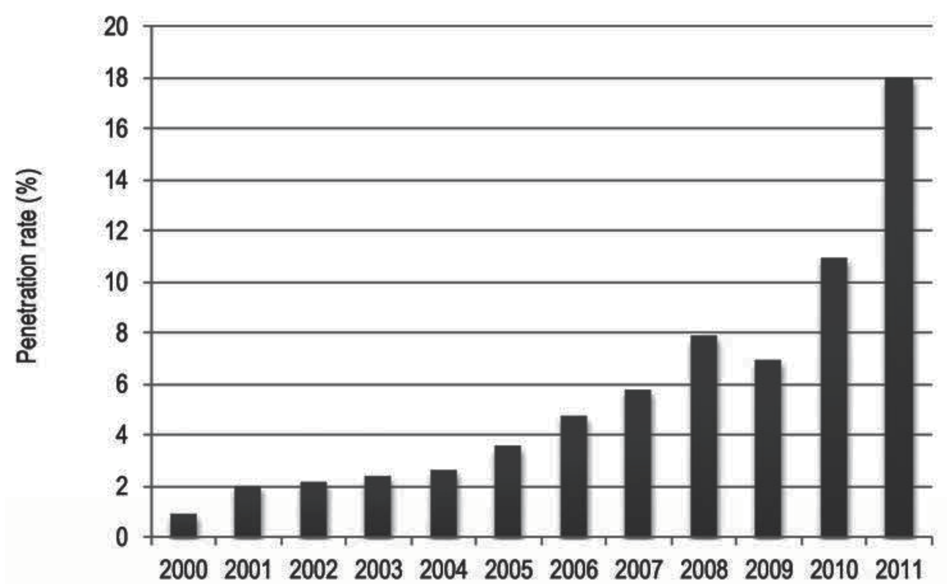
In terms of the sophistication of its ICT infrastructure the proportion of individuals using the Internet jumped from 10.9% in 2010 to 18.0% in 2011(ITU, 2012) (Figure 6.7). These figures still compare poorly with the ITU's estimates of Internet penetration in 2011 in Singapore (75%), Malaysia (61%), Viet Nam (35%) and Thailand (24%), but nevertheless represent a high rate of growth in the past few years. The number of fixed broadband subscriptions per 100 inhabitants in 2010, standing at 1.1, was also very low compared to levels in Singapore (25.5), Malaysia (7.4), Viet Nam (4.3) and Thailand (5.4).

There is also evidence of a clear digital divide. Sixty-seven per cent of personal computer owners and 70% of households with Internet access are concentrated in Java and Bali alone (Kominfo, 2010), and cable broadband distribution, which is currently not expanding, covers less than 9 million users and is only available in major cities in Java, Bali, Sumatera, Kalimantan and Sulawesi, with more than 50% of the capacity installed only in Jakarta and its satellite cities.

Apart from inadequate infrastructural elements, many other factors in the overall environment in which businesses operate in Indonesia are not conducive to either smooth operation or innovation (Figure 6.8). Perceived levels of bureaucratic inefficiency and corruption are high, with Transparency International ranking Indonesia joint 100th out of 183 in terms of perceived levels of corruption, and Indonesia ranked 129th out of 183 countries in the World Bank's 'Ease of Doing Business' list in 2011 (World Bank/IFC, 2012). Setting up a new business in Indonesia is also more complex and costly than in most other countries in the world.

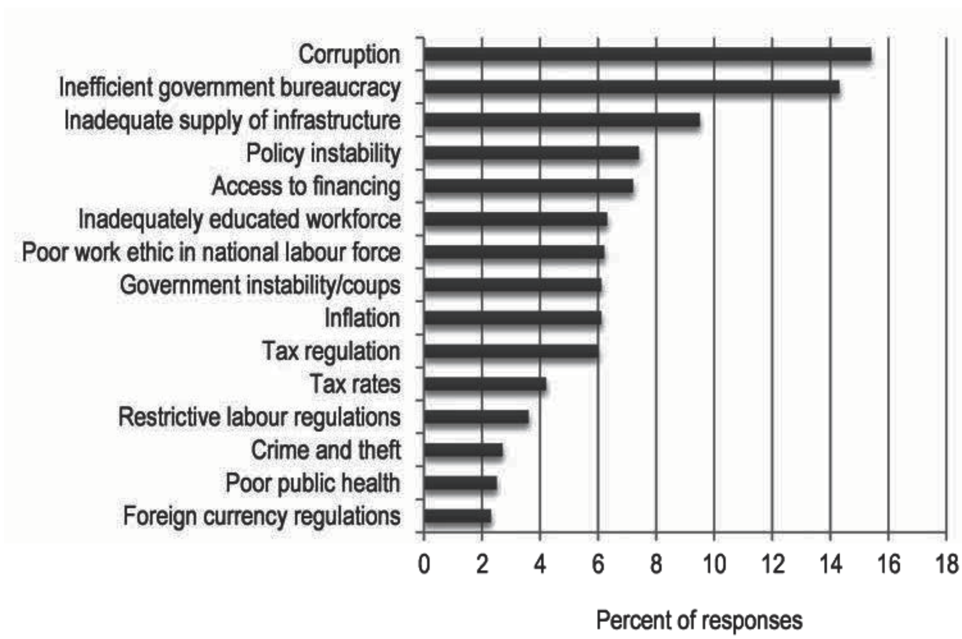
Access to finance is another factor limiting the establishment of new, innovative businesses (Figure 6.8). Banks are the primary source of finance, but the banking sector was badly affected by the Asian crisis and recovery has been slow, with productivity in the financial and business service sector still at 61% of its 1996 level and inefficiency a deterrent to risk-taking. What finance there is also tends to find its way to established firms rather than new ventures, and sources such as the World Bank and the Asia Development Bank have not prioritised efforts to raise the innovative potential of SMEs.

Figure 6.7. Internet users per 100 inhabitants, Indonesia, 2000-11



Source: International Telecommunications Union, 2012.

Figure 6.8. The most problematic factors for doing business in Indonesia



Source: World Economic Forum (2012). Percentages represent the weighted results of a ranking of the five most problematic factors from a list of 15 by respondents to the WEF survey.

At the turn of the century, Mertins (2002) noted that venture capital and other sources of risk financing for newly established technology-based companies were almost non-existent in Indonesia, while in the same year Kenney, Han and Tanaka (2002) reported that Indonesia, Thailand and Malaysia lacked the necessary conditions for a thriving venture capital industry, namely plentiful investment opportunities, liquid and well developed capital markets, talented venture capitalists and strong property protection and corporate governance. More recently, in 2012, the Global Venture Capital Private Equity Attractiveness Index ranked Indonesia as 55th out of a total of 116 countries in terms of its attractiveness to venture capital. Factors related to the lack of adequate property protection and the weak ICT infrastructure still make Indonesia relatively unattractive for venture and equity investors. Some venture capital firms have been created, but they tend to act in similar ways to normal banks, mainly channelling finance to established enterprises. There is also a lack of qualified VC project evaluators capable of assessing the technological and innovation potential of newly established companies.

Lack of transparency and weak implementation of tax regulations are also impediments to investment in innovation in Indonesia. Laws allowing taxes to be reduced when companies invest in R&D exist, but there is little evidence that they have been implemented. The lack of a consistent and transparent tax system also does nothing to reduce uncertainty concerning future financial burdens and decisions to invest in R&D (Mertins, 2002).

Patent regulations designed to protect intellectual property and stimulate innovation have been introduced in Indonesia. Regulations were originally introduced by decree in 1953 (WIPO, 2006) and the Patent Law of 1989, which complied with international standards, was the first patent law to be introduced (Branstetter et al., 2006). Significant changes to Indonesia's IPR legislation regime were then made in 1991 and again in 1997 after Indonesia had joined the WTO. These changes involved the introduction of the Patent Amendment Law (1997), the Copyright Amendment Law (1997) and the Trademark Amendment Law (1997), all of which were intended to bring Indonesia in line with the Agreement on TRIPS (Trade Related Aspects of Intellectual Property Rights).

Subsequent revisions were also made in 2000 with the introduction of the Protection of New Plant Varieties Law, the Trade Secrets Law, the Industrial Designs Law and the Layout Designs of Integrated Circuits Law. The passage of a new copyright law in July 2002 and accompanying regulations in 2004 further strengthened Indonesia's IPR regime. During the same period, the delegation of IPR matters to specialised commercial courts helped to build expertise in the legal system. This has sped up the process, and resulting IP decisions have been judged to be largely sound (Antons, 2007). In addition, special measures have been taken to meet the needs of SMEs, raise their IPR awareness, diffuse knowledge about the variety of intellectual property instruments, lower the cost and time for application, and encourage firms to develop their own IPR strategies (OECD, 2012).

Despite the government's significantly expanded efforts to improve enforcement, intellectual property piracy remains a major concern. A lack of company confidence in enforcement mechanisms deters them from accessing the system in the first place. It is costly to monitor potential infringement of IPRs, and the threat of litigation by more resourceful firms can sometimes intimidate SMEs (*ibid.*). Using an index designed to measure the strength of patent regimes in terms of coverage (inventions that are patentable), membership of international treaties, duration of protection, enforcement mechanisms and restrictions, Park (2008) concluded that Indonesia lagged behind many other countries. In 1995, Indonesia scored 1.56 compared to an average over 122 countries of 2.58; in 2000, Indonesia scored 2.47 compared to an average of 3.05; and in 2005 Indonesia scored 2.77 compared to an average of 3.34. Indonesia had narrowed the gap between its score and the sample average, but its score in 2005 was still less than the scores for Singapore (4.21), Malaysia (3.48) and Viet Nam (3.03).

6.2. Innovation performance

In terms of the World Bank's Knowledge Economy Index, which captures the ability of countries to generate and diffuse knowledge, Indonesia ranked only 108th out of 146 countries, three places lower than in 2000. In comparison, Singapore ranked 23rd, Malaysia 48th, Thailand 66th and Viet Nam 104th (Table 6.3).

Indonesia's innovation capacity has not benefitted greatly from FDI and technology transfer from other countries. Thee Kian Wie (2005) identified four major channels of international technology transfer to the Indonesian manufacturing sector: foreign direct investment; technical licensing agreements by foreign licensors; imports of capital goods; and technical assistance from foreign buyers. Their impact on local technological advancement is summarised in Table 6.4. Technology transfer via all four channels helped improve the country's basic production capabilities, and there has been mixed success in terms of improving the knowledge and skills needed for future investment in new technology and adapting technologies to changing circumstances, but there has been no or very limited success in terms of upgrading overall innovation capacity.

Table 6.3. Knowledge Economy Index and Knowledge Index, Indonesia, 2012

Indicator	Value
Knowledge Economy Index (KEI) #	3.11
Knowledge Index (KI) *	2.99
Economic incentive and institutional regime	*3.47*
Innovation	*3.24*
Education	*3.20*
ICT	*2.52*
Position in world rank	108
Change in rank from 1995	-3

The Knowledge Economy Index (KEI) is calculated based on the average of the normalised scores of a country on all four pillars related to the knowledge economy: economic incentive and institutional regime; education; innovation; and ICT.

* The Knowledge Index (KI) measures a country's ability to generate, adopt and use knowledge. The index is based on key variables in the three knowledge pillars: education; innovation; and ICT.

Source: World Bank (2012a).

Table 6.4. Major channels of International technology transfer to Indonesia and their impact on the development of local technological capabilities

	Technological capabilities			
Channel	Production	Investment	Adaptive	Innovative
Foreign direct investment	S	OS	OS	NS
Technical licensing agreements	S	S	S	NS
Capital goods imports	S	NS	OS	NS
Technical assistance from foreign buyers	S	NS	OS	NS

Note: S = successful, OS = occasionally successful, NS = not successful.

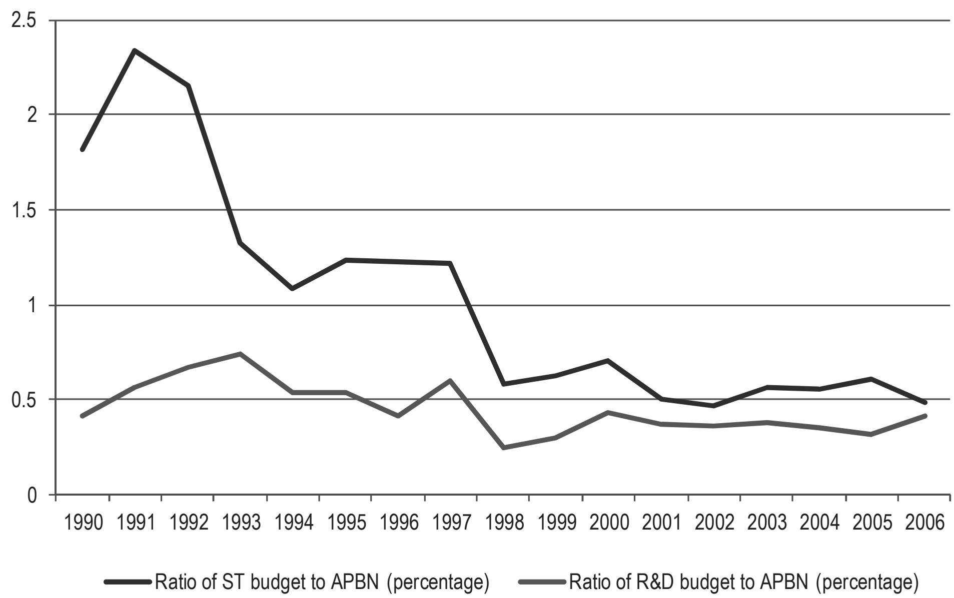
Source: Wie (2005).

Indonesia's investment in R&D is also low. Over the period 1987-97, there were only 182 scientists and engineers per million inhabitants engaged in R&D, and total expenditure on R&D (GERD) amounted to 0.07% of GDP. It had fallen to 0.05% by 2005 but rose to 0.06% in 2006 and reached 0.08% in 2009. These levels are comparable to the level of expenditure in Cambodia (0.05% of GDP in 2002), but very low compared to Singapore (2.2% in 2009), Malaysia (0.64% in 2006 and rising to 0.82% in 2008), Viet Nam (0.19% in 2002) and Thailand (0.21% in 2007).

Government expenditure on R&D in Indonesia accounted for 84.5% of all R&D expenditure over the period 2001-2006 (Pappiptek LIPI, 2009a), with business accounting for most of the remainder (14.7%) and only 0.8% coming from other sources (OECD, 2010d). In comparison with some of Indonesia's main Southeast Asian competitors, the proportion coming from industry is low. The private sector share in Singapore, for example, was 85% in 2006, while the share in Malaysia in 2006 was 85%. Concerning expenditure within the government sector in Indonesia, *i.e.* within government research institutions, the Indonesian government's share stood at 88.5% in 2005, with the business sector responsible for 5% and another 5% coming from foreign funds (RISTEK, 2010b).

The Indonesian Government's budget for 'science and technology' (which includes R&D, science services for information systems and statistical activities, and education and training in universities, ministries and non-ministerial institutions) as a share of the total state budget (or APBN), has decreased over the past thirty-five years. In 1970 it stood at 6.11% at a time when the Soeharto administration realized the importance of science and technology to development, but by 1991 it was 2.34% and had fallen to 0.49% in 2006 (Figure 6.9). Similarly, the proportion spent on R&D fell from 0.74% in 1994 to 0.42% in 2006.

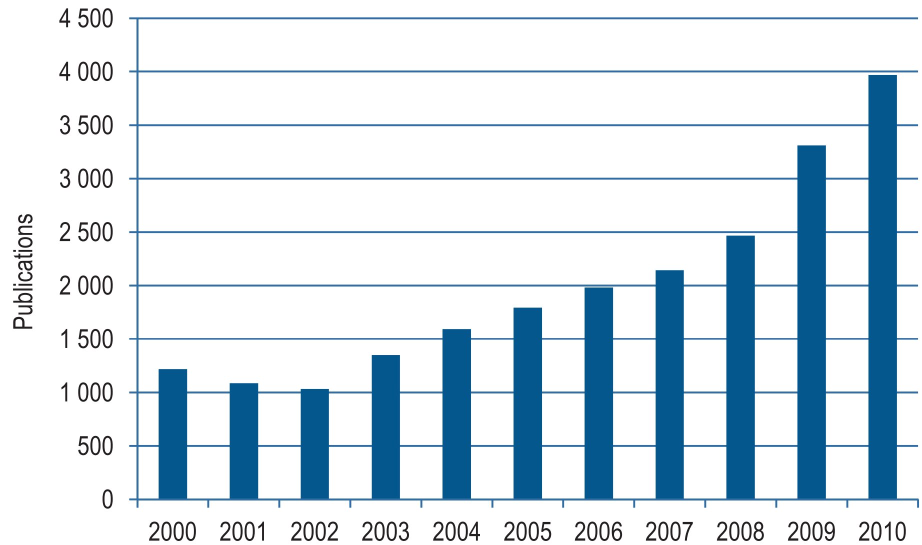
Figure 6.9. Ratio of state S&T and R&D budget to state budget, 1990-2006



Source: Based on Pappiptek-LIPI and Central Bureau of Statistics, 1996-2007.

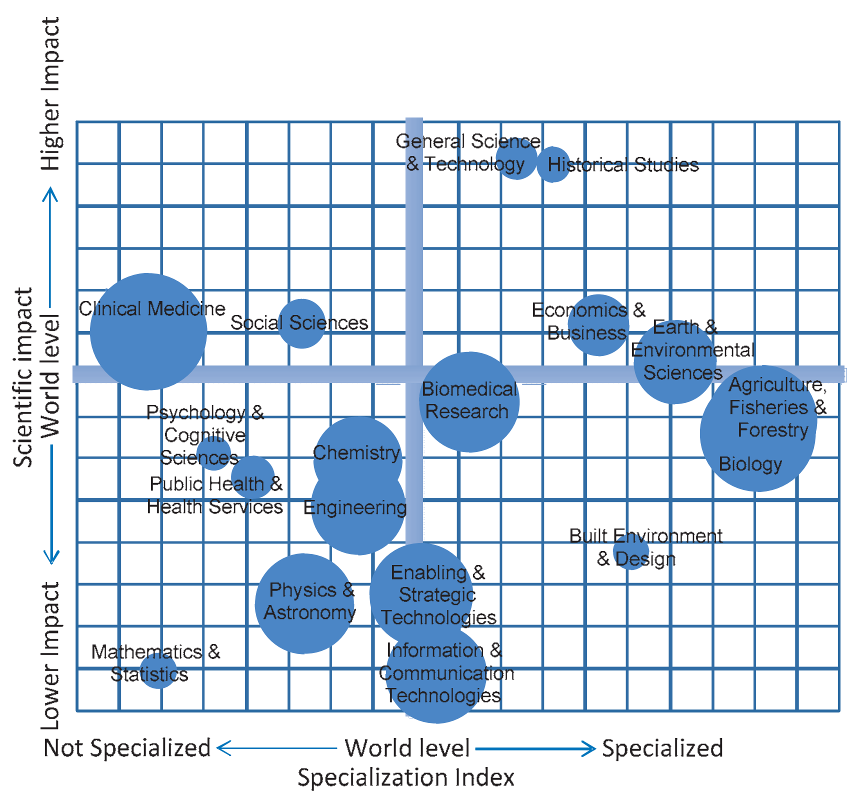
Indonesia's publication performance improved steadily over the period 2000-2010 (Figure 6.10), growing from a low base of around 1 000 publications a year to just under 4 000 publications per year in 2010. Publications grew across all major scientific disciplines from 2000-2009 with information science and technology, engineering and medicine being three particular sources of growth. However, the growth rate compared to other Southeast Asian countries was relatively low – only Singapore, which started from a much higher base, experienced slower growth. Over a similar period, the number of publications in English language journals also grew although there was a decrease in the share of publications published in English. One explanation for this could be growth in co-publications with Japanese partners which increased more rapidly than co-publications with EU-27, United States and Australian partners. Overall, 74% of publications involve international collaboration, with Japan the largest source.

Figure 6.10. Trends in scientific publications in Indonesia, 2000-10



Source: Science Metrix analysis of Scopus (Elsevier) database.

Figure 6.11. Positional analysis of Indonesia's scientific publications, 2000-10

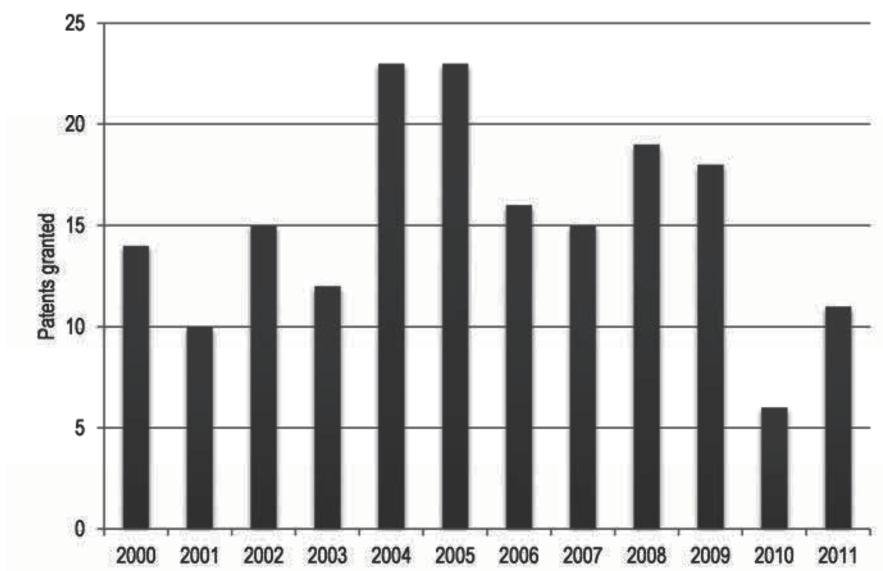


Source: Analysis of Scopus (Elsevier) database by Science Metrix. This combines the number of publications by scientific field (area of circles), the specialisation index (a measure of relative intensity in a field compared to the World average) and the average of relative citations (citations relative to the World average controlling for age and field).

Analysis of the field of publications (Figure 6.11) shows that life sciences (clinical medicine, biology and biomedical sciences) are among the largest publication fields alongside ICT, enabling and strategic technologies, and physics and astronomy. However these three latter fields had a low relative citation impact compared with the World average between 2000 and 2010. The largest relative specialisation is in the fields of agriculture, biology and earth and environmental sciences. General science and technology and historical studies were the highest-performing areas in terms of relative citation impact.

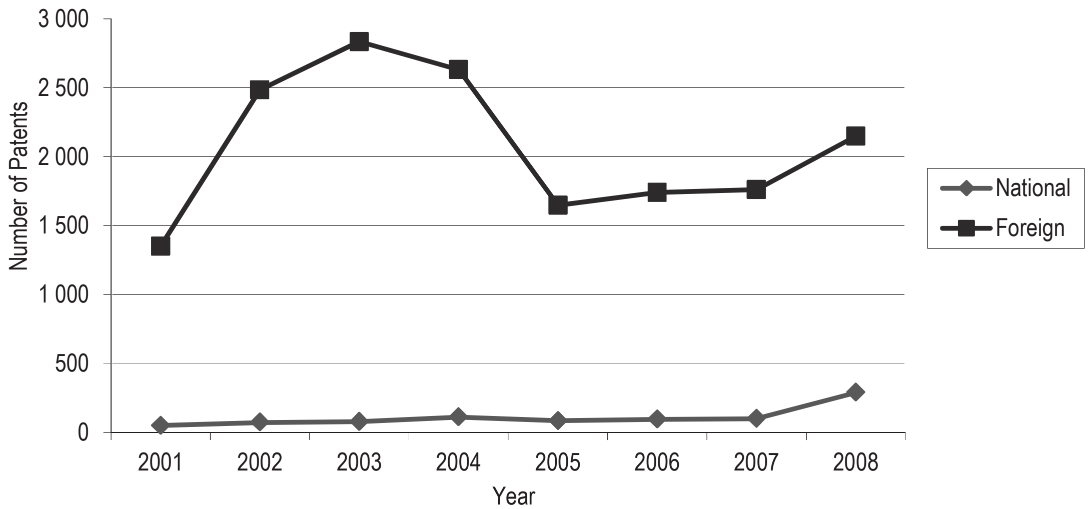
Indonesia's patenting performance in terms of USPTO patents granted is very weak, averaging around 15 per year over the period 2000-2011 (Figure 6.12). In comparison, over 180 USPTO patents were granted to Malaysian-based applicants in 2011 alone whilst Thailand accounted for over 70. The number of patents registered in Indonesia itself is much higher, but the picture is dominated by the patenting behaviour of foreign-owned firms (Figure 6.13).

Figure 6.12. Trends in USPTO patents granted to Indonesia, 2000-11



Source: US Patent and Trademark Office (USPTO, 2012). The origin of a patent is determined by the residence of the first-named inventor.

Figure 6.13. Number of patents registered in Indonesia



Source: Directorate for Patent, Directorate-General for Intellectual Property Right, the Indonesian Ministry of Justice and Human Rights (2010).

6.3. Innovation policy: Institutional framework and policy orientations

Science and technology were considered important for development in the 1970s and government funding was substantial, but the perceived importance of S&T faded and support dwindled. Indonesia's economic growth to middle-income status was trade-driven rather than science and technology-driven, and industrial and related policies did not, until recently, attempt to nurture innovative capacity.

S&T-related policies and support programmes were developed within a legal framework based on the Fourth Amendment of the Indonesian Constitution (1945) and governed, since 2002, by Law 18/2002, which covers with the National System of Research, Development and the Application of Science and Technology. Currently, however, new legislation is being drafted to provide a better footing for the development of broader-based R&D and innovation policies geared towards improving the national innovation system.

Although Indonesia spends remarkably little on R&D and innovation, the public sector institutional landscape in which policies are formulated and implemented and in which most R&D is conducted is densely-populated, labyrinthine and highly fragmented, though there have recently been significant attempts to improve coordination. In essence, the institutional landscape has been and still is populated by multiple ministries or departments with an interest in research, some of which also have an interest in innovation; multiple agencies/institutions that both implement policies (*e.g.* by launching support programmes) and conducting R&D in their own multitudinous research institutions and laboratories; a small number of high-level advisory bodies that advise on overall strategic direction and help formulate policies affecting different parts of the national innovation system; and numerous other lower-level co-ordination mechanisms, *e.g.* meetings and fora such as National Coordination Meeting for Research and

Technology and the Forum for Research and Technology Planning that are supposed to link and inform different elements of the innovation system. Until the recent formation of the National Innovation Committee (KIN), however, there was no single, independent high-level body with an oversight, steering and co-ordination function across the innovation system as a whole.

There are at least 19 ministries/departments with an interest in R&D, including the Ministry of Finance, the National Development and Planning Agency (BAPPENAS), and the Coordinating Ministry of Economic Affairs. The ministry with the largest budget for R&D is the Ministry of Research and Technology (RISTEK), which is responsible for the formulation, co-ordination and implementation of S&T policy at a national level and the promotion of technological development. RISTEK's expenditure on R&D, however, is only 29% of the total government R&D budget. Other big departmental spenders are the Department of Agriculture (DEPTAN – 23.5%), the Department of Energy and Natural Resources (DESDM – 13.9%) and the Department of National Education (DEPDIKNAS – 12%), which organises R&D programmes involving universities.

RISTEK oversees seven agencies/institutions (LPNK RISTEK) that operate in a fairly autonomous fashion and report not only to RISTEK but also directly to the Presidential Office. Six of them conduct R&D. The largest R&D spenders are the Indonesian Institute of Sciences (LIPI) and the Agency for the Assessment and Application of Technology (BPPT).

- LIPI accounted for 14.1% of the government R&D expenditure in 2006 and supports research nearer the 'science' end of the spectrum, though it opened a Centre for Innovation in 2005 in an attempt to establish links with industry.
- BPPT accounted for 5.8% of the R&D budget and focuses primarily on work at the 'technology' end of the spectrum, but it also seeks to strengthen the competitiveness of industry via support for technology transfer and related activities. At any one time, BPPT operates around 12 R&D programmes and receives funds both from RISTEK and directly from the Ministry of Finance, the Ministry of Education and others. Concerning innovation, it supports the Business Innovation Centre, set up in 2005 to promote innovation in industry and provide incubators for start-ups, and greater emphasis is being placed on the construction and management of high-tech parks. By 2025, it hopes to work 100% for industry and to receive only 50% of its budget from government.

Along with RISTEK, the ministry with the biggest interest in innovation is the Ministry of Industry (DEPPERIN), which is responsible for 4.1% of government spending on R&D. Its R&D and innovation-related activities are co-ordinated by the Agency for Research and Development of Industry, which oversees 32 different applied research and service organisations (10 focusing primarily on applied research; 11 specialising in specific commodities; and 11 operating as regional centres). The Ministry of Industry is also responsible for setting R&D priorities for the transportation, ICT, agribusiness and basic manufacturing sectors.

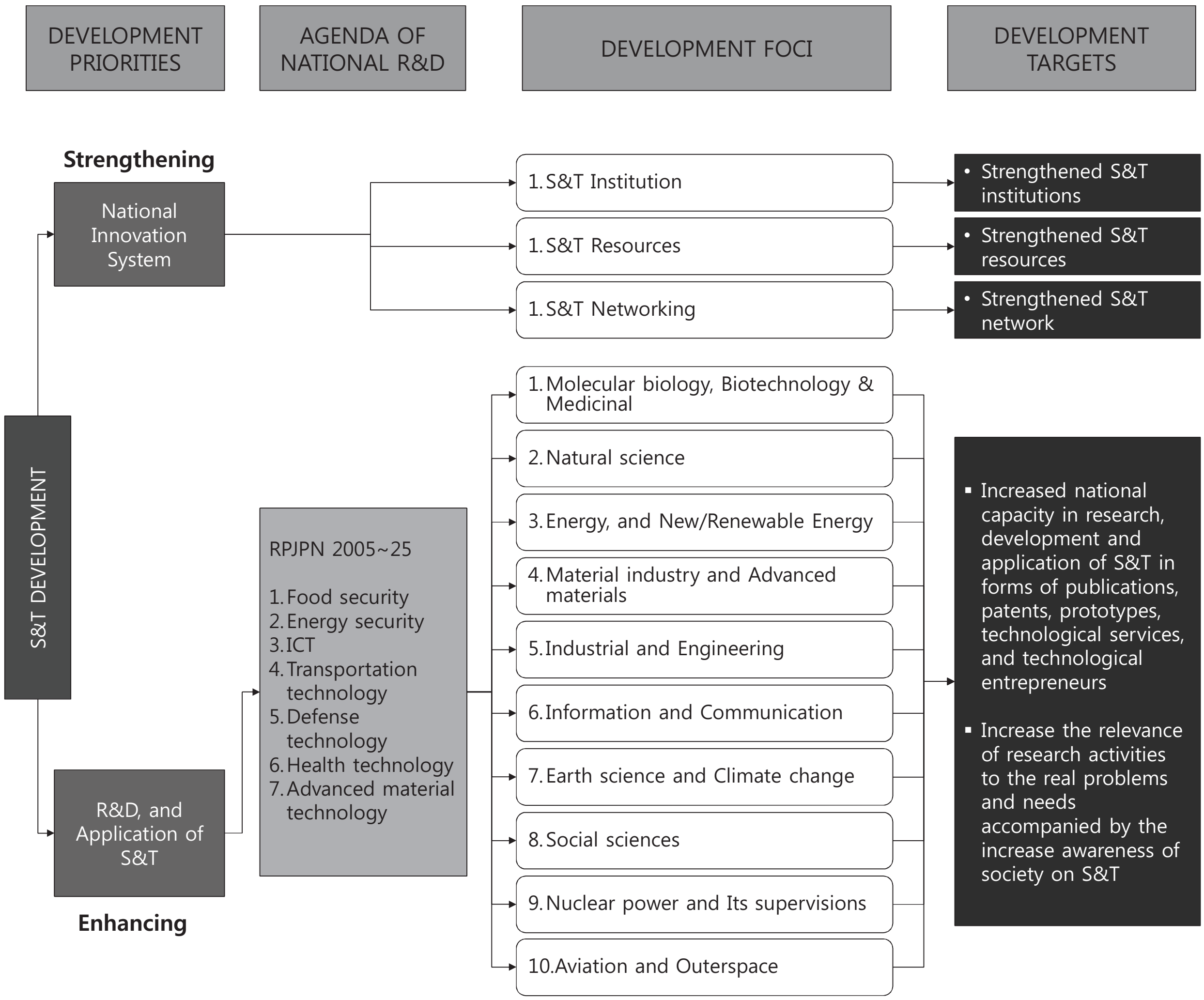
As for cross-government co-ordination of innovation policy, the National Innovation Committee (KIN) was established in 2010 to oversee and co-ordinate developments across the national innovation system. It is an autonomous body comprising 30 members and reports directly to the President. It covers nine areas (energy, food and water, education, health and medicine, maritime affairs, defence and weaponry, transportation, ICT, and the creative industries) and has established five working groups on innovation programme development, innovation in business and industry, innovation cluster development, innovation-related incentives and regulations, and the economic, social and cultural aspects of innovation. KIN is charged with advising the government on matters concerning the development of the innovation system. It is currently contributing to the government's proposal for a new bill designed to embed national innovation system concepts in the legal framework governing innovation, though its main task is to produce a plan for a National Innovation Policy by 2014.

Around the time KIN was formed, another advisory body, the National Economy Committee (KEN), was set up to work closely with the Coordinating Ministry for Economic Affairs, and one of KIN's first tasks was to contribute, along with KEN, to the formulation of the Master Plan for the Acceleration and Enlargement of Indonesian Economic Development (MP3EI) launched by the President in 2011 – an ambitious attempt to maintain high growth (7%-9% annually) while transforming the economy from a natural resource and trade-driven economy to an investment and innovation-driven economy. The plan has three main pillars: the development of six economic corridors throughout the archipelago; the development of strong links with other ASEAN countries and other countries in the world; and strengthening human resource, science and innovation capacity.

Other advisory bodies established before KIN and KEN continue to function, though how they will all interact in the future is as yet unclear. The National Research Council (DRN) was set up in 1984 to identify and define S&T development paths and priorities and to advise on the national S&T policies formulated by RISTEK. It is charged with producing National Research Agendas (NRAs) and has produced two to date covering the periods 2005-2009 and 2010-2014. Since 2010, it has also managed 'Incentive Research', a programme funded by RISTEK. There is also the Indonesian Academy of Science (AIPI), established in 1991, which continues to advise the government on the course of scientific developments, and numerous Local Research Councils (DRDs) that help local government to map S&T needs and suggest S&T development paths.

Research priorities suggested by the DRN feed into broader-based planning activities. Within the context of the production of a long-term National Development Plan covering the period 2005-2025 (the RPJPN), Indonesia has been producing a series of medium-term five-year plans (RPJMNs), each of which comprises five annual plans (RKPs). The first, covering 2005-2009, prioritised the establishment of a stable, prosperous democratic nation; the second (2010-2014) focused on human resource development and improved S&T capability. It was envisaged that the third (2015-2019) would have a similar focus, and that the fourth (2020-2024) would prioritise the establishment of a solid economic structure based on local competitive advantage, quality and strong human resources (Sulaeman and Pawennei, 2010). Concerning S&T, Figure 6.14 presents the vision outlined in the second RPJMN for 2010-2014. It emphasises the two main strands that constitute the Science and Technology National Strategic Policy. The first is strengthening the national innovation system via efforts designed to strengthen institutions, S&T resources and networking. The second focuses on R&D and the application of S&T in the priority research areas suggested by the National Research Council and detailed in the National Research Agenda.

Figure 6.14. The S&T vision in the Indonesian Development Plan, 2010-14



Source: RISTEK.

In terms of the provision of funding for S&T, research and innovation, the dominant mode in Indonesia is institution-based rather than programme-based, *i.e.* it takes the form of direct institutional funding rather than funding allocated via competitive programmes, with most funding used by public research institutes (PRIs) to conduct R&D and, on occasion, to provide technical services to industry. PRIs and their activities are described in Section 6.4.3. The university sector accounts for only a very small proportion of expenditure on R&D.

6.4. Actors of the national innovation system (NIS)

6.4.1. Business sector

The service sector accounted for 38% of total valued added in 2011, with industry accounting for 45% and agriculture the remaining 17%, though agriculture still employed 38% of the labour force (of 118 million) in 2010 (World Bank, 2012b). Moreover, in 2006, 96.2% of the workforce was employed in SMEs, which accounted for 53.3% of GDP (APEC SME Innovation Centre, 2007).

Private sector R&D and innovation activity is limited and largely concentrated in the manufacturing sector, which is still predominantly composed of medium-low and low technology SMEs and a much smaller number of larger firms and MNCs. As shown earlier, however, private sector investment levels in R&D are very low, with the public sector dominating expenditure. The vast majority of Indonesian companies do not invest in R&D and many are reliant instead on technologies developed elsewhere. Some, however, especially those located in high tech sectors with export potential, are increasingly interested in raising R&D competence levels and have started to co-operate with foreign research institutions.

As noted earlier, FDI levels in Indonesia are modest, accounting for just 2.1% of GDP in 2011. Most of this is in medium-high and high tech manufacturing, but little R&D is performed by MNCs in Indonesia. There would seem to be limited productivity spillovers, technology transfer and technological learning, which could increase the propensity of indigenous companies to invest in R&D and innovation.

A number of surveys over the last decade or so have thrown a little light on the extent of innovative activity in Indonesia and the barriers to it. One survey of 167 000 SMEs in 1999 (Kawasanto, 1999) found that 68% of SMEs encountered considerable technological difficulties, while another, conducted a few years later (Sakya, 2005), found that innovation was largely confined to medium-sized firms (15% of the population) and that only 11.5% of this sub-group attempted to manage technological change and innovation. These indications of low levels of innovative activity were further supported by the results of a survey of 14 000 large and medium-sized enterprises in 2007 (reported in Hidayat et al, 2011), which revealed that nearly 90% of firms had not conducted any innovation-related activities in the previous three years.

In contrast, a survey in 2009 of a much smaller population of 1 500 innovation-oriented firms revealed more about the nature of innovation in such companies (Pappiptek LIPI, 2009b). Most (84%) undertake innovation on their own rather than in co-operation with others and the diverse benefits of innovation are widely appreciated. Positive impacts of product innovation were reported on the quality of goods and services (55.1%) and on their variety (44.9%), while positive impacts of process innovations were reported on the speed and performance of supply chains (33.1%), production capability (26.9%), the flexibility of production processes (26.2%) and the reduction of labour costs per unit of output (13.8%). On the shop floor, product and process innovations had increased overall productivity (39.3%), improved the quality of work (37.9%) and enabled the expansion of business, while innovations in marketing and other areas had also had appreciable impacts. In terms of barriers to innovation, the most important were lack of access to funding, the high cost of innovative activity, the costs associated with commercialisation, high market entry barriers and demand uncertainty. For SMEs, difficulties identifying scientific and technological needs and lack of managerial competence to engage in R&D and innovation projects were also severe barriers.

6.4.2. Higher education institutes (HEIs)

The size of the student body has increased rapidly in recent years. In 1970, 237 000 students were enrolled in 450 private and government-funded HEIs; in 1990, there were 1.5 million students in 900 HEIs (Schüller et al, 2011); but by 2008/9 there were over 4.28 million students in 2 975 HEIs (Indonesian Ministry of Education, 2011). This figure includes universities, academic institutes, schools of higher learning, academies and polytechnics. Of these, 83 were state/public institutions, while the remainder were privately owned. The four most renowned universities are the Universitas Indonesia (UI), the Universitas Gadja Mada (UGM), the Institut Partanian Bogor (IPB) and the Institut Teknologi Bandung (ITB) (Schüller et al, 2011).

Funding for research comes largely from government sources (74% in 2004 – see LIPI, 2006), and many state-owned HEIs, have their own research centres. The universities' share of GERD, however, is low. During 2000-2002, for example, it stood at just 5.6% (UNESCO, 2008). R&D also accounted for a relatively low share (5.0%) of the overall HEI budget in 2007, although 40% of academics are said to engage in research (Indicator IPTEK, 2009).

Given the very modest levels of expenditure on R&D in the university sector, it is not surprising that publication performance in international journals is low, patenting activity is rare and interaction with the private sector limited, although some researchers within the HEI sector do perform contract research for industry and some competitive government schemes do exist to encourage university-industry research linkages. However, constraints on both spending research budgets (*e.g.* the need to return all unspent allocations at the end of every fiscal year) and on the accumulation of additional funds (all income generated from industry projects has to be transferred to the Ministry of Finance) act as major disincentives to the increased involvement of universities in joint activities with industry.

6.4.3. Public research institutes (PRIs)

The bulk of R&D in Indonesia is performed by PRIs, specifically government research institutions (GRIs). As noted in Section 6.3, there are seven research institutes/agencies that report to RISTEK and the presidential office (only one of which – BAPETEN, the Nuclear Energy Regulatory Board – does not undertake research), and 16 other research institutes/agencies that report to other government ministries or departments. The GRIs associated with the seven 'non-departmental' agencies account for nearly 29% of government expenditure on R&D in the government sector, while the 'departmental' GRIs account for around 70%. The small residual funds the R&D activities of local government.

The actual number of research centres or laboratories conducting research is difficult to ascertain with any accuracy, though it is very much larger than the number of GRIs since some conduct research on a number of sites. According to one source, for example, BPPT had "24 centres and an equal number of labs" (IDRC, 2007), while the BPPT website states that BPPT has 17 research centres covering the areas of climate and artificial rain; aero gas dynamics and pressures; ceramics; energy; starch production; structural testing; oceanic surveys; information science and technology; machine production and automation; biotechnology; hydrodynamics; seashore dynamics; polymers; environmental technology; thermodynamics; engineering centres; and technology incubators.

LIPI also has a number of research centres covering biology; oceanography; geo-science; applied physics and applied chemistry; metallurgy; limnology; biotechnology; electricity and electrical engineering; information and computer sciences; telecommunications, strategic electronics, components and material sciences; and calibration, instrumentation and metrology. Furthermore, outside of the RISTEK GRIs there are at least 45 other research institutions concerned with agriculture, veterinary science, medicine, the natural sciences and technology. Moreover, as noted earlier, the 32 research centres of the Agency for Research and Development of Industry conduct applied research and offer a range of services to industry, while at a local level, 78 research institutions are co-ordinated by the Ministry of Internal Affairs (Nugroho et al., 2011).

What can be said with more certainty, however, is that most of the money spent by GRIs on R&D supports projects in engineering and technology (32%) and agricultural and environmental sciences (30%), with natural sciences and social science each taking 18% of the budget and medical sciences and the humanities each taking a further 1% (RISTEK, 2010b).

6.4.4 Linkages between innovation actors

Historically, the linkages between the various R&D and innovation performers in the Indonesian national innovation system have been tenuous. Most research is conducted within GRIs, which tend to operate independently, and there are few research connections between the GRIs and university research units. Similarly, research linkages between GRIs and universities and the small industrial R&D community have been rare, with public sector inputs into the innovation process conspicuous by their absence. Some of the policies and programmes mentioned in Section 6.3 are attempting to rectify these weak linkages, but much still remains to be done.

6.5. Human resources

The proportion of GDP that Indonesia spends on education has increased over the past twenty years, as has the proportion spent on higher education. In 1990 the education share of GDP was 0.7%. In 2007 it was 3.5%. Similarly, the higher education share increased from 0.14% to 0.27%. Comparing trends internationally, however, Indonesia still lags considerably behind some of its ASEAN neighbours. Even by 2002, for example, the share for education had reached 8.1% in Malaysia and 5.0% in Thailand, while the share for higher education had reached 2.6% in Thailand and 2.2% in South Korea. The proportion of first degree holders in the workforce in 2005 was also low (3%) compared to the situation in countries such as the United States (39%), Japan (23%) and the Philippines (19%), which had the highest ratio amongst the ASEAN countries (Pappiptek LIPI, 2009a).

Concerning the scientific and technological workforce, details are scarce. Science and engineering students accounted for about 39% of the student population during the period 1987-97, but in overall terms the number of researchers and scientists in Indonesia is known to have fallen from 43 779 in 2004 to 42 722 in 2006 (RISTEK, 2010a). The ratio of natural science and engineering doctorates to all other doctorates is also low by international standards. In Thailand and South Korea, for example, the ratios were 57% and 48% respectively in 2005, whereas in Indonesia the ratio was 34% (Indicator IPTEK, 2009).

The scientific workforce is also static in terms of mobility. BPPT's Annual Report (BPPT, 2010), for example, notes that there has been little movement of its researchers to industry or vice versa. There are a very limited number of co-operative projects (the Annual Report mentions 46), and there are some short-term secondments, but real mobility between the public and private sectors is extremely limited. Scholarships are available, however, for bright Indonesian students to study abroad, providing them with an opportunity to enhance their own career prospects and Indonesia with an opportunity to enhance its scientific competence levels, but the fear of students pursuing their careers elsewhere in the world is very real.

6.6. SWOT analysis

Based on the material presented above, several strengths and weaknesses of Indonesia's NIS can be identified, along with future opportunities and threats. These are summarised in Table 6.5.

In terms of strengths, Indonesia's rise to middle-income status and continued high GDP growth, notwithstanding the dip and recovery associated with the Asian crisis of the late 1990s, has largely been based on trade related to its plentiful supply of natural resources, *e.g.* gas, oil, coal and forest and marine produce. Good trade links with Japan and the United States have also recently been complemented by improved links with its ASEAN neighbours and China, following the signing of trade agreements, and Indonesia has risen to 44th in terms of the World Economic Forum's ranking of international competitiveness.

Innovation has played little role to date in Indonesia's success, but there has been an improved contribution of total factor productivity (TFP) to output growth and there are indigenous pockets of concentrated S&T and R&D expertise, especially in the public sector, where most expenditure on research occurs. A small number of well-known universities produce qualified scientists and conduct research in an expanding higher education sector, while in the private sector a small cadre of innovation-oriented companies have grown to appreciate the benefits of innovation. There have also been marked recent attempts by government to develop policies geared towards knowledge- and innovation-related growth, with an accompanying emphasis on new co-ordination mechanisms to oversee and ensure coherent approaches to policy development.

Despite Indonesia's trade success, it still has a comparatively low GDP per capita and high poverty levels. It has also made little progress in terms of the transition to a modern, knowledge-based economy. It has a weak innovation culture and there is a high degree of risk aversion. It is only moving very slowly away from a low technology base and there are declining exports of high technology products and an increasing reliance on imports of these goods. Levels of foreign direct investment (FDI) are volatile and modest when compared to similar levels in competitor countries, and technology transfer and other technology-related spillovers have been limited.

Table 6.5. Summary SWOT (strengths, weaknesses, opportunities, threats) analysis

Strengths	Weaknesses
• Strong natural resource base • High trade-based growth rates largely based on natural resources • Good trade links with Japan and the United States and improving trade links with regional neighbours and China • Reasonable levels of international competitiveness • Improved contribution of TFP to output growth • Pockets of concentrated S&T and R&D expertise, though primarily in the public sector • Expanding higher education sector and small number of well-known universities • Small cadre of companies appreciative of the benefits of innovation • Recent attempts to focus government policy on innovation-related growth • Recent attempt to improve overall co-ordination of government R&D and innovation policies	• Low GDP per capita and high poverty levels • Slow shift away from a low technology base • Low productivity levels and TFP growth rates • Modest and highly volatile levels of FDI, with few technology or innovation-related spillovers • Underdeveloped infrastructure, including the ICT infrastructure • High perceived levels of bureaucratic inefficiency and corruption • High barriers to business formation • Limited access to capital for innovation • Low public and private investment in R&D • A system-wide failure to generate and diffuse technology • A low-ranked higher education and training system • Small number of researchers and scientists for a country of its size • Poor publication and patent performance • Highly fragmented R&D and innovation governance structure, with few attempts at overall co-ordination until recently • Lack of indicators and evidence base to underpin innovation policy
Opportunities	**Threats**
• Appreciable innovation potential and scope for moving up value chains • Large, young population • Scope for improving qualified human resource base • Market expansion in Southeast Asia and China • Scope for more coherent R&D and innovation policies • Scope for more innovation-friendly FDI • Scope for raising S&T competence levels via greater international co-operation • Scope for making public sector R&D more relevant to industry needs • Scope for increasing private sector involvement in R&D and lowering the barriers to innovation • Scope for service sector innovation	• Volatile global financial situation • Increased competition from emerging and developed countries • Depletion of natural resource base and/or related problems of environmental degradation • Continued emphasis on trade-based rather than knowledge-based growth • Continued underinvestment in infra-structure, higher education and R&D • Failure to attract/retain qualified human resources • Inadequate incentives for innovation generally • Inadequate incentives for innovation-friendly FDI • Inefficient implementation of R&D and innovation-related policies

Many aspects of Indonesia's overall infrastructure remain underdeveloped, and the ICT infrastructure in particular lags behind developments in some of its closest neighbours. Perceived levels of bureaucratic inefficiency and corruption are high and there are many barriers to the formation of new companies and the efficient functioning of existing firms. These include limited access to capital for innovation, a weak venture capital sector and inefficient regulatory, tax and IPR regimes. There is low public and private investment in R&D, limited S&T and R&D capability in industry and a system-wide failure to generate and diffuse technology adequately, as demonstrated by Indonesia's low ranking in terms of the World Bank's Knowledge Economy Index.

Despite the fact that Indonesia's expenditure on education and higher education is expanding, expenditure as a proportion of GDP is still low compared to some of its neighbours. Correspondingly, Indonesia produces a low number of scientists and researchers for a country of its size; publication and patent performance is weak; and there are very weak links between the public sector, where most S&T competence is to be found, and industry.

Although S&T was seen as an important determinant of development in the 1970s, this focus disappeared almost entirely over the next 30 years, with a very limited government focus on S&T, R&D and innovation until very recently. Declining levels of expenditure also created problems of critical mass given the extremely diverse and fragmented set of public sector actors concerned with both the implementation of policies and the conduct of R&D and innovation-related support services. Policy formulation also continues to be hindered by a paucity of adequate data and intelligence on the nature and scope of R&D and innovation-related activities in the country.

The limited steps Indonesia has taken towards an innovation-oriented economy represent both a weakness to date and an opportunity to take such steps in the future, since there is considerable innovation potential and scope for moving up innovation-oriented value chains. The country has a large, young population and there is ample scope for improving the education system and the quality of the human resource base. A large indigenous market and expanding markets in both the ASEAN area and China also augur well for the future.

All this will require more coherent approaches to the formulation and implementation of innovation-related policies, with a particular emphasis on strategies geared towards the attraction of innovation-friendly FDI, efforts designed to raise scientific competence levels via increased international co-operation, and initiatives designed to make public sector R&D more relevant to industry's needs. Better mechanisms to stimulate private sector involvement in R&D and lower the barriers to innovative activities are also needed, and given the increasing importance of the service sector in the national economy, there is scope for a new emphasis on service sector innovation.

There are considerable exogenous and endogenous threats to future progress, however. The global financial situation is still precarious, and competition from both developed and emerging countries is likely to be fierce, especially as some of the latter have taken greater strides to modernise their economies. Indonesia still has plentiful natural resources, but a continued over-reliance on trade in these could lead not only to problems of depletion or environmental degradation, but also to inadequate efforts to develop effective innovation-related policies. Similarly, continued under-investment in infrastructure and higher education would lead to a failure to attract, train and retain adequate levels of appropriately qualified human resources, which would again undermine efforts to build a sustainable base upon which to found a knowledge economy. Recent developments in the policy sphere suggest that government is taking the issue of innovation seriously, but considerable willpower and determination will be needed to develop adequate incentives for innovation generally, to attract innovation-friendly FDI, and to ensure the efficient implementation of all relevant R&D and innovation-related policies.

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Chapter 7

Malaysia innovation profile

An industrial sector based on the manufacture and export of the technology-based products of multinational enterprises (MNEs) has fuelled Malaysia's rise to a middle-income country. Electronics, particularly semiconductors, account for 40% of exports, followed by automobiles and parts, and a burgeoning services sector features tourism as well as Islamic banking and finance. Among Southeast Asian countries, Malaysia generally ranks second after Singapore in economic competitiveness.

Like Indonesia, Thailand and the Philippines, Malaysia used foreign direct investment (FDI) and export-led manufacturing to emulate the success of the first wave of East Asian Tigers. Growth slowed, however, following the Asian economic crisis of 1997, and the slowdown persisted until the global financial crisis made matters worse. Currently Malaysia shows some signs of recovery, but there is still concern that the recovery may be difficult. MNEs in Malaysia mostly confine themselves to manufacturing and assembly activities. There is little research and development (R&D) or technology transfer and technical spillover from foreign to domestic firms. The country also suffers from a continuing shortage of skilled labour. Consequently, there is little innovativeness in the economy as a whole. Moreover, the domestic economy has seen declining private investment and stagnating productivity growth, coupled with a lack of competition in sectors such as services. This has led to fears that Malaysia is caught in a "middle-income trap" that can only be overcome by a stronger emphasis on innovation as a driver of economic growth.

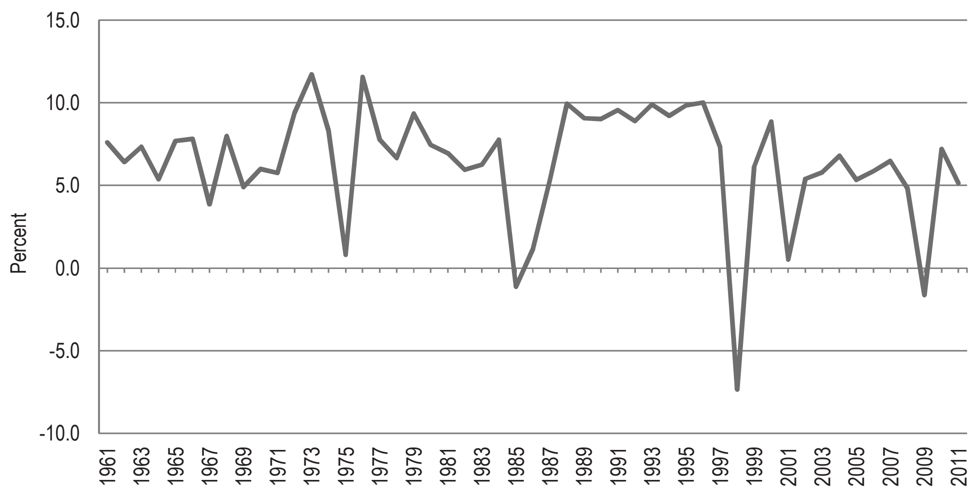
The Tenth Malaysia Plan (2011-15) and the New Economic Model (NEM) stress human capital development and improvements in innovation capacity. Substantial investments have been made in telecommunications infrastructure such as the Multimedia Super Corridor (MSC). The Plan emphasises the need to intensify research activities and outputs from universities and public research institutes, and to enhance their links with private companies in order to maximise commercialisation opportunities. Local content, R&D and technology transfer provisions for MNEs should be strengthened and incentives for firm training increased. The positive implications for growth of the NEM structural reform agenda are threatened by an increasing brain drain and the fiercely competitive regional environment for trade and foreign investment.

7.1. Macroeconomic performance and framework conditions for innovation

7.1.1. Performance and structure of the economy

Since independence in 1957, Malaysia has moved from an economy based on primary commodities to one fuelled by manufacturing and services based on foreign investment. Malaysia consistently achieved more than 7% annual growth in gross domestic product (GDP) (Figure 7.1) along with low inflation in the 1980s and the 1990s. However, following the Asian financial crisis of 1997, Malaysia lost ground to many Southeast Asian economies and economic growth averaged 4.8% over the decade 2000-2009. Again in 2009, the global financial crisis hit the country particularly hard; the reduction in GDP growth was the steepest among middle-income countries in the region (WEF, 2010). A fiscal stimulus is helping to put the economy back on track and economic growth was 5.1% in 2011 and is forecast by the World Bank to be 4.3% in 2012 (World Bank, 2012a).

Figure 7.1. Malaysia annual GDP growth, 1961-2011



Source: World Bank World Development Indicators.

The 1970s witnessed aggressive efforts by the government to bring in foreign direct investment (FDI) to spur the nation's industrialisation. These included generous incentives, tax relief and subsidised investment loans and succeeded in attracting a number of multinational enterprises (MNEs) to Malaysia. Based on foreign investment, the predominantly mining and agricultural Malaysian economy began to move towards a more diverse production profile that included both heavy manufacturing and services. However, the 1997 Asian financial crisis caused significant outflows of foreign portfolio investments and FDI, which also dipped during the global recession of 2008-09.

Since the 1980s, the industrial sector has led Malaysia's growth. The government's industrialisation programme targeted large-scale and capital-intensive projects including steel, machinery and equipment, petrochemicals, cement, and automobile manufacturing (Gustafsson, 2007). As a result, industry grew from 14% of GDP in 1970 to about 42% in2010, while agriculture and mining, which together had accounted for 43% of GDP in 1970, dropped to 10-15% (Table 7.1). The remainder of GDP is contributed by the fast-growing services sector, particularly trade, utilities and finance. Malaysia is the world's largest Islamic banking and financial centre. Tourism has become Malaysia's third largest source of foreign exchange income, although it is under threat from pollution and deforestation resulting from the growing industrial economy.

Table 7.1. Structural change of Malaysia's economy, % of GDP, 2000-10

Sector/Year	2000	2004	2008	2009	2010
Agriculture	8.33	7.97	7.32	7.45	7.08
Mining and quarrying	10.23	9.73	7.69	7.50	7.02
Manufacturing	29.90	29.93	28.17	25.87	26.92
Construction	3.80	3.40	3.01	3.23	3.17
Electricity, gas and water	2.89	2.99	2.84	2.89	2.92
Wholesale and retail trade	10.86	10.71	12.63	12.95	13.06
Accommodation and restaurant	2.17	2.17	2.33	2.42	2.38
Transport and storage	3.77	3.56	3.74	3.68	3.68
Communication	3.00	3.51	3.75	4.03	4.09
Finance and Insurance	8.87	9.68	10.71	11.41	11.31
Real estate and business services	4.26	4.19	5.09	5.28	5.31
Government services	6.14	6.45	7.15	7.39	7.35
Other services	5.80	5.71	5.56	5.89	5.72

Source: Thiruchelvam et al. (2011a), calculations based on Monthly Statistical Bulletin, January 2011.

Exports have become the country's primary growth engine. Export-led industrialisation transformed Malaysia into Asia's third-most open economy, with trade at its peak reaching twice the value of GDP. At one time, Malaysia was one of the world's largest producers and exporters of tin, rubber and palm oil. Over the last four decades, electrical goods and appliances and electronic goods, particularly semiconductor devices, came to represent some 40% of all exports. This was accompanied by a parallel drop in the importance of the resource-based sector, which initially accounted for some 95% of all exports and declined to 30% in recent years (MIDA, 2007). The United States, Singapore and Japan have been the top destinations for exports since 2000 (and also major sources of imports), with China joining them in recent years (Table 7.2).

Table 7.2. Malaysia's top trading partners, 2000 and 2010

Rank	Malaysia's top 10 export partners in 2000	USD million	Malaysia's top 10 export partners in 2010	USD million
1	United States	20 159	Singapore	26 553
2	Singapore	18 046	China	25 057
3	Japan	12 834	Japan	20 611
4	Hong Kong, China	4 435	United States	18 981
5	Netherlands	4 110	Thailand	10 628
6	Chinese Taipei	3 734	Hong Kong, China	10 118
7	Thailand	3 549	Korea	7 523
8	Korea	3 280	Australia	7 467
9	United Kingdom	3 044	India	6 516
10	China	3 028	Netherlands	6 286
	Malaysia's top 10 import partners in 2000	USD million	Malaysia's top 10 import partners in 2010	USD million
1	Japan	17 240	Japan	20 705
2	United States	13 637	China	20 680
3	Singapore	11 762	Singapore	18 732
4	Chinese Taipei	4 608	United States	17 551
5	Korea	3 663	Thailand	10 266
6	China	3 242	Indonesia	9 151
7	Thailand	3 154	Korea	8 891
8	Germany	2 442	Chinese Taipei	7 418
9	Indonesia	2 269	Germany	6 643
10	Hong Kong, China	2 252	Hong Kong, China	3 948

Source: UN Commodity Trade (Comtrade) Statistics Database.

Malaysia is at the top of the world league when measured by the ratio of high-technology exports to total exports. Table 7.3 shows that electronics and electrical products account for 56% of manufactured exports, although this is a decline from 65% in 2005. However, comparison of domestic value added to total output value suggests that Malaysia remains highly reliant on low- and semi-skilled intensive assembly-type manufacturing (Rasiah, 2009). The global economic crisis caused exports to decline by 17% in 2009 with a similar fall in the trade surplus. Malaysia's technology-based export products have high import content, so the fall in export orders from advanced economies resulted in a sudden drop in intermediate imports. At present, Malaysian exports continue their climb out of one of their most severe slumps in history, driven by regional and, increasingly, global demand. As growth prospects improved, firms in China resumed stocking parts and components from regional suppliers, particularly electronics from Malaysia. Demand from Japan, the United States and the European Union remains weak in comparison to pre-crisis levels (Thiruchelvam et al., 2011a).

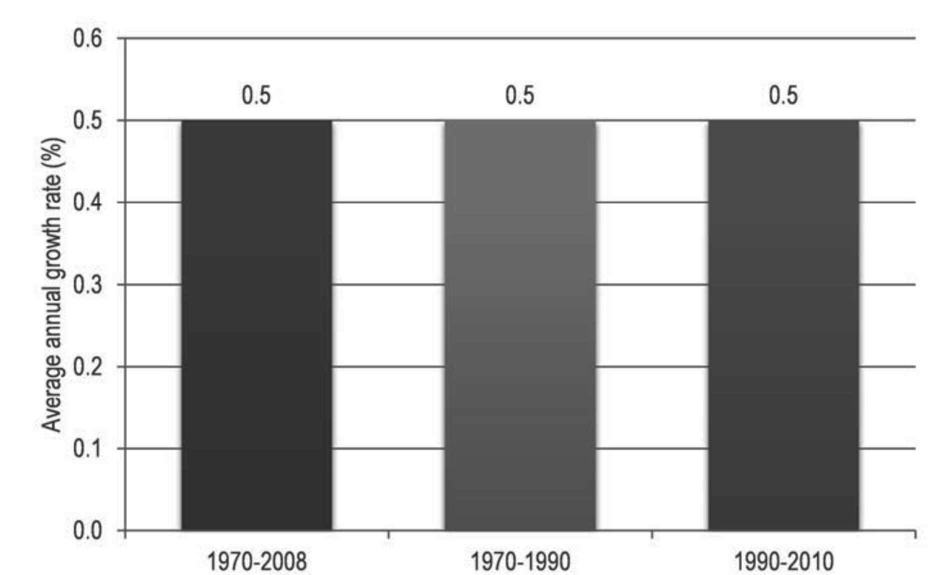
Total factor productivity (TFP) in Malaysia has been steady, with annual average growth of 0.5% over the periods 1970-1990 and 1990-2008 (Figure 7.2). Malaysia has therefore avoided the falls in TFP growth experienced by Indonesia and Thailand between the same two periods, but compares less favourably with the growth experienced by Singapore (an improvement from -0.1% in 1970-1990 to 1.2% in 1990-2010) and, most notably, China (an increase from 1.7% to 4.7%).

Table 7.3. Share of electronics and electrical in manufactured exports and value added: Malaysia, 2005-10

Years	Percentage of gross exports out of total manufactured exports							Percentage of value added
	Semi-conductors	Electronic equipment & parts	Consumer electrical products	Industrial & commercial electrical products	Electrical industrial machinery & equipment	Household electrical appliances	Total (electronics & electrical)	Value added in total manufacturing value added
2005	20.9	27.3	5.2	6.7	4.6	0.7	65.4	26.4
2006	19.8	27.0	4.0	7.3	4.7	0.7	63.5	24.7
2007	20.4	24.7	3.5	6.3	5.1	0.7	60.7	25.7
2008	18.3	21.6	4.0	6.7	5.0	0.7	56.4	20.7
2009	21.6	20.0	4.4	5.6	5.1	0.7	57.3	n.a.
2010	20.1	19.9	5.3	4.6	5.1	0.7	55.8	n.a.

Source: Thiruchelvam et al. (2011a), calculations based on monthly statistical bulletin, January 2011.

Figure 7.2. Trends in total factor productivity (TFP) growth: Malaysia, 1970-2010



Source: APO (2012).

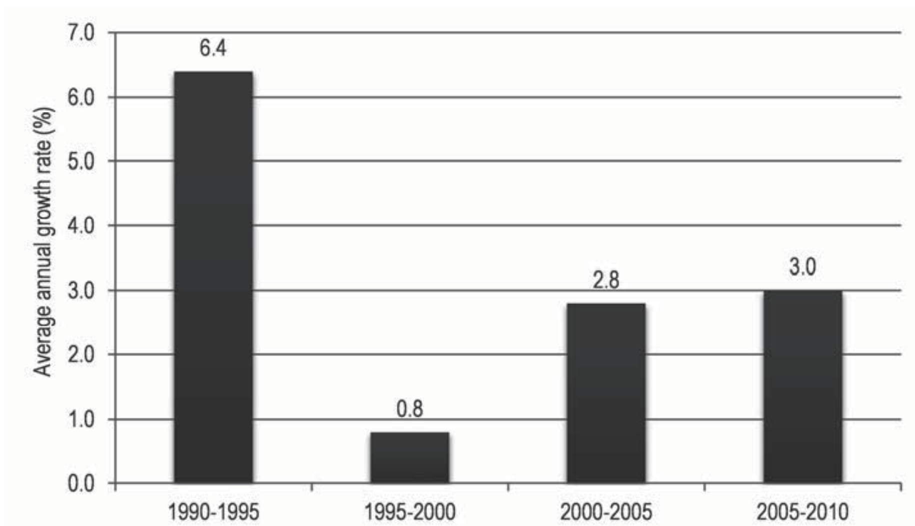
A closer look at trends over the last decade reveals that TFP has made a much bigger contribution to economic growth than in the past, though capital accumulation and labour inputs combined have been the more important driver of growth (Table 7.4). Sustained increases in TFP as well as labour productivity, which grew at an annual average rate of 2.8% over 2000-05 and 3.0% over 2005-10 (see Figure 7.3), hide trends in TFP at the sectoral level which suggest weakening dynamism in key sectors (Table 7.5). Prior to 2003 the manufacturing sector, for example, had the highest TFP growth (3.1% over 1999-2003), but the figure was only 0.8% over 2006-10. TFP performance improved, instead, in the services sectors (Thiruchelvam et al., 2011a) including finance.

Table 7.4. Growth of gross domestic product (GDP) and total factor productivity (TFP): Malaysia, 2001-10

Period	Growth (%)			
	Labour	Capital	TFP	GDP
2001-2010	1.36	1.75	1.52	4.63
2001-2005	1.53	1.77	1.39	4.69
2006-2010	1.19	1.72	1.65	4.56

Source: Malaysia Productivity Corporation (2011).

Figure 7.3. Trends in labour productivity growth: Malaysia, 1990-2010



Note: Average annual growth rate of GDP at constant basic prices per hour, using 2005 PPPs.

Source: APO (2012).

Table 7.5. Growth of total factor productivity (TFP) by sector: Malaysia, 2001-10

Sector	TFP growth (%)		
	2001-2010	2001-2005	2006-2010
Agriculture	1.38	1.73	1.03
Mining	0.18	1.49	-1.12
Manufacturing	0.91	1.08	0.78
Construction	0.79	0.11	1.47
Utilities	1.32	1.20	1.44
Transport	1.70	0.94	2.45
Trade	2.03	0.94	3.12
Finance	1.99	0.96	3.03
Others	1.00	0.54	1.42

Source: Malaysia Productivity Corporation (2011).

Rapid economic growth in Malaysia has led to large increases in per capita income and a reduction of the proportion of the population below the national poverty line from 10% in 1995 to 3.8% in 2008, but also to a rise in inequality. Income distribution and the incidence of poverty vary within Malaysia, owing to regional and urban-rural disparities. Urban poverty is estimated at nearly 2% and rural poverty at over 8% (World Bank, 2012d). The export-oriented industrialisation process, equity ownership restructuring, and unevenness in access to education and training underlie the persistence of inequality in the country, as shown by a GINI coefficient of 46% in 2009 (World Bank, 2010).

In 2011-12 Malaysia ranked 21st out of 142 countries on the Global Competitiveness Index of the World Economic Forum, again an improvement on previous scores. Among the Southeast Asian countries, Malaysia generally ranks second after Singapore on most indices (WEF, 2012).

A useful summary of recent economic trends was included in a recent World Bank Report (*Malaysia Economic Monitor: Modern Jobs*, 2012c). Commodities (in particular petroleum, palm oil and rubber-based products) contributed strongly to exports and manufacturing production in 2011 but non-commodity exports, which remain the largest component of the trade basket, were more vulnerable to weak global demand. Investment and private consumption are likely to remain robust in 2012 though setbacks to the global recovery remain a risk to short-term economic growth. The Bank noted the government's economic reforms had made significant progress to date but addressing more difficult structural reforms was now the challenge in the medium to long-term.

7.1.2. Framework conditions for innovation

The state plays a significant but declining role in guiding economic activity in Malaysia through macroeconomic five-year plans. The plans largely seek to accelerate growth by investing in selective sectors and improving their supporting infrastructure. The overall effectiveness of the five-year plans is disputed, as a large portion of allocated funds remain undisbursed and industrial competitiveness and innovation still tend to be confined to export-oriented subsidiaries of MNEs.

The current initiatives of the government are the New Economic Model (NEM) and the Tenth Malaysia Plan (2011-15), both of which emphasise, among other priorities, improving innovation capability and human capital development as well as institutional efficiency. National income per capita is targeted to grow at 6% a year, propelled by the services and manufacturing sectors. The Tenth Malaysia Plan aims to increase private sector investment at a rate of 12.8% a year and reduce the fiscal deficit from 5.3% of GDP in 2010 to less than 3% in 2015 (Thiruchelvam et al., 2011a).

Implementation of the productivity-enhancing structural reforms put forward in the New Economic Model is crucial to future growth. These range from improving the skills of the labour force to ensuring the inclusiveness and sustainability of the growth process. Other key features are an emphasis on quality rather than quantity in the accumulation of capital and labour inputs; private rather than public endeavours in promoting competition in the economy; bottom-up rather than top-down decision-making for more decentralised and participative processes; unbalanced rather than balanced regional growth with an emphasis on industrial clusters; selective and targeted incentives rather than sector-based approaches; and better use of foreign skilled labour (Day and Muhammad, 2011).

The NEM has identified growth drivers in the electrical and electronics industry, information technology (IT), nanotechnology, biotechnology and life sciences, palm oil downstream industries, high-end commercial agriculture, the oil and gas industry, medical and bio-tourism services, green technology industries and services, and integrated Islamic finance involving banking, capital markets and insurance. Specific incentives are being used to encourage MNEs to locate their research and development (R&D) centres as well as advanced production and assembly operations in Malaysia (Felker and Jomo, 2007).

Efforts will also be needed to improve competition in product markets. According to the World Bank (2010), competition is uneven. While the MNE-led manufacturing sector is exposed to intense external competition, competitive pressures in other parts of the economy are weak. In some cases this is due to the presence of public corporations and private monopolies; in others it is because the goods and services are not tradable.

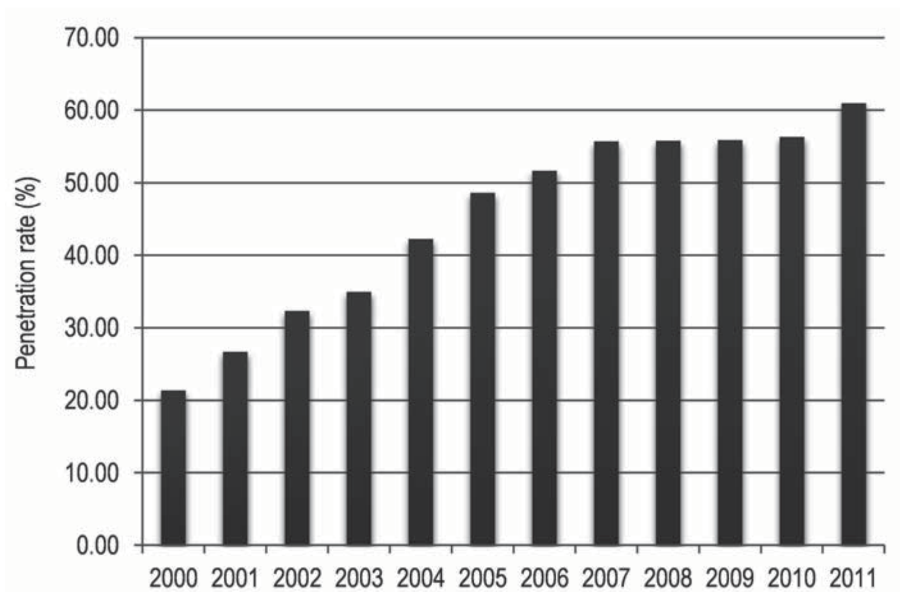
The organisation of industry and the structure of ownership limit the contestability of markets. Large conglomerates and government-linked corporations crowd the economic landscape. Variations in the ranking of leading firms are rare and there are few additions to these lists. In spite of recent liberalisation measures, the services sector remains highly protected. These factors point to limited dynamism in the business environment, which tends to inhibit innovative activities. This is highlighted to some extent in Malaysia's scores World Bank/IFC Doing Business indicators where Malaysia was only in 78th position out of 183 in terms of starting a business, although it ranked 18th in terms of overall ease of doing business.

Patenting by Malaysian companies is sluggish. Intellectual property rights (IPR) have been administered by the Intellectual Property Corporation of Malaysia (MyIPO) since its corporatisation in March 2003, and patent applications have since registered an upward trend, but this is primarily due to MNEs, which have actively protected their inventions owing to the importance of the Malaysian market.

Malaysia has made large investments in infrastructure development including telecommunications, transport and power generation to meet the bottlenecks caused by rapid industrialisation. Some of the more visible projects include the Kuala Lumpur International Airport, the Bakun hydroelectric dam, the national administrative city of Putrajaya and the Multimedia Super Corridor (MSC). The MSC was designed to catapult the Malaysian economy into the digital age. Roughly equivalent in size to Singapore, this 20-year project was meant to attract large information technology (IT) multinationals as well as local businesses, act as a test bed for digital invention and research, and support a large share of Malaysia's local information and communication technology (ICT) workforce (Rasiah, 2008). There are plans for other development corridors such as the Sarawak Corridor of Renewable Energy (SCORE). However, the corridors tend to act as tax havens for offshore production and call centres rather than as part of the integrated R&D efforts of large multinationals.

Internet penetration in Malaysia in terms of Internet users per 100 inhabitants rose from 21.4% to 61.0% from 2000 to 2011 (Figure 7.4). Owing to government investments, Malaysia's broadband infrastructure is more advanced than that of many of its regional neighbours. There were 7.44 fixed broadband subscriptions per 100 inhabitants in 2011 (ITU, 2012), a higher share than in Viet Nam (4. 3%) and Thailand (5.4%), but significantly lower than in Singapore (25.5%). The government has also taken measures to stimulate demand for broadband through the MSC and Internet connections for government offices, schools, universities and health-care facilities, and has considered fiscal incentives for increasing access to computers (Thiruchelvam et al., 2011a). According to the World Bank (Yusuf and Nabeshima, 2009), however, the current IT infrastructure in Malaysia and in other Southeast Asian countries cannot adequately support a more knowledge-intensive growth strategy. This will require not only improving the capacity and speed of Internet connections domestically, but also more capacity to connect to the rest of the world. Such an undertaking will entail more investment, especially in the main urban centres. An increase in international bandwidth is also needed in order to diversify connections.

Figure 7.4. Internet users per 100 inhabitants, Malaysia, 2000-11



Source: ITU (2012).

Funding for innovation comes from both the public and private sector but remains limited. Tax incentive schemes are available for firms undertaking R&D and providing R&D services, and the government supports loan schemes organised by development financial institutions. While MNEs rely mainly on in-house sources, commercial banking institutions constitute the main source of finance for small and medium-sized enterprises (SMEs). Currently Malaysia has 54 banks with 2 271 branches, and the majority of loans carry interest rates of less than 4%.

The venture capital market and the level of entrepreneurship in Malaysia remain embryonic. Although the number of venture capital firms and the volume of venture capital appear to have increased in recent years because of fiscal incentives, investments and deals have not (Table 7.6). There is a lack of skilled personnel to manage the funds, particularly for early-stage financing, and a large share of finance continues to be channelled to government-linked firms. Despite reforms to enhance the equity market, including revamping of the Malaysian Exchange of Securities Dealing and Automated Quotation (MESDAQ) known as the ACE Market, financing for potentially innovative firms is limited. In recent years, 43% of innovating firms have reported that they considered lack of access to appropriate finance a significant impediment to innovation (Thiruchelvam et al., 2011a).

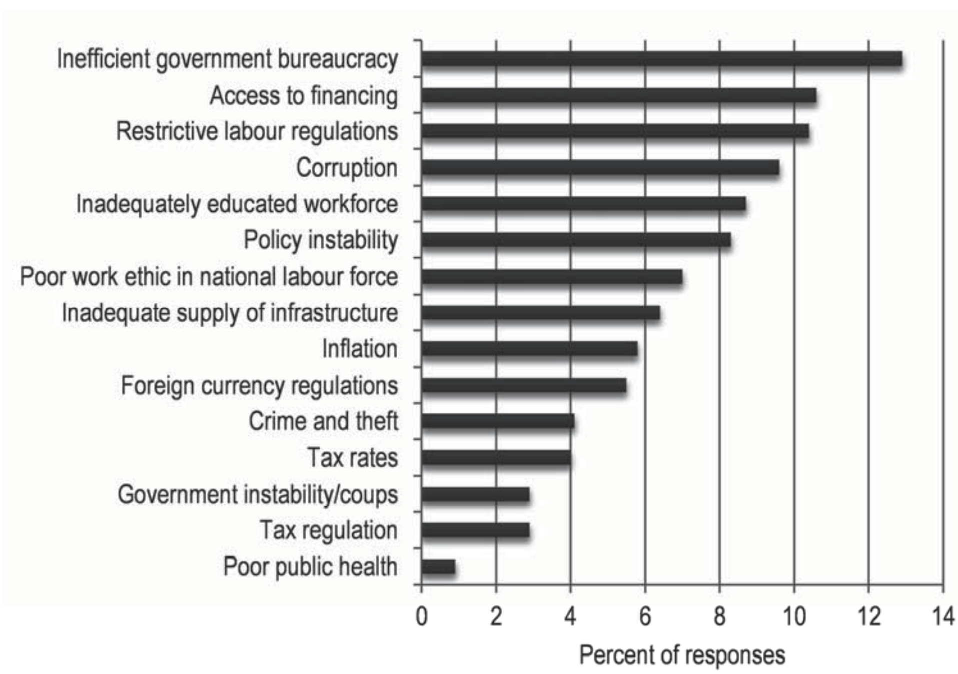
Other factors restricting entrepreneurial activity include a shortage of technical personnel to trigger innovative approaches and products, an inefficient government bureaucracy (Figure 7.5), and a particularly high regulatory burden associated with starting a business. Malaysia's current inability to foster domestic technological development or to convert research results into productive outcomes is mainly due to poor levels of education and difficulties in using information and skills efficiently. The failure to develop domestic human capital is undermining Malaysia's ambitions to become an innovation-driven economy, a goal that is also being undermined by an exodus of large numbers of talented Malaysians to other countries (World Bank, 2011).

Table 7.6. Provision of venture capital in Malaysia, 1996-2008

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2008
No of VC firms	17	22	27	30	31	41	38	43	38	56
Investment (MYR million)	734.4	723.8	723.6	999.0	1165.6	1357.1	1356.6	1444.8	1527.6	1929.0
No, of investee companies	231	259	277	194	159	235	183	298	332	450
Ratio of Investees to VC firms	13.59	11.77	10.26	6.47	5.13	5.73	4.82	6.93	8.74	8.04

Source: Bank Negara; Department of Statistics, Malaysia; Malaysian VC & Private Equity Directory, 2009.

Figure 7.5. The most problematic factors for doing business in Malaysia



Source: World Economic Forum (2012). Percentages represent the weighted results of a ranking of the five most problematic factors from a list of 15 by respondents to the WEF survey.

7.2. Innovation performance

Malaysia's innovation performance is in line with that of other middle-income countries in the Southeast Asian region, but has a significant gap with high-income countries. Malaysia has yet to enter a stage of innovation-led growth and research performance has not significantly improved in the last decade. While there has been improvement in patenting, for example, it has been from a relatively low base. The World Bank's Knowledge Economy Index, which captures the ability to generate and diffuse knowledge, ranked Malaysia 48th out of 146 countries in the 2012 report, three places below 2000 (Table 7.7).

Spending on R&D rose over the last two decades but remains low internationally. Gross domestic expenditure on R&D (GERD) grew from 0.50% of GDP at the beginning of the decade to about 0.82% in 2008 (Table 7.8). The government now aims to ensure that investment in R&D reaches at least 1% of GDP by 2015, a decrease from the target of 1.5% of GDP by 2010 in the Ninth Malaysia Plan (Thiruchelvam et al., 2011a).

The private sector's share of R&D expenditures, led by MNEs, was over 70% in 2008, although the overall level of their research spending is small by global standards. In the manufacturing sector, MNEs accounted for two-thirds of R&D expenditure, where the office, accounting and computing machinery sector accounted for the largest fraction of overall manufacturing R&D in 2008 (Table 7.9).

Table 7.7. Knowledge Economy Index and Knowledge Index, Malaysia, 2012

Indicator	Value
Knowledge Economy Index (KEI)[1]	6.10
Knowledge Index (KI)[2]	6.25
Economic incentive and institutional regime	*5.67*
Innovation	*6.91*
Education	*5.22*
ICT	*6.61*
Position in world rank	48
Change in rank from 2000	-3

1. The Knowledge Economy Index (KEI) is based on the average of the normalised scores of a country on all four pillars related to the knowledge economy: economic incentive and institutional regime; education; innovation; and ICT.

2. The Knowledge Index (KI) measures a country's ability to generate, adopt and use knowledge. The index is based on key variables in the three knowledge pillars: education; innovation; and ICT.

Source: World Bank (2012b).

Table 7.8. Malaysia's gross expenditure on R&D (GERD) by sector, 1996-2008

	1996	1998	2000	2002	2004	2006	2008
R&D expenditure (MYR million)							
Total GERD	549.3	1 127.0	1 671.5	2 500. 6	2 843.8	3 646.7	6 070.8
Ratio GERD/GDP	0.22	0.39	0.50	0.69	0.63	0.64	0.82
Government agencies and research institutions	108.7	247.3	417.5	507.1	296.9	189.5	603.1
Institutions of higher learning	40.4	133.6	286.1	360.4	513.3	360.8	1 188.3
Public sector	149.2	380.9	703.6	867.5	810.2	550.3	1 791.4
Private sector	400.1	746.1	967.9	1 633.1	2 033.5	3 096.4	4 279.4
Proportion of R&D expenditure (%)							
Government agencies and research institutions	19.8	21.9	25.0	20.3	10.4	5.2	9.9
Institutions of higher learning	7.4	11.9	17.1	14.4	18.1	9.9	19.6
Public sector	27.2	33.8	42.1	34.7	28.5	15.1	29.5
Private sector	72.8	66.2	57.9	65.3	71.5	84.9	70.5

Source: MASTIC (2012). Expenditures are nominal.

Table 7.9. R&D by manufacturing industry, Malaysia, 2008

Sector	R&D expenditure (MYR million)
Radio, television & communication eq.	108.8
Office, accounting & computing machinery	292.9
Other transport equipment machinery	130.3
Machinery & equipment n.e.c.	115.6
Rubber & plastic products	75.4
Food products & beverages	72.1
Chemical products	38.9
Electrical machinery & apparatus n.e.c.	32.3
Other non-metallic mineral products	30.7
Motor vehicles, trailers & semi-trailers	30.4
Others	77.1
Total	2004.5

Source: Based on *Monthly Statistical Bulletin,* Department of Statistics, Malaysia, January 2011.

On the domestic side, firms in the automotive sector are the biggest R&D spenders, followed by office equipment manufacturers. The national car manufacturer Proton spent 8% of sales revenue on research in recent years, largely through government subsidies; this amounted to over three-quarters of research expenditure by the automotive sector. The oil and gas industry, thanks largely to the state-owned Petronas, had the fourth largest amount of research expenditure.

Private-sector R&D statistics mirror those of other Southeast Asian countries with a large degree of dispersion across regions (with poorer regions performing less well), industries (with garments, wood, textiles and food processing scoring lowest), and firm characteristics (with SMEs, non-exporters and domestically owned firms performing less well than MNEs). Federal sources provide the vast majority of public research funding in Malaysia, as states have limited financial capacity. Most of the national R&D budget is spent in the four most developed states.

SMEs comprise 95% of firms in Malaysia and contribute about 32% of GDP but conduct little research or innovative activity (Boon-Kwee, 2011). In terms of total national R&D expenditure, businesses with revenues under MYR 10 million account for only about 9% of research expenditures. This is partly because 86% of SMEs are concentrated in the services sector rather than in manufacturing or agriculture, but it also reflects inertia and the limited capabilities of smaller firms (Rasiah, 2008).

The evolution of the number of personnel engaged in R&D in Malaysia (Table 7.10) has mirrored developments in research spending. The number of researchers per 10 000 labour force increased to 21.3 in 2004, decreased to 17.9 in 2006, but rose again to 28.5 in 2008. The Malaysia Higher Education Plan (2007-10) set an ambitious target of raising this to 100 researchers per 10 000 labour force by 2020, but this seems unlikely at the current rate of progress. In Malaysia, unlike in most advanced nations, the majority of R&D personnel work in universities (45%) or public research organisations (17%) rather than in the industrial sector (38%) (Day and Muhammad, 2011).

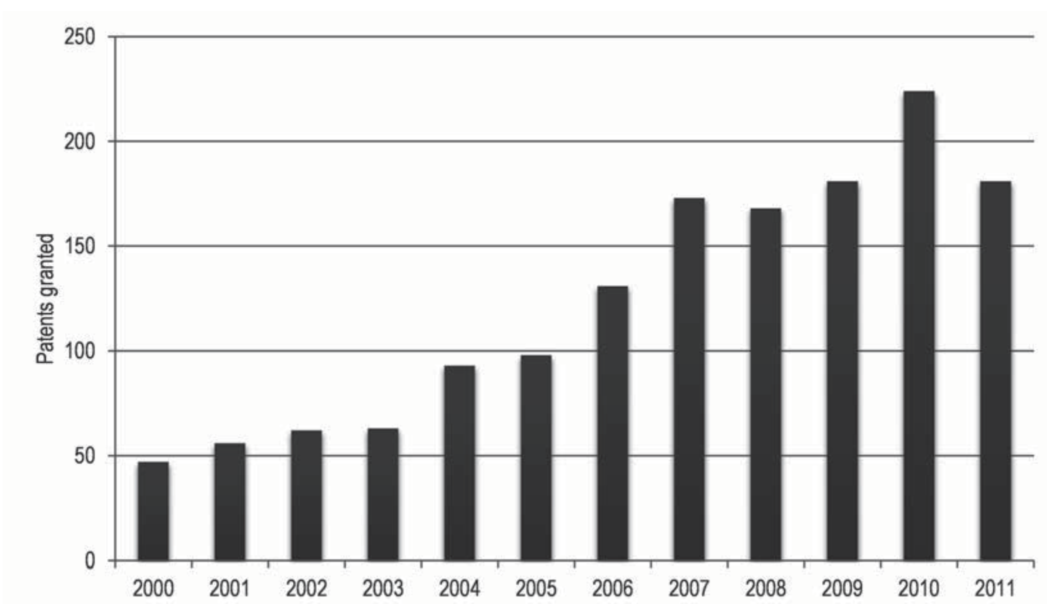
Table 7.10. Researchers to labour force/population ratios, headcount and full-time equivalence, 1994-2008

	1996	1998	2000	2002	2004	2006	2008
Total population (millions)	21.2	22.2	23.3	24.5	25.6	26.6	27.7
Total labour force (thousands)	8 616	8 883	9 616	9 886	10 856	10 628	11 028
Researcher per 10 000 labour force	5.1	7.0	15.6	18.0	21.3	17.9	28.5
Researcher per 10 000 population	2.0	2.8	6.4	7.3	9.0	7.1	11.3
Headcount (researchers, technicians and others)	9 233	12 127	23 262	24 937	30 983	24 588	40 840
Full-time equivalence	4 437.3	6 656.3	10 059.7	10 730.9	17 886.5	13 415.9	22 287.3

Source: MASTIC (2012).

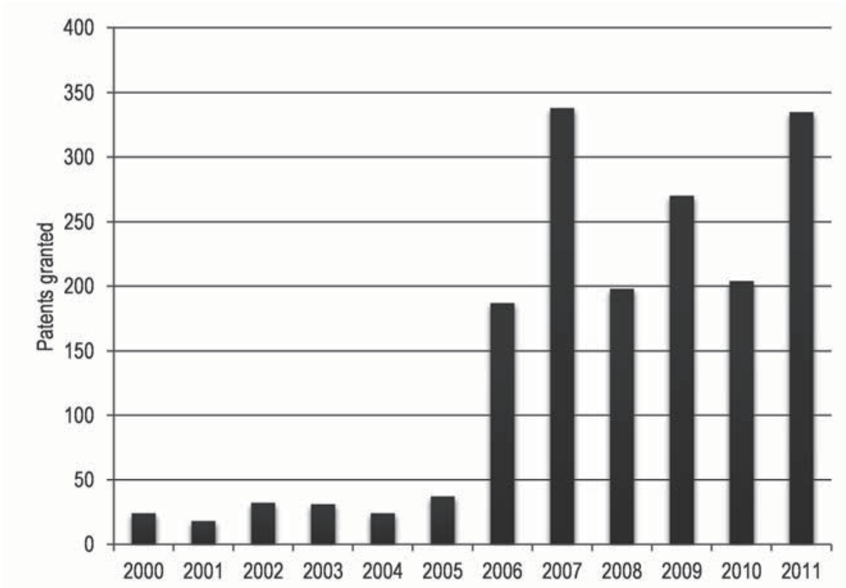
Malaysia's patenting performance is mixed. The number of USPTO patents granted to applicants residing in Malaysia has improved steadily since 2000 (Figure 7.6) and the recent increase in domestic patents (Figure 7.7) is due in part to incentive schemes for patent registration within universities and government research institutes. Most US patents are granted to MNEs located in Malaysia. Between 1995 and 2008, US patents issued to residents of Malaysia rose 20-fold from a very low base. However, Malaysia's improving patenting record, although second among countries of the Association of Southeast Asian Nations (ASEAN), is weak in international comparisons. Most patents granted in Malaysia have been to foreigners (Table 7.11), and Malaysia's most patented technology class is active solid-state devices, including transistors and solid-state diodes. Following the creation of the Intellectual Property Corporation of Malaysia (MyIPO), an increasing share of patents has gone to locals (about 8% of the total in 2009). With the exception of individually owned patents, four Malaysian organisations – Silterra, Malaysian Palm Oil Board (MPOB), Harn Marketing and Universiti Putra Malaysia (UPM) – were granted five or more patents each between 2003 and 2007. The patents issued domestically are mainly for chemistry and metallurgy, operational technology, electricity and physics (Chandran and Wong, 2011).

Figure 7.6. USPTO patents granted to Malaysia, 2000-11



Source: US Patent and Trademark Office (USPTO, 2012). The origin of a patent is determined by the residence of the first-named inventor.

Figure 7.7. Domestic patents granted to Malaysians, 2000-11



Source: Intellectual Property Corporation of Malaysia (MyIPO).

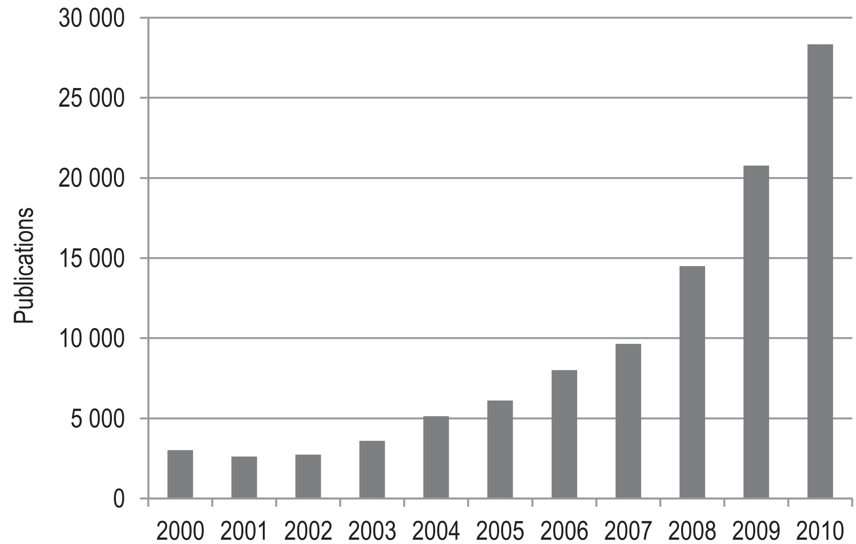
Table 7.11. Profile of patents filed and granted in Malaysia

Year	Application			Granted		
	Malaysian	Foreign	Total	Malaysian	Foreign	Total
1988	73	1 547	1 620	0	6	6
1992	151	2 260	2 411	10	1 124	1 134
1996	221	5 354	5 575	79	1 722	1 801
2000	206	6 021	6 227	24	381	405
2004	522	4 920	5 442	24	2 323	2 347
2008	864	4 539	5 403	198	2 044	2 242
2009	1 234	4 503	5 737	270	3 198	3 468
2010	1 275	5 189	6 464	204	1 973	2 177
2011	1 136	5 423	6 559	335	2 057	2 392
Total (1988 to June 2012)	10 463	106 844	117 307	2 155	44 014	46 169

Source: Intellectual Property Organisation of Malaysia (MyIPO).

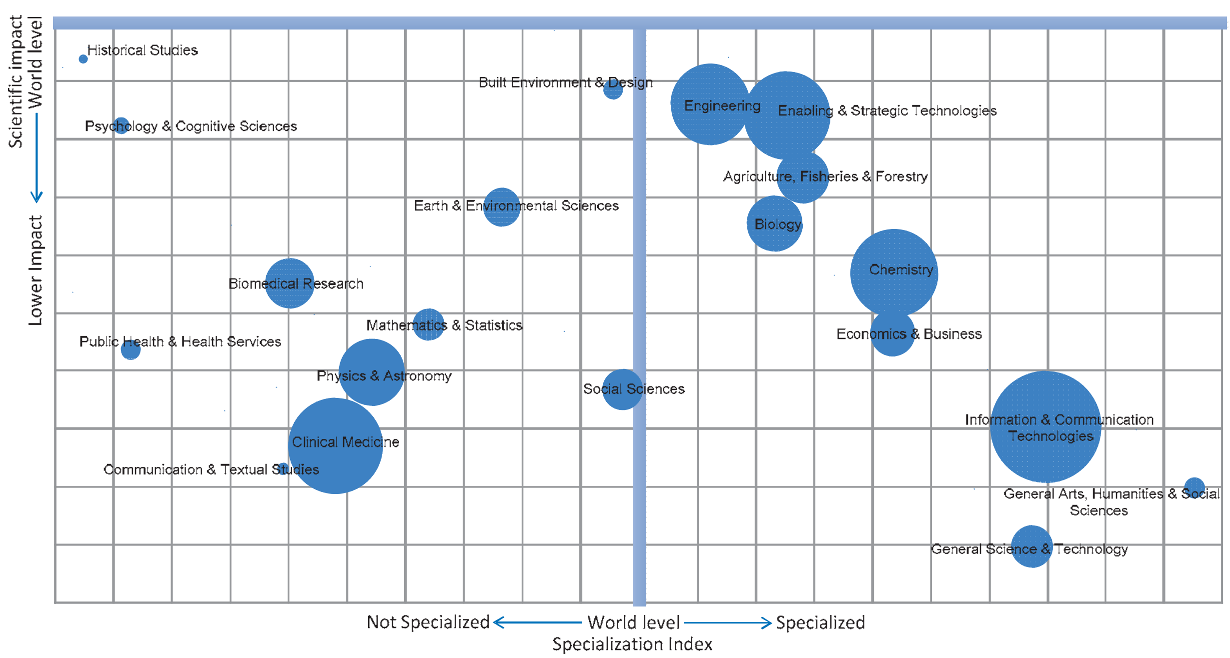
Malaysia's performance in publications, both in overall terms (Figure 7.8) and in English language journals, has also improved. It has now overtaken Singapore in the total number of scientific publications a year (28 330 in 2010 compared to 26 722 for Singapore, based on the Scopus database). The number of publications has grown rapidly since the early 2000s when there were fewer than 3 000 publications per year. Publications in information science and technology, starting from a very low base in 2000, have provided one of the largest contributions to growth. International co-publication is relatively low compared to other counties in the region at around 33%, reflecting developments in the domestic R&D infrastructure. The United Kingdom, the United States and Japan were the leading co-publication partners for Malaysia, over the decade 2000 to 2010.

Figure 7.8. Scientific publications, Malaysia, 2000-10



Source: Science Metrix analysis of Scopus (Elsevier) database.

Figure 7.9. Positional analysis of Malaysia's scientific publications, 2000-2010



Source: Analysis of Scopus (Elsevier) database by Science Metrix. This combines the number of publications by scientific field (area of circles), the specialisation index (a measure of relative intensity in a field compared to the World average) and the average of relative citations (citations relative to the World average controlling for age and field).

In terms of disciplines (Figure 7.9), publications in 2000-2010 were concentrated in areas such as ICT, clinical medicine, enabling and strategic technologies and engineering. ICT in particular represents a relative specialisation compared to the world average. However, publications in all scientific disciplines in Malaysia are ranked below the World average in terms of relative citation impact (*i.e.* citations controlling for age and subfield of publication). Engineering and enabling and strategic technologies are close to the World average but clinical medicine and ICTs both score badly on this measure of scientific quality.

7.3. Innovation policy: Institutional framework and policy orientations

The historical development of Malaysia's innovation-related policy within the broader context of economic development and industrial policy is sketched out in Table 7.12. Science and technology have been a featured part of Malaysia's economic planning since 1986 when the First National Science and Technology Policy was formulated and was included as a distinctive strand in the 5th Malaysia Plan (1986–90). In 1991, Malaysia developed Vision 2020, its blueprint for a knowledge-based economy (Felker and Jomo, 2007). The Tenth Malaysia Plan (2011–15) announced a new structure to streamline the governance of science and technology, with a more prominent role for the Prime Minister's Office. The Unit Inovasi Khas (UNIK), the Special Innovation Unit under the Prime Minister's Office, was created to oversee an integrated innovation policy and entrusted with commercialising research findings from public research institutions and universities. UNIK is also responsible for drafting the National Innovation Policy, while a statutory organisation, the Malaysian Innovation Agency (AIM), was established in 2011 to drive the nation's innovation agenda (Thiruchelvam et al., 2011a).

The Ministry of Science, Technology and Innovation (MOSTI), originally in 1973 the Ministry of Technology, Research and Local Government, is the general administrator of science and technology policy in Malaysia. MOSTI provides the bulk of grants for research through specialised schemes including the ScienceFund, TechnoFund and InnoFund. Its programmes are currently clustered into five focus areas: biotechnology, ICT policy, industrial technology, sea to space, and the science and technology core services. In addition, a Nanotechnology Directorate was created in 2010 when the Prime Minister launched the National Nanotechnology Statement to promote research in this field (Thiruchelvam et al., 2011a).

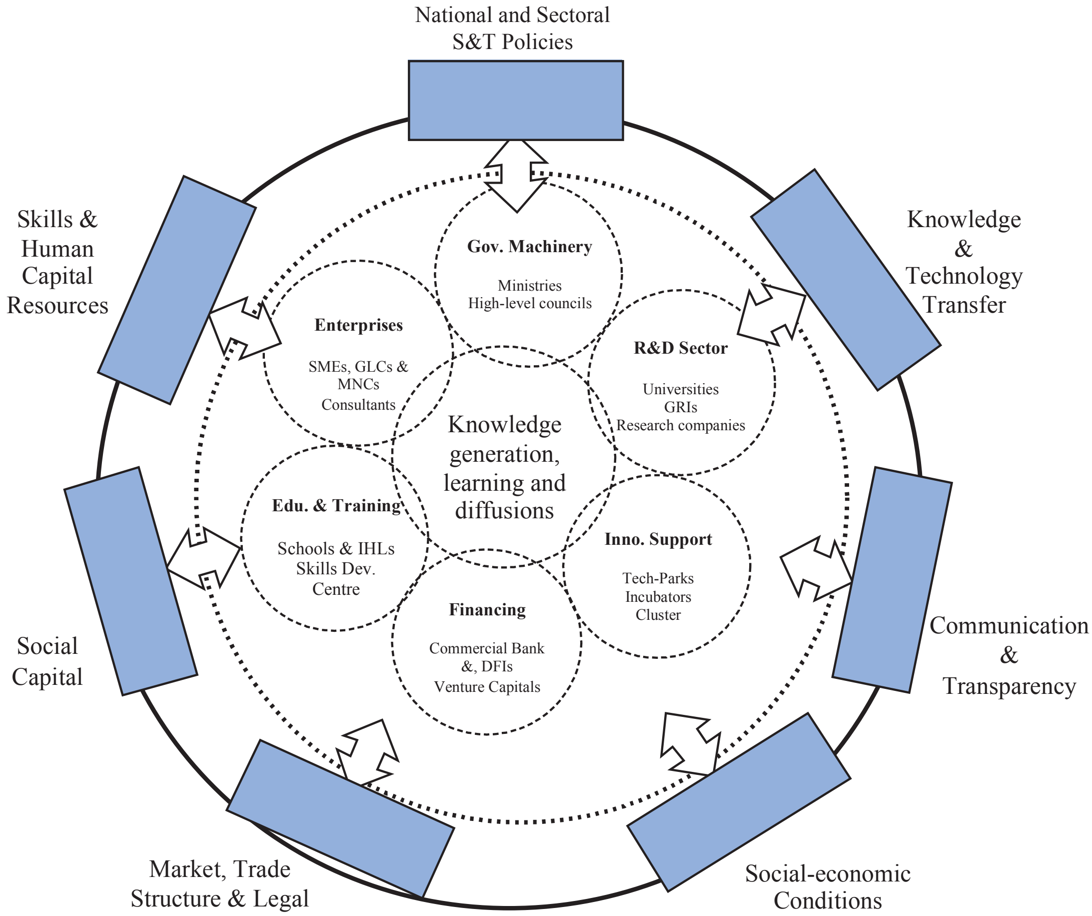
Decisions on the allocation of the S&T budget, the integration of S&T plans with national development planning and the determination of manpower requirements to execute these plans rest with the Treasury, the Economic Planning Unit, and the Public Services Department, respectively. A number of sectoral ministries have a role in S&T development through research institutions under their jurisdiction. These include the Malaysian Agricultural Research and Development Institute (MARDI) and the Malaysian Palm Oil Board (MPOB), which report to the Ministry of Agriculture and the Ministry of Plantation Industries, respectively. In addition, technology transfer is under the Ministry of International Trade and Industry, while fiscal and financial incentives for R&D are administered by the Ministry of Finance.

Table 7.12. Malaysia's economic trajectory and national innovation system

	1960s	1970s	1980s	1990s	2000s	2010
Population & GDP (at current USD)	8.1 million/ USD 2.4 billion	10.9 million/ USD 4.3 billion	13.8 million/ USD 24.9 billion	18.1 million/ USD 44 billion	23.3 million/ USD 93.8 billion	28.3 million/ USD 192.8 billion
R&D budget as % of GDP	-	-	-	0.22	0.47	0.21
Development stage of NIS	Primary commodities; agriculture; provision of basic infrastructure as well as developing operational capabilities		Investment-driven stage; shift to manufacturing; focus on learning as well as developing duplicative imitation and adaptive capabilities		Focused towards knowledge based / innovation economy	
Major industrial policy direction	Heavy dependence on primary export commodities; decline of rubber prices, beginning of import substitutions	Move from net oil importer to exporter as petroleum prices rose sharply; free trade zones (FTZs) attracted MNEs, export-led industrialisation	Regulatory reforms led to more liberalised private sector investment, gradual shift to heavy industries, Industrial Master Plan 1	Growth strategies favouring modernisation/ industrialisation, shift to new and emerging technologies *e.g.* ICT; Industrial Master Plan 2; promotion of clusters	Focus on productivity-driven growth; stimulating knowledge-based domestic innovation, Industrial Master Plan 3, Knowledge-based Economy Master Plan	Greater emphasis on knowledge-based, innovative economic growth
STI policy and role of government	Limited focus	Dedicated Ministry for Science established as well as the NCSRD	1st National S&T Policy; first chapter on STI in Malaysia Plans; IRPA grants established; double deduction incentives for R&D	Multimedia Super Corridor established; National IT Council; mega-projects era; Returning Scientist Programme	2nd National S&T Policy; National Innovation Council; Biotech strategy announced; IRPAs streamlined; Brain Gain Programme launched	Year of Innovation; Talent Corporation established; UNIK, PEMANDU
Macroeconomic policy framework/ conditions	1st Malaysia Plan (1966-70) launched (to be followed by plans every five years); substantial increases in public sector expenditure	New economic policy focused on national unity, restructuring society for greater Malay urbanisation and employment	Large investments in heavy industries; significant growth in FDI; major recession in mid-1980s	Vision 2020 announced; APITD; Asian economic crisis	NEAC, National Innovation Model; second phase of 2020, focused on key strategic thrusts for sustainable growth	New Economic Model; Tenth Malaysia Plan (2011–15) launched; global economic crisis; New Economic Programme
Education Policy	Becomes federal responsibility; focus on basic education for all	Focus on improving quality; system begins adjusting to economic needs	Continued focus on improving quality and access, National Vocational Training Council	Rapid transformation/ reform; Opening of private sector/ institutions; Human Resource Development Fund	Ministry of Higher Education established; National Higher Education Action Plan; creation of research universities; APEX university; University Grading System; Implementation of MQF; NDTS	Science and maths to be taught in Bahasa Malaysia (the official language of Malaysia) from 2012

Source: Adapted from Asgari and Wong (2007), Oyelaran-Oyeyinka and Rasiah (2009), and Day and Muhammad (2011).

Box 7.1. A bird's eye view of Malaysia's national innovation system: Actors and linkages



Organisations in the R&D sector, innovation support centres, institutes in the financing sector, education and training institutes, commercial enterprises and government agencies and bodies are the main innovation actors. These actors are linked through formal and informal networks and contribute in various ways to the generation and diffusion of knowledge.

The knowledge generation and diffusion process, as well as the networks and linkages between innovation actors, are affected by developments in their broader institutional framework. Of particular importance are S&T policies; the factors governing knowledge and technology transfer; levels of communication and transparency; overall social and economic conditions; market, trade and legal frameworks; social capital; and skills and human capital resources. These elements of the broader institutional framework function as innovation enablers of the national innovation system (NIS).

The whole of Malaysia's NIS is now orchestrated by UNIK.

Source: Boon-Kwee in Thiruchelvam et al. (2011a).

Organisations under the Prime Minister's Office such as the Malaysia-Industry High Technology Group (MIGHT) provide advisory services and engage in technology foresight and industry-specific activities. Other relevant bodies include the Academy of Sciences Malaysia, inaugurated in 1995, which fosters general science across Malaysia and provides independent advice to the government on matters related to science, technology and engineering. The Malaysian Science and Technology Information Centre (MASTIC) is the official reference centre for science and technology statistics and indicators. In 2011, a revamped National Science and Research Council (NSRC) was established to replace the National Council for Scientific Research and Development (NCSRD) formed in 1975 (Thiruchelvam et al., 2011a).

The Ministry of Education (MOE) has oversight of the school system from pre-school to secondary level where students are streamed into academic, technical, vocational or religious studies. The Ministry of Higher Education is responsible for tertiary education and currently aims to develop 20 centres of excellence that are internationally recognised in terms of research output; to ensure at least 75% of lecturers possess a PhD or equivalent and that 30% of lecturers in polytechnics and community colleges possess a Master's degree; and to attract foreign students (up to 10% of the total student population at university level) (World Bank, 2007). Box 7.1 describes the key actors of the Malaysian national innovation system and their relations.

In recent years, Malaysia has introduced a range of fiscal and non-fiscal measures to promote research and innovative activities by foreign and domestic firms. These include attracting foreign knowledge-intensive companies and promoting technology acquisition and diffusion. Fiscal incentives extended to spur R&D include a double deduction on non-capital expenses incurred for undertaking R&D activities. Fiscal relief also covers activities for export promotion and branding. Large firms have been the main beneficiaries of the R&D tax incentives; small firms find the procedures too cumbersome (Thiruchelvam et al., 2011a).

Malaysia has expanded its banking system and capital markets to promote the establishment of new companies although results to date have been disappointing. Under the national plans, funds have been channelled to various government-linked venture companies to promote and finance innovation, technology acquisition and commercialisation of R&D findings. Recently, the Mudharabah Innovation Fund was formed to provide risk capital to government-backed enterprises. In 2009, the Securities Commission of Malaysia introduced new tax incentives guidelines that would make venture capital companies eligible for a five-year tax exemption if they invest at least 30% of their funds in seed capital, start-up and/or early-stage financing.

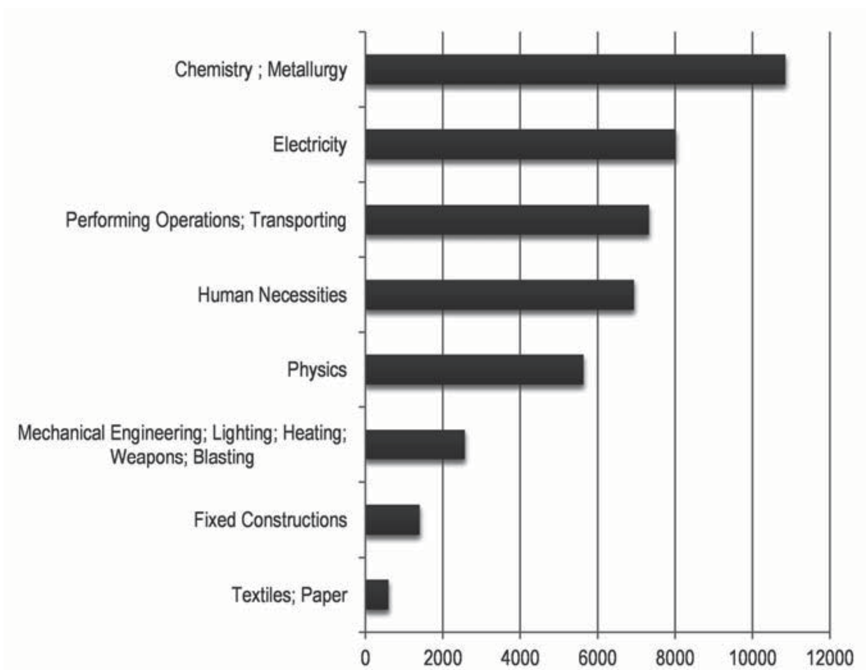
7.4. Actors of the national innovation system

7.4.1. Business sector

Malaysia's economy is dominated by the MNEs that assemble and export electronics and other manufactured products. Large state-owned enterprises in automotive, oil and gas, and commodity sectors also feature on the economic landscape. SMEs, which constitute almost 95% of the total population of firms, have minimal linkages with the larger companies. The small number of additions to the ranks of the largest business entities indicates the limited dynamism of Malaysia's business environment (Rasiah, 2009). No Malaysian manufacturing firm, for example, has established itself as a major contract (original equipment manufacturer – OEM) supplier of a product or a service with an expanding international market. Firms such as Eng Teknologi and Pentamaster have acquired original design manufacturer status, but such firms are rare and remain relatively small regional suppliers (Yusuf and Nabeshima, 2009).

On average, although the private sector accounts for over 70% of R&D expenditure, only 5.5% of firms, mostly MNEs, actively participate in R&D activities, and foreign firms are granted more patents than Malaysian firms. A large number of research-performing MNEs have a presence in Malaysia, including global brands such as Hewlett Packard, Motorola, Intel and Dyson, but it is difficult to know what share of their activities in Malaysia is R&D-oriented as opposed to manufacturing or after-sales support. It is also difficult to ascertain the number of scientific personnel they employ (Rasiah, 2008). Research activity is concentrated in the electrical and electronics (E&E), chemicals, food and beverages, rubber and plastics, and automotive sectors. The electronics sector alone accounts for 46% of total foreign R&D. In 2008, in the wake of the global financial crisis, the number of firms involved in R&D shrank significantly, although research investment per establishment is increasing. The chemistry, metallurgy and electricity sectors lead in numbers of patents granted (Figure 7.10).

Figure 7.10. Malaysian and US patents granted to Malaysian industry, by sector, 1993-2011



Source: Intellectual Property Corporation of Malaysia (MyIPO).

Factors that account for the limited scale and scope of R&D activities in the Malaysian manufacturing sector include the reliance of MNEs on research activities conducted elsewhere, the predominance of activities with undemanding technological content (*e.g.* electronics assembly and testing), the lack of public-sector participation in industry-linked research, and poor organisational support in terms of skilled labour and infrastructure. The level of human capital and industry's low absorptive capacity have also contributed to the limited transfer of knowledge from MNEs to domestic firms (Rasiah, 2009).

Among domestic firms, most R&D is conducted by the large state-owned enterprises, including the automobile manufacturer Proton, the oil and gas company Petronas, and the large palm oil firms. These companies rely on government subsidies for their research investments. While most R&D in the electronics sector is conducted by foreign firms, the National Automotive Policy and local content requirements have helped to increase automotive research. The state-owned automobile company Proton accounts for nearly 76% of Malaysia's R&D expenditure in this sector. Foreign players such as Honda and Toyota tend to maintain their research strongholds in Thailand (Wad and Chandran, 2011).

The presence of MNEs has provided export-oriented platforms, but Malaysia has had limited success in transferring the technological capabilities of MNEs to domestic companies and in creating linkages between MNEs and the domestic economy. Clusters have developed around the MNE-led manufacturing core, but these are primarily logistical (they derive benefits from the reduction of supply chain costs) rather than technological or knowledge-based. For example, transfer of knowledge from Japanese subsidiaries in the electrical and electronics sector to their local suppliers is mostly in product and process technology. For products, this involves physical and technical specifications for manufacturing, while process technology transfers primarily concern the supply of tools and input procurement. A small number of Malaysian firms, such as Pentamaster and Eng Teknologi, have become major suppliers of plant automation equipment and parts by working closely with MNEs such as Dell, Intel, Agilent and Seagate (all of which have factories in Penang), but instances of vertical transfers are few (Yusuf and Nabeshima, 2009).

Surveys undertaken by the World Bank in 2002 and 2007 also suggest that innovation efforts by firms in the manufacturing sector in Malaysia generally declined (Table 7.13).

Table 7.13. Share of manufacturing firms undertaking innovation activities (%), Malaysia, 2002 and 2007

	All Firms		E&E Firms	
	2007	Change from 2002	2007	Change from 2002
Upgraded an existing product line	48.0	- 4.6	81.3	0.0
Developed a major new product line	26.2	- 3.6	46.9	-18.7
Upgraded machinery and equipment	60.3	- 2.0	84.4	0.0
Introduced new technology to change production process	27.6	- 1.7	50.0	+12.5
Filed patent/utility or copyright protected materials	11.1	- 3.2	9.7	-6.4
Subcontracted R&D projects to other organisations	6.1	+ 1.5	6.3	+6.3
Agreed a new joint venture with foreign partner	5.2	+ 1.0	6.3	-9.3

Source: World Bank (2007).

7.4.2. Higher education institutes

The Ministry of Higher Education oversees Malaysia's 20 public higher education institutes (HEIs) as well as private universities, foreign branch campuses and colleges. Prior to 1969, there was only one university in Malaysia. Following the passage of the *Private Higher Educational Institutions Act*, private universities were permitted to operate. Presently there are 33 private institutions (Table 7.14) and four branch campuses of foreign universities (Thiruchelvam et al., 2011a).

Table 7.14. Number of higher education institutes in Malaysia

Type of institution	Number
Public higher education institutions	20
Private universities	18
Private university colleges	15
Foreign university branch campus	4
Private colleges	488
Polytechnics	24
Community colleges	37

Source: Ministry of Higher Education, Malaysia.

A rating system for Malaysian higher education institutes (SETARA) was introduced in 2007 to enhance quality and promote best practices in public universities. In order to intensify research and innovation activities, the government accorded four universities research university status. As part of this process, universities were encouraged to participate in the competitive Accelerated Programme for Excellence (APEX). In 2008, the Universiti Sains Malaysia (USM) became the first APEX university. With this title comes greater autonomy in governance, finance and admissions and prioritised infrastructure investments. In non-APEX institutions, the Ministry of Higher Education still tightly controls student admissions, course structure, remuneration and financial management, and academic mobility between universities is limited.

Despite the massive investments by the government in the higher education sector, the research output from universities has been disappointing. About 53% of the nation's R&D personnel are found in higher education institutions, which account for about 10-15% of total R&D expenditures in Malaysia. The proportion of academic staff with PhD qualifications in public universities rose slowly to 36% in 2009. The system of research assistants is not well established in Malaysia as many scientists go straight from their PhD to a university position where they have a heavy teaching load and lack the experienced assistance needed for research. Malaysia would benefit from a post-doctoral scheme that enables early career scientists to strengthen their research and teaching experience as part of their career development (Chandran et al., 2009).

Nevertheless, some excellent research institutes are associated with universities. These include USAINS, the commercialisation arm of Universiti Sains Malaysia, and the Institute of Bioscience associated with Universiti Putra Malaysia (UPM). This institute has five laboratories for natural products, molecular biomedicine, industrial biotechnology, marine science and aquaculture, and cancer research. The Department of Pathology at the University of Malaysia has pioneered a number of scientific developments, from laboratory information systems to microwave-stimulated antigen-retrieval techniques. Closely aligned with the National Biotechnology Policy, research programmes span plant biotechnology, drug discovery, vaccine technology, and immunotherapeutics.

Universities funded under the grants for intensification of research in priority areas commercialise only 5% of their research results. The failure to improve this rate is attributed to insufficient industry-relevant research projects and a lack of funding for the various stages of the commercialisation process, including pilot projects and marketing. Patents applied for and granted to universities are typically at an early stage of development and thus have a high degree of technical and market uncertainty (Chandran et al., 2009). In recent years, the Malaysian government introduced incentives for university researchers and inventors to publish, patent and commercialise their research with cash rewards on disclosure of an invention and funding for initial development when a patent is granted.

7.4.3. Public research institutes (PRIs)

The PRIs largely focus on the agricultural sciences; other areas include forestry, materials, engineering and biotechnology. In addition to the Malaysian Agricultural Research and Development Institute (MARDI), a large share of public funding goes to commodity research organisations such as the Malaysian Palm Oil Board (MPOB), Malaysian Rubber Board (MRB), Malaysian Cocoa Board (MCB) and Forest Research Institutions Malaysia (FRIM). These research institutes tend to work closely with firms in the agriculture and forestry sectors (Chandran et al., 2008).

In order to strengthen technological capability in the manufacturing sector, several PRIs and complementary institutions provide research and services related to industry and engineering. These include the Malaysian Institute of Microelectronic Systems (MIMOS) for research on electronics and information technology development. The Standards and Industrial Research Institute of Malaysia (SIRIM) and the Malaysian Productivity Corporation (MPC) conduct research to help improve overall productivity. To spur advances in selected fields, Nuclear Malaysia provides nuclear technology research facilities; the Malaysian Remote Sensing Agency fosters the development of remote sensing technology in national planning and resource management; and the Malaysian Institute of Economic Research (MIER) provides expertise in economic, financial and business related issues (Thiruchelvam et al., 2011a).

A number of PRIs safeguard the quality of health care, such as the Institute for Medical Research (IMR) and the National Heart Institute (IJN). The Cancer Research Initiatives Foundation (CARIF) focuses on diseases commonly found in Asian countries. It has a growing reputation in cell and molecular biology, gene expression, and drug discovery techniques. Individual and corporate donors such as Sime Darby and Petronas supplement government funding for CARIF. Biotechnology is another priority for investment, with a focus on pharmaceutical breakthroughs at the Agro-Biotechnology Institute, the Malaysia Genome Institute, and the Institute of Nutraceuticals and Pharmaceuticals. The Tenth Malaysia Plan identifies some broad areas of research in the public interest – tropical medicine, global warming, food security, infectious diseases, and water and energy security – to be undertaken by public institutes (EPU, 2010).

7.4.4. Linkages between innovation actors

The extent to which Malaysian scientists are collaborating internationally is relatively high – 33% of scientific publications between 2000 and 2010 were internationally co-authored compared to a world average of 20%. The share of international co-authorship was much higher over the same period in Indonesia and Viet Nam at around 75%, but this partially reflects the lack of domestic R&D capacities in those countries.

Table 7.15. Barriers to the commercialisation of university/research institute R&D

Barriers to commercialisation	Key issues for universities, research institutes and industry
Availability of funding	• Lack of pre-seed and seed funding, market funding, prototype funding • Lack of funding and incentives to support private-sector commercialisation of research • No angel investors • Poor venture capital availability (no active involvement of private VC companies). The 57 registered VC companies in Malaysia are risk-averse • No evidence of private VC extending investment to seed and start-up deals • No strategic map for VC industry • Poor financing by banking sectors for start-up and new ventures • Reliance on government VC funding • Existing seed funding seldom reaches initial public offering (IPO) and revenue-generating stage • Difficulties in accessing funds at expansion phase through soft loans, equity arrangements, and expansion funds
Collaboration	• Limited university-industry linkages • Limited industry-sponsored research activities • Limited R&D activities especially among SMEs • Lack of co-ordination among government, university and industry • Less focus on establishing linkages with nascent companies • Lack of government support for linking companies with research agencies and universities
Internal structure	• Poor R&D management practices in public and private sectors • Lack of structural and system flexibility in universities, research institutions, and private sector • Lack of effective monitoring of commercialisation success in both public and private sector • Poor technology transfer offices in universities and research institutions • Champions and leaders • Organisational culture • Communication systems • Lack of income-generating agendas within universities and research institutions
External institutional arrangements	• Overlapping roles of agencies with less focused efforts • Lack of institutional support to manage the risk of ineffective allocation and use of funds because of agencies' overlapping roles • Lack of effective one-stop shop for information on commercialisation efforts • Lack of centres to ensure the promotion of industry-sponsored research • Lack of agencies to manage and assess the impact of R&D funding and management of various government funds
Other mechanisms	• Ineffectiveness of tax breaks in promoting VC and R&D efforts • Troublesome procedures in filling grants/funds (no support agencies) • Failure of market mechanisms in seed and commercialisation stages • Lack of technical support in incubators – most incubators only provide facilities and commercial incubation (except MSC, USAINS, SIRIM, MTDC and FRIM) • All mechanisms to promote commercialisation emphasise incentives in terms of funds and lack technical assistance and sufficient expertise and skills for commercialisation

Source: Chandran (2010).

While many PRIs and universities are involved in R&D, their contribution to industrial development in Malaysia is limited. Bureaucratic procedures and the lack of relevance of university research to industry are cited as the main reasons deterring firms from collaborating with higher education institutes. The lack of industrial extension programmes and weak bridging organisations have also hampered the transfer of research results and technology from the PRIs. An exception is the close links between the sector research institutes and industry in commodities such as rubber and palm oil (Thiruchelvam et al., 2011b). A summary of the main barriers to commercialisation is provided in Table 7.15.

Malaysia has had mixed success in facilitating technology transfers from multinational enterprises and in creating links with domestic firms. Domestic firms have widely dispersed capabilities which offer possibilities for the diffusion of knowledge through best practice programmes, SME assistance and technology brokers. However, forward and backward linkages with MNEs have not contributed significantly to technology learning or upgrading of Malaysian suppliers. While technology transfer from MNEs to local businesses has been weak, state-owned companies such as Petronas have had more success in nurturing smaller enterprises. There is also potential for improving the productivity of upstream and downstream activities in the palm oil sector, as Malaysia is the world's second largest producer of palm oil after Indonesia.

There is presently a lack of organisations entrusted with the transfer of industrial technology from universities and PROs to industry, particularly SMEs. In addition to improving the teaching and research capabilities of universities, intermediary organisations are needed to facilitate matchmaking between universities and the private sector in specific fields. Technology support organisations have failed to co-ordinate their roles to support the commercialisation of R&D outputs from Malaysian public research (Thiruchelvam et al., 2011b).

A number of projects aim at fostering high-technology clusters in Malaysia and the government has supported a number of science parks across the country (Malairaja and Zawdie, 2008). These benefit from strong government support, adequate funds for infrastructure, and tax incentives, yet links with universities are relatively weak. The first park was the Kulim High Technology Park in 1993, which focuses on high-technology manufacturing. Technology Park Malaysia (TPM), established in 1996, is targeted to R&D-based businesses and is now home to over 160 firms. The third largest park is the ICT-focused cluster of Cyberjava located in the Multimedia Super Corridor, which has attracted Dell, Hewlett-Packard, Motorola and Ericsson.

7.5. Human resources

Malaysia lags behind OECD countries and advanced Southeast Asian economies such as Singapore and Hong Kong, China, in terms of the education and skill levels of its labour force. Education is one of the main instruments used by the Malaysian government to improve the socioeconomic status of its population and fuel overall development. From the 1970s, Malaysia has invested heavily in human capital. The government focused on primary and secondary education before embarking on a transformation of higher education to satisfy the increased demand for skilled labour. In recent years, education expenditures have averaged 17% of total public expenditure and around 5% of GDP. Primary school enrolment is now nearly universal and 68% of students attend secondary school (Thiruchelvam et al., 2011a).

Despite the large rise in enrolments, especially in primary education, the quality of education remains below that of comparable economies (WEF, 2012). The tertiary education system is disadvantaged by a secondary school system that does not prepare its students for university education. Only 20% of tertiary entrants graduate; this raises serious problems for the government's target of creating 100 000 PhDs by 2020 under the "MyBrain 15" initiative. In 2008, Malaysia had fewer than 4 000 PhDs, over half of whom were educated in part outside the country. In general, there is concern about the quality of tertiary education and the serious mismatches between the graduates of the higher education system and industrial skill needs (Day and Muhammad, 2011).

Malaysia's higher education system has undergone a rapid transformation (Table 7.16 and World Bank, 2007). In the Eighth Malaysia Plan (2000–05), nearly 47% of the allocation for education was designated for tertiary institutions. The government also allowed private and foreign universities to assist public institutions in catering for the increasing demand for skilled labour. Higher education enrolments increased to 30% of the 18-24 year old population. The international student population grew and by 2008, 70 000 international students were enrolled in Malaysian universities. The number of students enrolled in science and technical subjects at both undergraduate and graduate level more than doubled.

Table 7.16. Enrolment and graduation of students in higher education institutions, Malaysia, 2002-08

		Number of enrolments/graduates						
		2002	2003	2004	2005	2006	2007	2008[1]
Public higher education institutions	Enrolment	281 839	294 359	293 978	307 121	331 025	382 997	403 009
	Graduation	57 435	75 842	71 924	79 934	81 095	85 448	56 317
Private higher education institutions	Enrolment	294 600	314 344	322 891	258 825	323 787	365 800	419 778
	Graduation	139 150	137 018	134 987	57 953	83 186	83 431	51 571
Colleges/polytechnics/ community colleges	Enrolment	56 105	59 916	73 327	83 707	93 318	98 688	102 429
	Graduation	18 774	20 714	21 441	28 555	31 870	34 451	35 873
Total	Enrolment	632 544	668 619	690 196	649 653	748 130	847 485	925 216
	Graduation	215 359	233 574	228 352	166 442	196 151	203 330	143 761

1. 2008 data up to July 2008 only.

Source: Ministry of Higher Education (MOHE) (2008).

The Tenth Malaysia Plan specifically addresses the human capital deficiency and the need to train qualified students and develop a skilled workforce. The Higher Education Strategic Plan under the Ministry of Higher Education was put in place to revamp education to meet labour market needs. Emphasis is placed on enhancing the quality of students, teachers and delivery systems. At lower educational levels, efforts concentrate on improving quality, ensuring literacy and numeracy, and raising the standards of secondary schools. Government policy is also focused on shifting the balance of student enrolments at the tertiary level to a ratio of 60:40 in favour of science-based studies. This will largely depend on a greater focus during secondary education on these fields and on sufficient career opportunities in the broader economy (EPU, 2010).

Realising Malaysia's ambition to move from a focus on assembly in the manufacturing sector towards higher-value, front-end aspects such as design will also depend on increasing the pool of engineers and technical personnel. Over 18% of students in tertiary education are now enrolled in engineering, but few are trained in the maintenance of highly complex scientific instruments and machinery. Would-be technicians have been deterred from vocational training, which is seen as inferior to university qualifications. Statistics show that only about 10% of students are enrolling in technical and vocational education. Improving the availability, access and quality of the technical track is as important as upgrading the academic track (Thiruchelvam et al., 2011a).

The government set up several new university colleges to revamp the science, technology and engineering education system by incorporating some vocational training in secondary and tertiary education. A national dual training system has been incorporated into existing vocational education to address technical labour shortages. This apprenticeship programme involves a two-year training programme carried out 70-80% in workplaces and the remaining 20-30% in selected training institutions. Graduates are expected to acquire hands-on experience that is immediately applicable in the labour market in order to play a role in modernising production and in innovation.

In spite of the substantial expenditures on education, the shortage of skilled labour in Malaysia remains. Labour force participation rates by education level show that the majority of workers have a secondary education or below. In 2010, unskilled workers represented more than 75% of total workers employed; those with tertiary education and applicable skills made up only a quarter of the workforce. Only 28% of Malaysian jobs are in the higher skilled bracket. Shortages in critical professions such as engineers, scientists and R&D personnel are limiting the evolution of current industries and firms into higher value added activities (Thiruchelvam et al., 2011a).

The nature of skill shortages is also changing. Table 7.17 lists the skill shortages perceived as critical by firms in 2002 and again in 2007. In 2002, English-language proficiency was by far the most critical skill shortage, with "knowledge society" skills (adaptability, creativity and innovation, numeracy, problem-solving, IT and technical and professional skills) accounting for just 16%. By 2007, however, 58% of respondents identified critical shortages in these skills.

Higher education in Malaysia is still biased towards academic disciplines and a rote-learning model. To ensure that the curriculum and courses offered by Malaysia's 50 universities are of high quality and relevant to the needs of industry, programmes are being reviewed for compliance with the Malaysian Qualification Framework (MQF) to determine whether standards are in line with international best practices. Firms are demanding that universities build better curricula and impart not only technical skills but also intangible skills such as creativity, communication and problem-solving as well as language skills, especially English.

To its credit, Malaysia has many programmes to promote gender equality. The illiteracy rate for women decreased from 35% in 1980 to about 12% at present compared to 5% for males. At the secondary school level, female students achieve significantly higher scores than their male counterparts and a large share of university enrolees are women. These educational gains for women are not reflected in the labour market, as women constitute only about 30% of the labour force, mostly in the household service sectors. The female share of higher skill jobs, including professionals and technicians, is under 25%.

Table 7.17. Critical skill shortages, 2002 and 2007

Skill	Percentage of respondents	
	2002	2007
English language proficiency	47.5	16.5
Professional communication skills	14.0	6.4
Social skills	8.8	2.5
Team-working skills	6.6	5.9
Leadership skills	4.4	5.5
Time management skills	3.8	5.0
Adaptability skills	1.9	4.2
Creativity and innovation skills	4.1	10.0
Numerical skills	1.1	1.6
Problem-solving skills	1.4	4.0
IT skills	4.1	20.4
Technical or professional skills	3.2	18.0

Source: Yusuf and Nabeshima (2009).

Malaysia's foreign labour policy allows firms to employ unskilled foreign workers, and the current wage structure does not encourage employees to upgrade workers' skills. A lack of spending on training by firms, especially SMEs, limits knowledge upgrading and undermines progress towards activities with higher value added and higher productivity. With limited financial resources and human resource personnel, firms have difficulties sourcing and planning training programmes for their employees. At the same time, the number of skilled expatriates working in Malaysia has declined in recent years, limiting opportunities to leverage their knowledge and technological capabilities. The result is a very tight market for skilled labour.

The outflow of Malaysian talent is also increasing (World Bank, 2010). It is estimated that about 4% of the country's population resides overseas, approximately 40% in Singapore. More than 300 000 Malaysians – many of whom possess tertiary qualifications – have migrated annually in recent years. The government now views this substantial "brain drain" as a potential asset and is increasing ties with talented overseas Malaysians. In 2011, it established the Talent Corporation Malaysia aimed at retaining talent and attracting skilled Malaysians residing abroad to fill the country's growing deficits in skilled manpower. The Skills Development Fund is dedicated to financing more PhD students and extending educational loans. Top students currently overseas will have their final year of study paid for by the government on the condition that they return. Greater visa flexibility for foreign researchers and technicians has also been instituted to fill private sector skills gaps.

7.6. SWOT analysis

Based on the material presented above, several strengths and weaknesses of Malaysia's national innovation system (NIS) can be identified, along with future opportunities and threats. These are summarised in Table 7.18.

Table 7.18. Summary SWOT (strengths, weaknesses, opportunities, threats) analysis

Strengths	Weaknesses
• Large presence of multinational enterprises in electronics and automotive sectors • Research capabilities in agricultural commodities • High competitiveness ranking and ease of doing business • Relatively young population • Good natural resource endowments • Economic and political stability • Islamic leadership credentials • A new coherent vision for the country under the Tenth Malaysia Plan • Substantial investments in telecommunications infrastructure	• Poor quality education and inadequate supply of skilled labour despite significant investment • Declining private investment and low productivity growth in domestic economy • Stagnant R&D and innovative capacity • Low absorptive capacity of SMEs and little technology transfer and technical spillovers from foreign to domestic firms. • Few industry links to public research • Little entrepreneurship and venture capital • Anti-competitive practices in some sectors such as services • Unco-ordinated national S&T policy and weak implementation of strategies

Opportunities	Threats
• Increasing focus on high-technology exports to developed economies • International reputation as centre for Islamic banking and finance • Burgeoning service sector including expansion of tourism industry • Sizeable Malaysian diaspora • Diversification of trade and production towards more knowledge-intensive goods/services • Increasing engagement of SMEs in more innovation-driven strategies	• Impacts of regional and global economic downturns • Increasing competition from other Asian economies for trade and foreign investment • Increasing brain drain • Racial polarisation and religious extremism

Malaysia has an established middle-income economy based largely on the manufacture and export of technology-based products of MNEs. Malaysia's strengths stem primarily from the large presence of MNEs in the electronics and automotive sectors, its high competitiveness ranking and the existence of a new coherent vision for the future in a politically stable environment. Its weaknesses include inadequate supplies of skilled labour, stagnant R&D and innovative capacity, low levels of entrepreneurship and venture capital, and a poor track record in turning political visions into coherent policies and effective programmes.

There is potential for growth via improvements in innovative capacity and an increased focus on high-technology exports and the needs of a burgeoning services sector. This will require sustained efforts to stimulate the creation of a vibrant domestic innovation capability, primarily via the increasing engagement of SMEs in more innovation-related activities and the diversification of trade and production towards more knowledge-intensive goods and services. It will also involve a much greater emphasis on appropriate human capital development. Major threats include the impact of regional and global economic downturns, increased competition from other Asian economies and the continued exodus of talented individuals to other countries.

Annex 7.A1

Case studies: Innovation in the electrical and electronics, automotive and furniture industries

This section presents the evolution of innovation activities in three major industries: electronics, automotive and furniture. It borrows heavily from the work of Chandran (2010), Wad and Chandran (2009, 2011) on the electronics and automotive sectors, respectively, and Boon-Kwee (2011) on the furniture sector.

The electrical and electronics (E&E) industry

The Malaysian electronics industry has recorded remarkable progress. With fewer than 600 workers and an output of MYR 25 million in 1970, it has become the largest contributor to Malaysia's manufacturing output, employment and exports (Best, 2007; Jomo, 2007, Chandran, 2010). In 2006, it comprised more than 1 695 companies and provided 596 272 jobs (38.3% of total employment in manufacturing) for an output of MYR 214.9 billion (MIDA, 2007). The export-oriented strategy to promote industrial development has resulted in a structural change in Malaysia's production networks. During the 1980s massive efforts were made to relocate MNEs' manufacturing operations in Malaysia. Intense competition and the search for lower production costs have further contributed to relocation (Rasiah, 1994). An attractive investment climate – free trade zones (FTZ), licensed manufacturing warehouses and a ten-year pioneering status – attracted many investors to the electronics industry (Gustafsson, 2007; Li and Imm; 2007; Rasiah, 1988). Today, the industry accounts for nearly 60% of total manufacturing gross exports (Table 7.A1.1). Semiconductors account for the largest share of the E&E sector's exports (22% and 20% in 2009 and 2010, respectively). The industry's total value added as a percentage of total manufacturing value added was 26% in 2007 but fell to 21% in 2008. Given its contribution to economic performance E&E is regarded as Malaysia's key strategic industry.

Table 7.A1.1. Percentage of gross exports and value added of E&E: Malaysia, 2005-10

Years	% of gross exports in total manufacturing exports							% of value added
	Semi-conductors	Electronic equipment & parts	Consumer electrical products	Industrial & commercial electrical products	Electrical industrial machinery & equipment	Household electrical appliances	Total (electronics & electrical)	Share of value added in total manufacturing value added
2005	20.9	27.3	5.2	6.7	4.6	0.7	65.4	26.4
2006	19.8	27.0	4.0	7.3	4.7	0.7	63.5	24.7
2007	20.4	24.7	3.5	6.3	5.1	0.7	60.7	25.7
2008	18.3	21.6	4.0	6.7	5.0	0.7	56.4	20.7
2009	21.6	20.0	4.4	5.6	5.1	0.7	57.3	n/a
2010	20.1	19.9	5.3	4.6	5.1	0.7	55.8	n/a

Source: Thiruchelvam et al. (2011b), based on Monthly Statistical Bulletin, January 2011.

Among the three important electronics industry clusters (Klang Valley, Penang, Johor), Penang attracted large amounts of foreign direct investment (FDI) and leading multinationals and has had significant technological upgrading. By the 1990s, even its small and medium-sized firms (SMEs) were involved in exportation (Ariffin and Figueiredo, 2004; Rasiah, 1994). Penang's electronics industry is clearly moving towards higher value added activities. Movement towards newly emerging technologies (*e.g.* RF technology by Agilent, ALTERA), growth in the number of system integrators, establishment of electronic supply chain platforms (*e.g.* Rosettanet) and the automation cluster (established in 2005) are changing the industrial structure. Local firms, too, have to some extent moved up the value chain. Starting with simple assembly activities, the industry is now involved in manufacturing as well as testing and design. In the 1980s, they were mainly involved in assembling PCBs or burn-in tests (as subcontractors), while in the 1990s some local manufacturers became global players (*e.g.* Globetronics, Eng Teknologi, Wong Engineering, LKT, AKN, Technology, and Atlan Industries) and managed to diversify to other activities. Indeed, many precision engineering and machine and tooling companies have been involved in the automation clusters in Penang.

This rapid development is due to MNEs' decision to relocate manufacturing and design activities (Narayanan and Lai, 2000). MNEs helped transfer production know-how; subsequent outsourcing enabled local firms to master related functions such as maintaining, repairing and modifying machinery (incremental innovation). Although the global value chain and supply chain integration have significantly transformed the Penang's electronics industry, challenges to move higher on the value chain remained. The government met the needs of the industry in terms of basic infrastructure by establishing a good transport, power, water, telecommunication infrastructure and supportive training and education systems. Factors impeding further upgrading of the industry largely relate to a lack of R&D infrastructure and low active involvement of other actors of the national innovation system – universities, R&D institutions and venture capital – all of which play a role in technological catch-up. The industry also suffers from a shortage of scientists and engineers able to support technological upgrading activities.

Technological learning in the electronics cluster of Penang involved customers, suppliers, technical service providers as well as active involvement in strategic alliances with firms. This indicates the role of forward and backward linkages in technological upgrading (Box 7.A1.1). Poor networking and collaboration with others in the system, especially R&D organisations, limits the progress of this industry.

Box 7.A1.1. Drivers of innovation in the Malaysian electronics Industry

Evidence suggests that the electronics industry, especially the electronics cluster of Penang, has to some extent become a global player, with active participation by local industries. Local industries have improved their export capability through learning by doing with customers (clients). Significantly, SMEs are also involved in exports (Ariffin and Figuereido, 2004).

Sources of learning. A well-established global integration programme can promote innovation. Insertion of local firms into the global value chain promotes technological upgrading. Clients and suppliers are the main source of learning among firms within the cluster. Overall, however, local firms participate relatively little in the global value chain owing to insufficient absorptive capacity. Among electronics firms in Penang only local firms that are well integrated globally pursue technological upgrading. Through sustained learning, mentoring and nurturing, local firms such as EngTek, Globetronics Technology, LKT and Vitrox Corporation have become respected names in the electronics manufacturing industry. Additionally, Penang Skill Development Corporation provides training schemes that are valuable for helping industries to upgrade their skills pool and move into R&D activities.

The success of the Engtek Group. The Engtek Group is a home-grown Malaysian corporation primarily involved in precision engineering and manufacturing. It started operations in 1974 in Penang and has grown to be among the top precision engineering and manufacturing supply chain players for the electronics industry in the Asia-Pacific region. Eng Teknologi Holdings Bhd (ETHB), the Group's parent company, is located in Penang and serves as regional headquarters. It is listed in the technology section on the Main Board of the Kuala Lumpur Stock Exchange (KLSE). The Engtek Group currently has seven key operating subsidiaries of which three are based in Malaysia, and one each in the Philippines, China, Singapore and Thailand. The Group has annual sales in excess of MYR 240 million and its cumulative investments exceed MYR 200 million. The success of the Engtek Group can be attributed to a few key factors. First, its establishment was due to support from Intel which encouraged knowledge and technology transfer in an effort to increase local outsourcing and focus on more complex and value added activities (Rasiah, 1987, 1994). This created a technological opportunity. A second factor is the Malaysian government's effort to promote the growth of the country's SMEs. Another contributing factor is the various incentives granted to Engtek's operating subsidiaries. Learning and upgrading absorptive capacity are crucial.

Source: MIDA (2011), Chandran (2010).

Automotive

In the automotive industry Malaysia pursues a national strategy to develop its own auto industry and related segments, especially parts and equipment manufacturers. The primary incentive for R&D and innovation in this sector is government support for national automotive firms. As of June 2009, the two national car manufacturers, Proton and Perodua, controlled 57.8% of the total vehicle market, of which 27.1% for Proton and 30.7% for Perodua.[1] (MAA, 2009). In 2005, there were six motor vehicle manufacturers and nine assemblers as well as ten assemblers of foreign cars, including for MNEs such as Toyota and Honda.

1 Perodua and Proton control 33.8% and 29.7%, respectively, of the passenger vehicle market.

The original equipment manufacturer (OEM) parts and components are supplied mainly to auto manufacturers and assemblers (export and domestic) while the replacement equipment manufacturers (REM) produce and supply to the OEM and export/domestic markets. Progress in these sub-sectors mainly depends on derived demand from auto manufacturers and assemblers. In the OEM segments, demand for quality and competitive prices has obliged producers to upgrade to the stringent standards of global brands. In 2008, some 690 firms were manufacturing and supplying over 4 000 automotive components and parts (MIDA, 2009), 70% of which were OEMs. The components and parts sector accounted for MYR 6.37 billion in sales, with MYR 4.6 billion in imports and MYR 2.0 billion in exports in 2008. Around 45 component manufacturers export components and parts, notably steering wheels, rims, brake pads, wheels, bumpers, bodies, exhausts, radiators and shock absorbers. In this segment, major players include foreign manufacturers such as Delphi Automotive Systems, TRW, Siemens VDO, Bosch and Nippon Wiper Blade; the major local players include APM Automotive, Sapura, Delloyd and Ingress (MIDA, 2009). Some firms (Ingress, Hicom Teck See, Sunchirin, APM Corporation and Delloyd) have invested in ASEAN countries such as Thailand and Indonesia. While there are some well-established firms in this segment, most still lag in terms of technology. Despite continuous efforts to upgrade the industry, it still lags in R&D investment and human capital development. Investment in technology is also a major obstacle owing to heavy reliance on Proton which might not provide the needed economies of scale. Issues of quality, high price and dependence on technology suppliers for design have made these segments more vulnerable during the crisis. The inability of local suppliers to meet quality standards and provide cheaper components and parts has encouraged auto manufacturers to import components, and suppliers, owing to commitments to foreign partners in return for technological know-how, have little possibility to export. With low R&D spending (on average 0.14% of sales for 2000-05), the equipment manufacturers have limited opportunity to compete with foreign counterparts. Although exports have increased over the years, they are still far below those of Thailand and other emerging economies. Compared to China, Malaysia's export competitiveness in this sub-sector improved very slowly (Loke, 2007).

Furniture

Wooden furniture is the main downstream activity of Malaysia's timber industry and contributes around 30% of that industry's total export value. Malaysia is currently the world's tenth largest furniture exporter, the third in Asia and the second in Southeast Asia. Low entry barriers are considered beneficial to local players. In fact, the whole value chain of Malaysia's wooden furniture industry is composed of local enterprises. It is the only (or among the very few) Malaysian industries able to transform raw materials into final products and penetrate the global market. One successful furniture cluster is located in the Muar district in Johor state and has existed for more than three decades. There are currently some 300-350 furniture manufacturers in the district. The cluster is anchored by seven large furniture enterprises or consortiums which are listed on the Malaysian Stock Exchange. Today, the town of Muar accounts for 40% of the Malaysian furniture industry, worth MYR 8.5 billion (MFA, 2008).

Box 7.A1.2. Backward and forward linkages as a driver of process innovation

Within the segments of auto manufacturers/assemblers and component and parts manufacturers, progress in backward and forward linkages in the automotive sector is partly due to government policy and the historical development of the industry. Two policy instruments are important in this respect, the local Material Content Programme and the Vendor Development Programme. Local sourcing is higher in the automotive industry than in other industries. A survey by Ling and Yong (1999, pp. 131-152) found that automotive manufacturers' local sourcing of components and parts was around 30% compared to the electrical and electronic sector's 14%. Although the local content requirements were formulated in the early 1970s, the components and parts sub-sector benefited primarily because of the first and second national car projects. As of 2007, nearly 1 129 vendors existed, of which 248 supplied major components to manufacturers while others provided support services and components to first-tier vendors (MIGHT, 2008).

The vendor development programmes, besides increasing the output of parts and components suppliers, have also ensured financial and technical assistance. In addition, to improve suppliers' technological capabilities, Proton has helped suppliers to establish partnerships with foreign auto component and parts manufacturers (Abdulsomad, 1999). Owing to Japan's early dominance of the industry, forward linkages mainly exist with Japanese manufacturers, especially in the local car manufacturers, Proton and Perodua. Although the transfer of state-of-the-art technologies is limited, the transfer of process technologies has contributed to advances in the auto manufacturing industry. In addition, national auto manufacturers have moved into original design manufacturer (ODM) with a focus on R&D and design engineering. Proton's collaboration with Lotus has helped to improve design capabilities. This will eventually contribute to capability development in OEMs and first-tier suppliers. However, the lack of development of frontier technologies (*e.g.* energy-efficient vehicles) will limit the success of national car manufacturers and increase the vulnerability of the automotive industry. The Malaysian External Trade Development Corporation (MATRADE) initiatives to promote the auto industry, especially the components and parts sub-sector through various fairs and exhibitions, also help develop links to global markets and potential sales.

Source: Wad and Chandran (2009).

One factor that contributed to the emergence of Muar as a world-class furniture cluster was the transfer of furniture-related investment and know-how from Chinese Taipei to Muar during the 1980s. At that time, Malaysian rubberwood had proven to be a versatile, affordable and well accepted raw material for furniture production. The recognition of rubberwood as an environmentally friendly raw material is a significant advantage because it is abundantly available in Muar and neighbouring districts. Moreover, since Muar is a relatively small town, there is a close relationship between the community and industry players which fosters mutual understanding and creates social capital among competitors. The cluster's achievements are built upon the collective efforts of industry players who are prepared to share business opportunities and information. A specific characteristic of Muar's wooden furniture industry is its greater dependence on the collective efforts of industry practitioners than on government support. Actors in the immediate business environment, such as manufacturers, buyers, suppliers and retailers, are the main sources of innovation for the cluster. Their linkages and interaction are essential features of the cluster's dissemination of knowledge and successful innovation (see Box 7.A1.3).

Box 7.A1.3. Elements of the Muar furniture cluster

Knowledge and technology. Malaysia is a pioneer in rubberwood furniture manufacturing. The Muar cluster currently uses one of the best technologies available worldwide. Concerted efforts are being made to expand the use of automation and computer numerical control (CNC) machinery to reduce dependence on foreign labour. Most of the machinery is imported from China, Chinese Taipei, Germany and Italy. There is no clear distinction between the large manufacturers and SMEs in terms of their technological capabilities. The learning processes are basically in-house and on-the-job training. Knowledge is accumulated through experience gained from everyday work. In addition, knowledge upgrading occurs when the next generation (children with sufficient education at foreign and local higher education institutions) takes over the family furniture business. Significantly, this new generation revamps the businesses and introduces more innovative processes including organisational innovations such as new marketing methods, and other innovative approaches to business.

Actors and linkages. The most important actor is the locally owned SME. These firms secure orders from foreign retailers and function as parts and components suppliers to large enterprises through sub-contracting. The cluster is supported by a large number of supporting industries, such as coating, varnishing, finishers, wood products, etc. The Muar Furniture Association (MFA) helps unite the manufacturers and organises international furniture exhibitions in the country. The relationship between SMEs and large furniture manufacturers is symbiotic and mutually beneficial. The furniture manufacturers form a close partnership with their immediate business environment, that is, suppliers, customers, retailers and support industries.

Institutions and social networks. All furniture manufacturers, regardless of their size, work collectively for the success of the industry. In fact, one of the main assets of the furniture industry in Muar is its social capital in the form of co-operative spirit, trust and loyalty among the industry practitioners. A number of public support measures – for financing innovation, vocational training and international trade missions – have been made available by government agencies in order to enhance the cluster’s competitive advantages.

Source: Boon-Kwee (2011).

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Chapter 8

Singapore innovation profile

As a relative latecomer to industrialisation and technological development in the global economy, Singapore has made significant progress in developing its science, technology and innovation (STI) capability over the near half century since full political independence. This effort was initially based on evolving a national system of innovation that emphasised attracting and leveraging global multinational corporations (MNCs) to transfer increasingly advanced technological operations to Singapore, and developing infrastructure and human resources to absorb and exploit new technologies rapidly. In the last decade or so, however, the country has started to shift towards a more balanced approach, with increasing emphasis on developing its own R&D and innovation capability.

While the government has played a significant "developmental state" role in guiding S&T 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. Moreover, even though Singapore's national innovation system (NIS) is certainly the most advanced in Southeast Asia and there is an opportunity to further consolidate its role as the region's innovation hub, its geographic proximity and strong business and cultural links to the two major emerging markets in Asia, China and India, offer both opportunities and risks. As a small economy, the key challenge is for Singapore to move nimbly and strategically to stay ahead of regional competitors in capability development in selected S&T technology clusters. Its continuing ability to attract global talent, especially innovative and entrepreneurial talent, is crucial to achieving this, even as it seeks to nurture greater entrepreneurship and innovation among its local population.

8.1. Macroeconomic performance and framework conditions for innovation

8.1.1. Performance and structure of the economy

Among late-industrialising economies, Singapore has achieved one of the most impressive economic growth records since its full political independence in 1965, averaging 8% GDP growth annually from 1960 to 2010 (Table 8.1). Singapore's per capita gross domestic product (GDP) of USD 61 103 in 2011 (on a purchasing power parity [PPP] basis in current dollars) is the third highest in the world and above the United States (USD 48 442) (World Bank, 2012). However, the economy has been vulnerable to regional and global shocks over the past 15 years – GDP shrank in 1998 following the Asian financial crisis, in 2001 following the collapse of the 'dot-com' bubble and global economic turbulence, and most recently in 2009 reflecting the economic crisis and weak global demand. Economic growth in the 2000s therefore lagged behind the preceding decades. Nevertheless, in 2010 GDP growth rebounded strongly to 14.8% and was 4.9% in 2011.

Table 8.1. Aggregate economic growth performance, 1960-2010

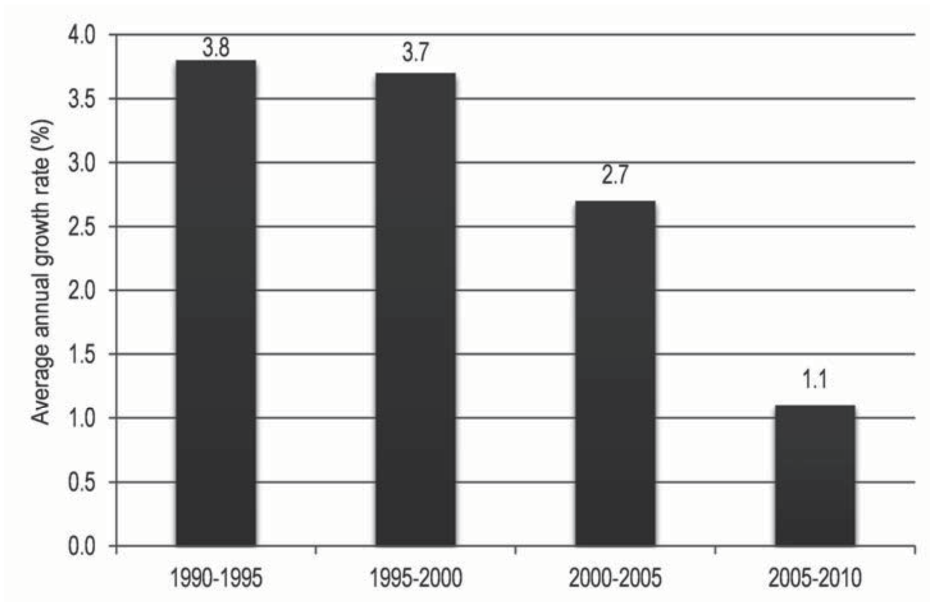
	% Real growth p.a.					
	1960-70	1970-80	1980-90	1990-2000	2000-05	2005-10
GDP at 2005 market prices	9.2	9.0	7.7	7.2	4.8	6.4
	SGD at current prices					
	1970	1980	1990	2000	2005	2010
Gross national income per capita[1]	2 820	9 900	20 100	39 600	42 983	57 603

1. Gross national product per capita prior to 1997.

Source: Calculated from *Yearbook of Statistics Singapore* (various years), *Economic Survey of Singapore* (various years). Per capita GNI obtained from Singstat website *www.singstat.gov.sg/stats/themes/economy/hist/gnp.html*. Mid-year population estimate for 2000 obtained from Singstat website, *www.singstat.gov.sg/FACT/KEYIND/keyind.html*.

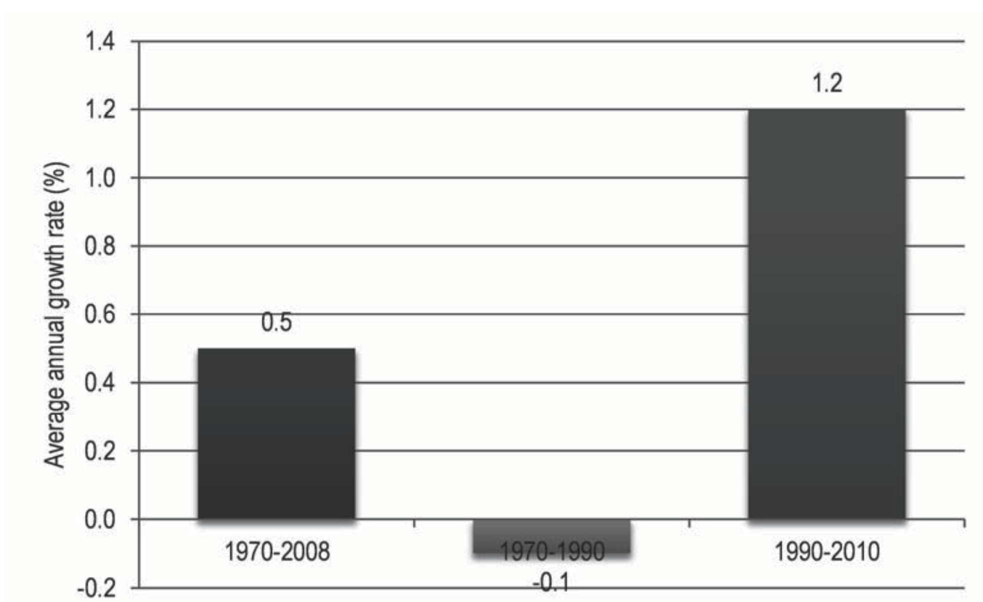
Singapore's rapid economic growth has been achieved through continuous industrial restructuring and technological upgrading. In the first decade after independence, growth was led largely by labour-intensive manufacturing. In the two subsequent decades, it was propelled by the growth of increasingly technology-intensive manufacturing activities of foreign MNCs, with high-technology products contributing an increasing share of total value added. Labour productivity has increased since 1990, though growth was slower in the 2005-10 period (Figure 8.1). Total factor productivity (TFP) has also increased since 1990, though average annual TFP growth was negative in Singapore between 1970 and 1990 at a time when productivity was increasing in other countries in the region (Figure 8.2). More recently, TFP fell in 2008 and 2009 before contributing strongly to a rebound in GDP growth in 2010.

Figure 8.1. Trends in labour productivity growth: Singapore, 1990-2010



N.B. Average annual growth of GDP at constant basic prices per hour, using 2005 PPPs.
Source: APO Productivity Year Book (2012).

Figure 8.2. Trends in total factor productivity growth: Singapore 1970-2010



Source: APO Productivity Year Book (2012).

Singapore's development into an increasingly important business, financial, transport and communications services hub in the Asia-Pacific region has provided additional engines of growth since the 1980s (Table 8.2), yet manufacturing has remained important to the economy, with its share of GDP remaining above 25% in most years during the last two decades. Since the 1990s, knowledge-intensive services and manufacturing have become the key drivers of Singapore's economic growth.

Table 8.2. Singapore's distribution of GDP by sectors, 1960-2010

Percentage

Industry	1960	1970	1980	1990	2000	2005	2010[1]
Agriculture & mining	3.9	2.7	1.5	0.4	0.1	0.1	0.04
Manufacturing	11.7	20.2	28.1	28.0	25.9	27.8	23.2
Utilities	2.4	2.6	2.1	1.9	1.7	1.8	1.6
Construction	3.5	6.8	6.2	5.4	6.0	3.9	4.7
Commerce	33.0	27.4	20.9	16.3	19.1	17.5	19.5
Transport & communication	13.6	10.7	13.5	12.5	11.1	14.7	12.7
Financial & business services	14.4	16.7	18.9	25.5	25.3	23.4	27.1
Other services	17.6	12.9	8.7	9.9	10.9	10.9	11.2
Total	100%	100%	100%	100%	100%	100%	100%

1. Preliminary figures.

Notes: Figures may not add up to 100 due to rounding.

Sources: Calculated from Department of Statistics, *Yearbook of Statistics Singapore*, various years; Ministry of Trade and Industry, *Economic Survey of Singapore*, various years.

Given its rather small domestic market, the Singaporean economy has been highly dependent on regional and global markets for growth. Indeed, a cornerstone of Singapore's public policy has been to promote openness to external trade and investment. This is reflected in the stock of inward foreign direct investment (FDI) in Singapore, which amounted to SGD 470 billion in 2008 (triple the amount in 1998). The recipient sectors are relatively concentrated, with 41.8% in financial and insurance services and over one-fifth in manufacturing (Table 8.3). In terms of regions, Europe is the largest contributor to FDI in Singapore (41% in 2008), followed by Asia (23%, with Japan contributing 10.4%). US and Japanese companies accounted for similar amounts of FDI. Singapore's regional neighbours account for only a small share of inward investment, with 3.6% of FDI coming from ASEAN countries.

Table 8.3. Stock of foreign direct investment In Singapore by industry, 1999 vs. 2009

	1999	2009
Total stock of FDI in Singapore (SGD millions)	170 821	552 276
	Percentage	
Manufacturing	34.0	21.8
Construction	0.9	0.4
Wholesale & retail trade	15.2	17.2
Hotels & restaurants	1.2	0.7
Transport & storage	3.5	6.6
Information & communications	0.5	1.0
Financial & insurance services	37.8	41.8
Real estate, rental & leasing	3.3	2.6
Professional & technical, administrative & support services	3.3	6.5
Others	0.2	1.3
Total	100.0	100.0

Source: Department of Statistics, *Yearbook of Statistics Singapore 2011*.

Concerning trade, although the United States and Malaysia remained leading sources of imports and destinations for exports in 2010, the most noticeable changes since 2000 have been the increasing importance of China as a source of imports, and China, and Hong Kong, China, in particular, as destinations for exports. The decline in the relative importance of Japan as both an import and export partner is also noteworthy, though trade levels still remain high in absolute terms (see Table 8.4).

Table 8.4. Singapore's top trading partners, 2000-10

Rank	Singapore's top 10 export partners in 2000	USD million	Singapore's top 10 export partners in 2010	USD million
1	Malaysia	25 026	Malaysia	41 969
2	United States	23 891	Hong Kong, China	41 210
3	Hong Kong, China	10 838	China	36 351
4	Japan	10 400	Indonesia	33 056
5	Chinese Taipei	8 225	United States	22 951
6	Thailand	5 865	Japan	16 410
7	China	5 380	Korea	14 364
8	Korea	4 913	India	13 301
9	Germany	4 275	Chinese Taipei	12 964
10	Netherlands	4 086	Thailand	12 701
	Singapore's top 10 import partners in 2000	USD million	Singapore's top 10 import partners in 2010	USD million
1	Japan	23 154	Malaysia	36 342
2	Malaysia	22 832	United States	35 619
3	United States	20 270	China	33 666
4	China	7 116	Japan	24 425
5	Chinese Taipei	5 967	Chinese Taipei	19 741
6	Thailand	5 800	Korea	18 002
7	Korea	4 815	Indonesia	16 844
8	Saudi Arabia	4 333	Saudi Arabia	11 233
9	Germany	4 233	Thailand	10 281
10	Hong Kong, China	3 511	India	9 228

Source: UN Commodity Trade (Comtrade) Statistics Database.

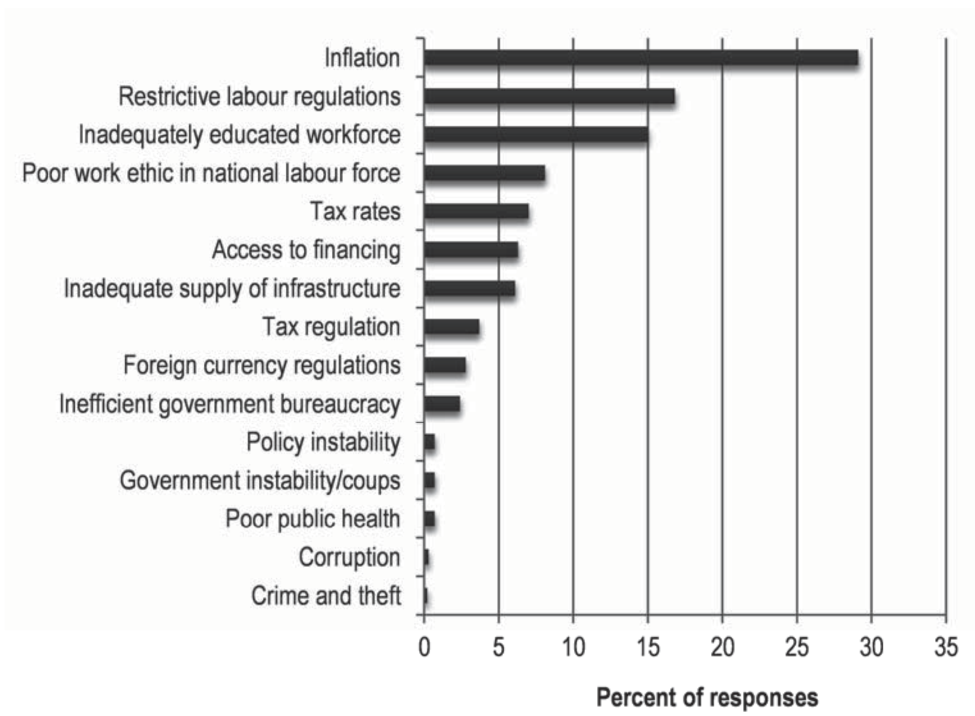
8.1.2. Framework conditions for innovation

In the World Economic Forum Global Competitiveness Report for 2011-12, Singapore is in second place out of 142 countries, the highest-ranked country in Asia and second only to Switzerland (WEF, 2012). Singapore ranks first for the efficiency of its goods markets, its institutions and for its financial market sophistication and second for labour market efficiency. In addition, the country's competitiveness is underpinned by a strong focus on education to provide individuals with the skills needed for a rapidly changing global economy.

Because of the openness of the economy and the strong reliance on external market forces, local Singaporean firms are by and large very exposed to global competitive market pressures and the demand for quality that they imply. In particular, the presence of many leading world-class global MNCs in Singapore contributes significantly to the articulation of demand for quality and process improvement in manufacturing and logistics services (Wong, 2003). It is thus no surprise that Singapore has developed among the best air- and sea-transport infrastructures and logistic support industries in the world: they had to innovate or risk losing customers to regional competition.

The World Bank's benchmarking survey on the ease of doing business (World Bank/ IFC, 2012) ranks Singapore first in the world out of 183 economies, helped considerably by its political stability and efficient bureaucracy (Figure 8.3). It is also ranked by Transparency International as one of the least corrupt countries in the world. On the downside, land is scarce and labour often has to be imported to meet the skills demands of a knowledge-based economy. Nevertheless, Singapore remains one of the easiest places in the world in which to set up a new business.

Figure 8.3. The most problematic factors for doing business in Singapore



Source: World Economic Forum (2012) Percentages represent the weighted results of a ranking of the five most problematic factors from a list of 15 by respondents to the WEF survey.

As MNCs provided risk capital in the early years of Singapore's high-technology development, there was little need for financial institutions that support investment in high technology. Although the government has subsequently acted to strengthen the availability of such financing, the high-technology venture financing ecosystem in Singapore is still relatively under-developed. It was only from the 1990s that the number and amount of venture capital (VC) funds managed out of Singapore started to grow, spurred in part by a significant injection of co-funding by government holding companies as institutional investors (Temasek Holdings, TIF Ventures), as well as by the establishment of a number of VC funds directly managed by government agencies or government-linked companies.

Despite this, real growth of the VC industry in Singapore occurred only in 1999, with the establishment of the USD 1 billion Technopreneurship Investment Fund (TIF), launched at the height of the dot-com boom under the T21 Initiative. This "fund of funds", wholly owned by the Economic Development Board (EDB), aimed to jumpstart Singapore's VC industry by inducing leading VCs to use Singapore as their regional hub and train a core of experienced VC professionals. Although the fund was successful in attracting several leading US VC firms to Singapore (such as Draper Fisher Jurvetson, Crimson Ventures), others that received sizable funding from the fund did not follow suit. The fund closed in the late 2000s with moderate returns.

The government's efforts enabled Singapore to establish itself as the preferred location for VC regional hub operations in Southeast Asia, but in terms of the volume of venture deal flows Singapore still lags considerably behind Chinese Taipei (Wong, 2006). Indeed, while the cumulative amount of funds managed in Singapore grew impressively, reaching over SGD 16 billion in 2004, in terms of investment in Singapore-based ventures, the record appears less impressive. Over 2000-05, a total of less than SGD 1.8 billion was invested in 500 Singapore-based firms, or just over 10% of the total VC funds managed out of Singapore in 2004. Thus a sizable portion of the VC funds managed in Singapore appears to have been invested overseas and their impact on the formation of high-technology start-ups in Singapore has been quite modest.

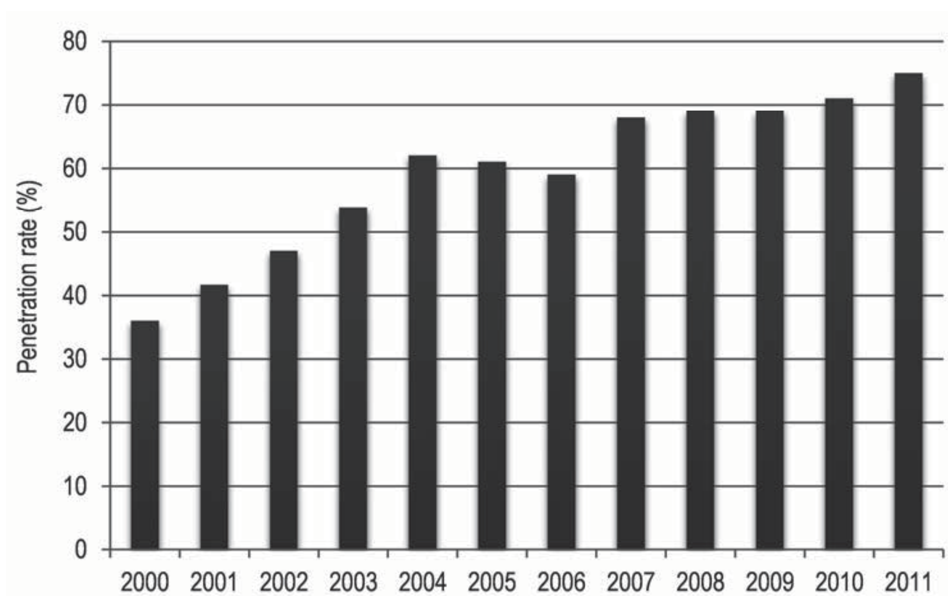
Another factor contributing to the low level of deals funded by venture capital in Singapore is the lack of available, sophisticated business angel investing at the seed stage, which is typically needed to fund early start-ups to grow to a stage at which they are fundable by venture capitalists. Recognising the critical need for early-stage financing in Singapore, EDB introduced in 2001 a public co-investment scheme (Startup EnterprisE Development Scheme or SEEDS, now administered by SPRING, the Standards, Productivity and Innovation Board) to stimulate early-stage business angel investment. A related programme, Business Angel Funds (BAF) co-funds investment by pre-approved business angel groups. Some recently introduced National Research Foundation (NRF) schemes, such as the Early Stage Venture Funding (ESVF) scheme, also target this gap. Both SEEDS and BAF were launched after consultation with the Business Angel Network (Southeast Asia) (BANSEA), an angel investment networking organisation established in Singapore in 2001 by a group of Singapore-based angel investors, with network connections to investor groups in Thailand, Malaysia, Viet Nam and Indonesia (BANSEA website). Similar to angel networks like the Band of Angels and Tech Coast Angels in California, BANSEA has emerged to fill the gap in early-stage start-up funding by facilitating match-making between start-up entrepreneurs and early-stage investors.

Singapore has a world-class infrastructure, ranked third in the WEF 2011-12 Global Competitiveness Report, with excellent roads, ports and air transport facilities. Singapore's innovation infrastructure and services are also well developed. The first science park was set up in 1980, under a government initiative seeking to emulate the success of science and high-technology clusters such as Silicon Valley and Route 128. With a total land area of 30 hectares, the park was fully occupied by the mid-1990s, with a mix of tenants including government agencies and numerous private companies. The development of Science Park II, with a land area of 20 hectares, began in 1993, with tenants mainly comprising information and communication technology (ICT) companies and related public research institutes (PRIs).

Following the completion of these two science park programmes, the government embarked in the early 2000s on a much larger infrastructure development project called One North, which would house a new innovation-based city comprising R&D facilities, campuses for new higher educational institutions, living quarters for research scientists, hotel, convention and restaurant facilities, as well as offices for venture related services such as intellectual property (IP) law firms and VCs (Wong, 2011). The aim was to facilitate the formation of informal networks for knowledge sharing and accelerating the growth of a critical mass of S&T expertise in Singapore (Finegold et al., 2004). Occupying 190 hectares of land near the campus of the National University of Singapore (NUS), One North represents the most ambitious R&D infrastructure support project attempted by the government to date.

The One North development currently comprises two major hubs. The first is the biomedical hub, known as Biopolis. Having opened its first phase in 2003, Biopolis houses both the biomedical research institutes of the Agency for Science, Technology and Research (A*STAR) as well as biomedical companies. The second is the hub for ICT, media and physical sciences and engineering, known as Fusionopolis and opened in 2008. Like Biopolis, Fusionopolis houses both science and engineering PRIs and corporate labs. Singapore's various industry-development public agencies (SPRING, EDB and the Media Development Authority or MDA) are also in the process of locating there. The two hubs are near each other with a view to facilitating opportunities for the fusion of capabilities across diverse scientific domains, thus paving the way for multidisciplinary research. Scientific facilities are also shared to encourage greater collaboration among researchers. In addition, the lifestyle areas are used as test-bedding sites to accelerate the adoption of new technologies.

Figure 8.4. Internet users per 100 inhabitants, Singapore, 2000-11



Source: International Telecommunications Union, 2012.

The telecommunications infrastructure in Singapore is relatively well developed. Internet penetration rose from 36% of the population in 2000 to 75% in 2011 (Figure 8.4), compared to 61% for Malaysia, 35% for Viet Nam and 24% for Thailand. Fixed broadband subscriptions also rose to 25.5% of the population, compared to less than 10% in most other countries in the region, with the notable exceptions of Korea (37%) and Hong Kong, China (32%).

8.2. Innovation performance

As an indicator of innovation performance, Singapore ranks 23rd in the world in terms of the World Bank's Knowledge Economy Index (Table 8.5), three places down on its 2000 ranking but ahead of many leading Western economies.

Table 8.5. Knowledge Economy Index and Knowledge Index, Singapore, 2012

Indicator	Value
Knowledge Economy Index (KEI) #	8.26
Knowledge Index (KI) *	7.79
Economic incentive and institutional regime	*9.66*
Innovation	*9.49*
Education	*5.09*
ICT	*8.78*
Position in world rank	23
Change in rank from 1995	-3

The Knowledge Economy Index (KEI) is calculated based on the average of the normalised scores of a country on all four pillars related to the knowledge economy: economic incentive and institutional regime, education, innovation and ICT.

* The Knowledge Index (KI) measures a country's ability to generate, adopt and use knowledge. The index is based on key variables in the three knowledge pillars: education innovation and ICT.

Source: The World Bank (2012a).

R&D in Singapore was minimal until the late 1980s, with a gross expenditure on R&D (GERD) to GDP ratio of only 0.86% in 1987, significantly below the levels of OECD countries. Since then, however, R&D investment intensity in Singapore has increased significantly, with the GERD/GDP ratio reaching 2.2% in 2009, only slightly behind Germany (2.6%), Chinese Taipei and the United States (2.8%), although it still lags significantly behind Korea (3.4%) and some of the small advanced European countries such as Sweden and Finland (around 3.8%) (Table 8.6). Singapore faces a shortage of skilled R&D manpower and has endeavoured to address this issue through a range of policies incorporating both education and attraction of foreign talent through immigration. Although the absolute number of research scientists and engineers (RSEs) has increased substantially, Singapore's technical human resource development may still have some way to go to catch up with other small advanced countries with similarly small domestic population bases. The number of researchers per 10 000 labour force in Singapore in 2008 (97) is lower not only than Korea and Chinese Taipei, but also than Finland, Sweden and Denmark (Wong and Singh, 2008).

Table 8.6. R&D intensity and researchers in the labour force, Singapore, 1995-2010

	1995	2000	2005	2006	2007	2008	2009	2010
GERD/GDP	1.11	1.85	2.19	2.16	2.37	2.65	2.24	2.09
Number of researchers per 10 000 labour force	40	74	92	91	101	95	101	102

Source: OECD Main Science and Technology Indicators.

Data on R&D expenditure in Singapore show that the private sector, government sector and higher education sector all contributed to the rapid increase in R&D intensity (Table 8.7). From the late 1970s, much of the R&D investments in Singapore have been performed by the private sector. The share of private-sector R&D in total GERD grew significantly from the mid-1980s to mid-2000. R&D intensity in the private sector has hovered at around two-thirds since 2005 (with some fluctuations in more recent years), with the balance more or less split evenly between the three sectors of public R&D: higher education, public research institutes and various government sectors.

R&D in both the public and private sectors has traditionally been concentrated in incremental, applied work (Table 8.8). Basic R&D only began to take an increasing share of total R&D spending in Singapore from 2001, rising to 20.3% in 2009. The shift in focus to more basic, strategic and longer-term R&D from the late 1990s is reflected in the national S&T policy in the 2000s (see below).

Singapore's publication performance has steadily improved over the last decade, in terms both of overall number of scientific publications a year (Figure 8.5) and publications in English-language journals. Growth rates are slower than in other countries in the region – growth in overall publications from 2000 to 2010, for example, was 260% in Singapore compared to over 900% in Malaysia – but growth in the latter country, and in other countries in the region, was from a much lower baseline. Growth in the 2000s was especially strong in biosciences, nanosciences, energy and multidisciplinary sciences. Co-publication also increased, with the United States and China being the primary sources of international co-authors.

Table 8.7. R&D expenditure by sectors, Singapore, 1978-2009

Year	Breakdown of R&D expenditure (%)				
	Private sector	Higher education sector	Government sector	Public research institutes	Total
1978	67.5	21.7	10.8	n.a.	100.0
1984	49.8	32.5	17.7	n.a.	100.0
1990	54.1	20.9	17.4	7.5	100.0
1995	64.5	14.2	8.1	13.3	100.0
2000	62.0	11.2	14.1	12.7	100.0
2005	66.2	10.4	9.7	13.8	100.0
2006	65.7	11.5	10.3	12.4	100.0
2007	66.8	9.5	12.2	11.5	100.0
2008	71.8	10.0	7.6	10.6	100.0
2009	61.6	14.1	11.3	12.9	100.0
2010	60.8	14.92	10.4	13.9	100.0

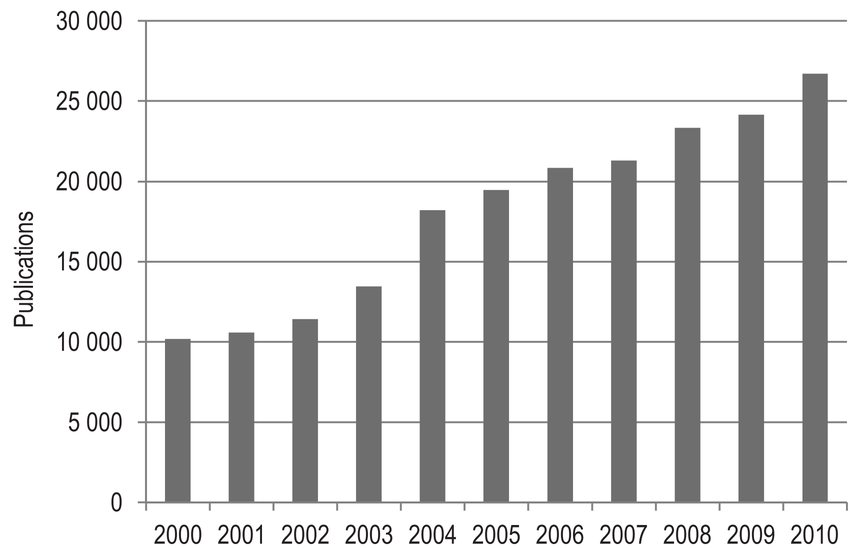
Source: National Survey of R&D Expenditure and Manpower (various years); Science Council of Singapore (prior to 1990); National Survey of R&D in Singapore (various years); National Science & Technology Board (1990-2000); Agency for Science, Technology & Research (2001-10).

Table 8.8. R&D expenditure by type of R&D, Singapore, 1993-2009

Type of R&D	Breakdown of R&D expenditure (%)								
	1993	1997	2000	2005	2006	2007	2008	2009	2010
Basic research	16.1	12.8	11.8	21	20.6	17.4	17.0	20.3	20.6
Applied research	39.1	43.8	35.0	33	31.9	24.7	25.3	32.5	32.9
Experimental development	44.9	43.3	53.2	47	47.4	57.9	57.7	47.2	46.5

Source: National Survey of R&D Expenditure and Manpower (various years); Science Council of Singapore (prior to 1990); National Survey of R&D in Singapore (various years); National Science & Technology Board (1990-2000); Agency for Science, Technology & Research (2001-10).

Figure 8.5. Trend in scientific publications, Singapore, 2000-10



Source: Science Metrix analysis of Scopus (Elsevier) database.

Table 8.9. Quantity and quality of publications, Singapore, 2000-10

Economy	Number of papers	Number of citations	Citations per paper
Singapore	62 947	589 433	9.4
Chinese Taipei	169 555	1 195 634	7.1
Korea	266 682	1 892 966	7.1
Ireland	43 668	503 196	11.5
Sweden	180 269	2 702 126	15.0
Finland	89 436	1 244 315	13.9
China	762 098	4 578 689	6.0
United States	3 069 500	49 593 619	16.2

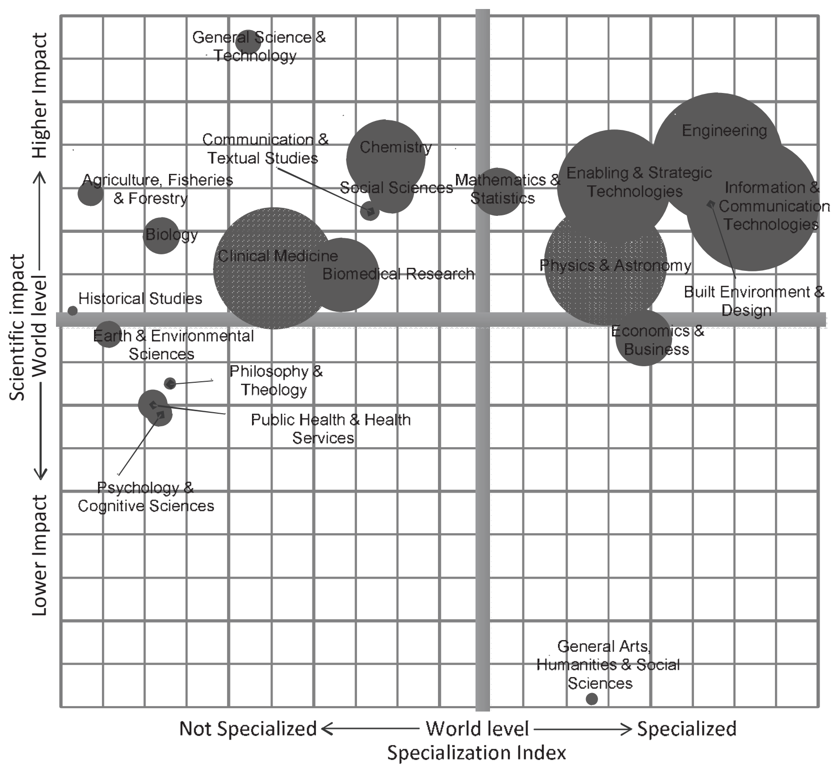
Note: Thomson Scientific-indexed journal articles only.

Source: Essential Science Indicators.

Table 8.9 shows that the number of Thompson Scientific-indexed journal articles produced by Singapore over 2000-10 (589 400) was about the same as those produced by Ireland, though fewer than the numbers produced by Chinese Taipei and Korea or by the small, advanced European countries, Sweden and Finland. However, citations received per paper for Singapore (9.4) were slightly higher than for Chinese Taipei and Korea (7.1), although lower than for the European countries (12 or higher).

Analysis of publications in the Scopus database (Figure 8.6) reveals, however, that relative citation impact of publications from Singapore were above the global average in the majority of disciplinary areas in 2000-2010. Engineering, ICTs, physics and astronomy, and enabling and strategic technologies represent relative specialisations in Singapore and have relatively high citation impacts. General science and technology, chemistry and mathematics and statistics also perform strongly in terms of citation impact.

Figure 8.6. Positional analysis of Singapore's scientific publications, 2000-10



Source: Analysis of Scopus (Elsevier) database by Science Metrix. This combines the number of publications by scientific field (area of circles), the specialisation index (a measure of relative intensity in a field compared to the World average) and the average of relative citations (citations relative to the World average controlling for age and field).

The absolute number of Singapore-based patents is still low, totalling 7 063 patents granted by the USPTO (US Patent and Trademark Office) as of 2010 (Table 8.10), although its patenting performance has improved significantly over the last decade. The cumulative number of USPTO-granted patents to Singapore-based inventors was only 427 up to 1995. This more than tripled to 1 370 by the end of 2000, and over 2001-10, another 5 693 were granted, *i.e.* 80% of the total cumulative number of US patents have been granted in the last 10 years.

Until 2000, foreign companies accounted for more than half of all US patents granted to Singapore-based inventions, owing to the dependence of Singapore on R&D by foreign MNCs. However from 2000 to 2003, patents assigned to Singapore companies outnumbered those assigned to foreign companies, an indication of the growth in domestic innovation capabilities in both the public sector and the local private sector, including the emergence of local high-technology start-ups (Wong and Singh, 2008). Nevertheless, from 2004, patents assigned to foreign companies once again outnumbered those to local companies, a sign of the growing importance of Singapore as a regional R&D hub for MNCs.

Table 8.10. Growth in patents issued by the USPTO, Singapore, 1976-2010

	1976-85	1986-95	1996-2000	2001-05	2006-10	Total
Patents by Singapore inventors						
Singapore assignee	30	148	480	1 303	1 443	3 404
Foreign assignee	22	227	463	1 239	1 708	3 659
Total	*52*	*375*	*943*	*2 542*	*3 151*	*7 063*
Patents by foreign inventors assigned to Singaporean organisations						
	11	30	64	134	1 865	2 104
Total	*63*	*405*	*1007*	*2 676*	*5 016*	*9 167*

Source: Compiled from NUS Entrepreneurship Centre's Singapore Inventor Database of the US Patent and Trademark Office.

Singapore ranked fourth in patenting propensity among Asia-Pacific economies in 2009, with 134 US patents per million population, an increase from 105 in 2005. Its domestic ownership of patenting (44.4% for 2006-09) is substantially lower than Korea's (94.2%) and Chinese Taipei's (74.7%), both of which have much stronger national science, technology and innovation capabilities in their local industries. Singapore's share of domestically owned patents is also slightly lower than that of Hong Kong, China (47.1%), but higher than that of China (36.1%) and India (29.9%).

An IP and innovation survey conducted in 2005 also revealed that, relative to the extent of innovation, the level of IP creation in Singapore was low. Only 60% of firms owned some form of IP. About one-third had applied for patents, and only about 28% owned patents that were still in effect. Ownership of non-patent IP was more widespread, with almost half the firms owning some form of non-patent IP. The results also showed that a significant proportion of innovating firms did not have IP protection for their innovations.

The survey also revealed a number of shortcomings with regard to firm's IP management. First, many did not fully track their IP usage. They therefore did not know how much the technologies developed from their patents contributed to their revenue, or how much royalties from licensed-out IP contributed. A similar situation existed for licensed-in IP. Second, firms did not fully exploit their IP. A high percentage of patents (almost one-quarter) were not utilised, particularly by non-innovating firms. Third, IP was generally not considered a high strategic priority in firms, and IP strategies tended to focus on protecting their own IP and expanding their IP portfolio in order to limit competitors' commercial activities. Relatively few tried to maximise revenue generation from IP by pursuing multiple strategies, such as licensing, forming spin-offs and selling to third parties. In a related issue firms were generally in the very early stage of IP strategy adoption. Most had not implemented IP strategies, and very few had a documented strategy for managing their IP (Wong et al., 2006). Given that firms' IP portfolios have grown significantly since this survey was carried out, it is certainly possible that many have more sophisticated IP strategies today.

8.3. Innovation policy: Institutional framework and policy orientations

Singapore's openness to external markets does not mean that the state plays an insignificant role in shaping the formation of new markets. Unlike the largely *laissez-faire*, hands-off role of the state in Hong Kong, China (Sharif and Baark, 2008), the Singaporean state has pursued an active, opportunistic role by identifying new market trends and quickly devising policy incentives to attract global players to locate part of their activities in Singapore, especially those well placed to capitalise on these new market development trends. Parallel investment in supporting infrastructures and resources then allows Singapore to reap an "early-entry" advantage.

Singapore's first significant policy recognition of the economic importance of R&D came in 1989 when a Committee of Ministers of State was formed to outline the long-term strategy and direction of Singapore's development. The result was a "vision" document called "The Next Lap", which highlighted the need to focus on R&D and specialise in high-technology niches so that Singapore could catch up with the advanced countries over the next 20 years (Government of Singapore, 1991). Two years later, the first five-year National Technology Plan (NTP) was released. The key objectives of the NTP were to promote industrially relevant R&D, build up S&T human resources, and develop an S&T support infrastructure. A new statutory board, the National Science and Technology Board (NSTB), was simultaneously established to implement the NTP. To this end, a SGD 2 billion allocation was given to NSTB. A key outcome of the NTP was the establishment of a series of PRIs, which were to be funded and managed by NSTB. This was done through a combination of creating new institutes and reorganising and transferring a number of existing research institutes from the higher education and government sectors. The NTP was followed by the formulation of a second five-year plan in 1996, called the second National Science and Technology Plan (NSTP), for which the budget allocation was doubled to SGD 4 billion. It also recognised the importance of investing in science in addition to technology. Nonetheless, the NSTP was still heavily skewed towards promotion of applied R&D rather than basic research. Indeed, the initial mission of most of the PRIs established under the NTP was to develop the applied technologies deemed critical for Singapore's industrial clusters (Wong, 2003), and this applied focus continued into the late 1990s.

The late 1990s then saw a drastic shift in Singapore's S&T policy direction. The Asian financial crisis in mid-1997, which led to a severe regional economic downturn, raised concerns about the need to diversify markets and achieve greater penetration of European and North American markets. This clearly required a stronger technological competitive edge. In addition, growing competition from China and India meant that Singapore would be subject to severe cost pressures. Finally, the leadership had become increasingly impressed by the Silicon Valley model of high-technology innovation (including the successful variants from Israel and Chinese Taipei) as the key to success in the global knowledge-based economy. All these factors motivated the government to launch in 1999 a new economic development programme called the Technopreneurship21 (T21) initiative. However, with the bursting of the Internet bubble in 2000, policy makers realised the need for start-ups to have truly innovative technologies and defensible intellectual property – and hence the need to improve basic research and innovative capabilities. At the same time, the government recognised the need to make a big push into the life sciences.

Accordingly, the NSTB was restructured in 2001 and renamed the Agency for Science, Technology and Research (A*STAR). It focused on developing Singapore's R&D capabilities, particularly the attraction and training of an R&D workforce. At the same time, the NSTB's former role of nurturing "technopreneurship" was transferred to the EDB. Planned public spending on S&T was also increased to SGD 7 billion in the Third Science & Technology Plan for 2001-05 (NSTP), with SGD 5 billion allocated to A*STAR to fund public research and to develop postgraduate research personnel; the remaining SGD 2 billion was managed by EDB to support private-sector R&D. The Plan also allocated a larger proportion of the public R&D budget to long-term strategic and basic research (Wong, 2003; A*STAR, 2001).

This shift in emphasis towards building long-term basic research capabilities further intensified in 2006, with a budget of SGD 13.55 billion for R&D over five years planned in the National Science & Technology Plan 2010 (STP 2010) and the establishment of the National Research Foundation (NRF) (Wong, 2011). The current 2011-15 R&D budget of SGD 16.1 billion represents a 20% increase over STP 2010; moreover, greater emphasis will be placed on technology commercialisation to recoup some of the cost of R&D, by encouraging public-private R&D partnerships and the establishment of technology transfer offices and enterprise incubators (Teh, 2010).

A characteristic feature of Singapore's approach to S&T policy implementation is a relatively top-down approach to technology policy formulation which is strategic in nature, yet flexible in terms of actual implementation. Indeed, Schein (1996) had described this approach as "strategic pragmatism". Although his work focused on the EDB, much of what he found appears applicable to the S&T policy arena in general. In essence, Singapore's political leaders at the Cabinet level formulate broad, long-term strategic economic development initiatives, but delegate much of the detailed implementation to the designated implementation agencies. Moreover, the government has been quite prepared to revise substantially an earlier strategic plan and replace it with a newer one, if and when it perceives that opportunities or threats have changed materially. This change in strategic direction is typically not due to changes in specific political leadership, since Singapore has had one-party rule since political independence in 1965.

One consequence of this top-down approach is that S&T policy is typically not formulated in isolation, but as an integral part of a larger economic development strategy. This "developmental state" approach has meant that S&T policies are strongly integrated in ministries with significant economic development roles. Indeed, it is telling that, until today, Singapore does not have a separate Ministry of Science and Technology; instead, these policy-making and implementation functions have been subsumed by the ministries involved in economic development, particularly the Ministry of Trade and Industry (MTI), but also the Ministry of Information, Communications and the Arts (MICA), which promotes ICT deployment through the IDA (Infocomm Development Authority of Singapore). The MTI is responsible for co-ordinating science and technology policies and formulating key economic policies for the country. The main statutory boards under MTI implementing STI policies are EDB, A*STAR and SPRING.

- EDB is Singapore's lead government agency for the promotion of inward foreign direct investments and knowledge-based industries. It is responsible for raising the level of private-sector R&D by attracting more MNCs to locate corporate R&D activities in Singapore (Wong, 2011).
- A*STAR is responsible for the development of domestic R&D capabilities, including overseeing the PRIs. To achieve its mission, it set up two councils: the Bio-Medical Research Council (BMRC), responsible for promoting R&D and developing human capital in the life sciences, and the Science and Engineering Research Council (SERC), which does the same in targeted science and

engineering clusters such as ICT, chemicals and engineering clusters. In total, A*STAR oversees 21 research institutes, centres and consortia.

- SPRING promotes innovation among small and medium-sized enterprises (SMEs). As such, it is responsible for administering a number of financing schemes targeting the development of technologically weak SMEs, as well as the cultivation of entrepreneurship in Singapore.

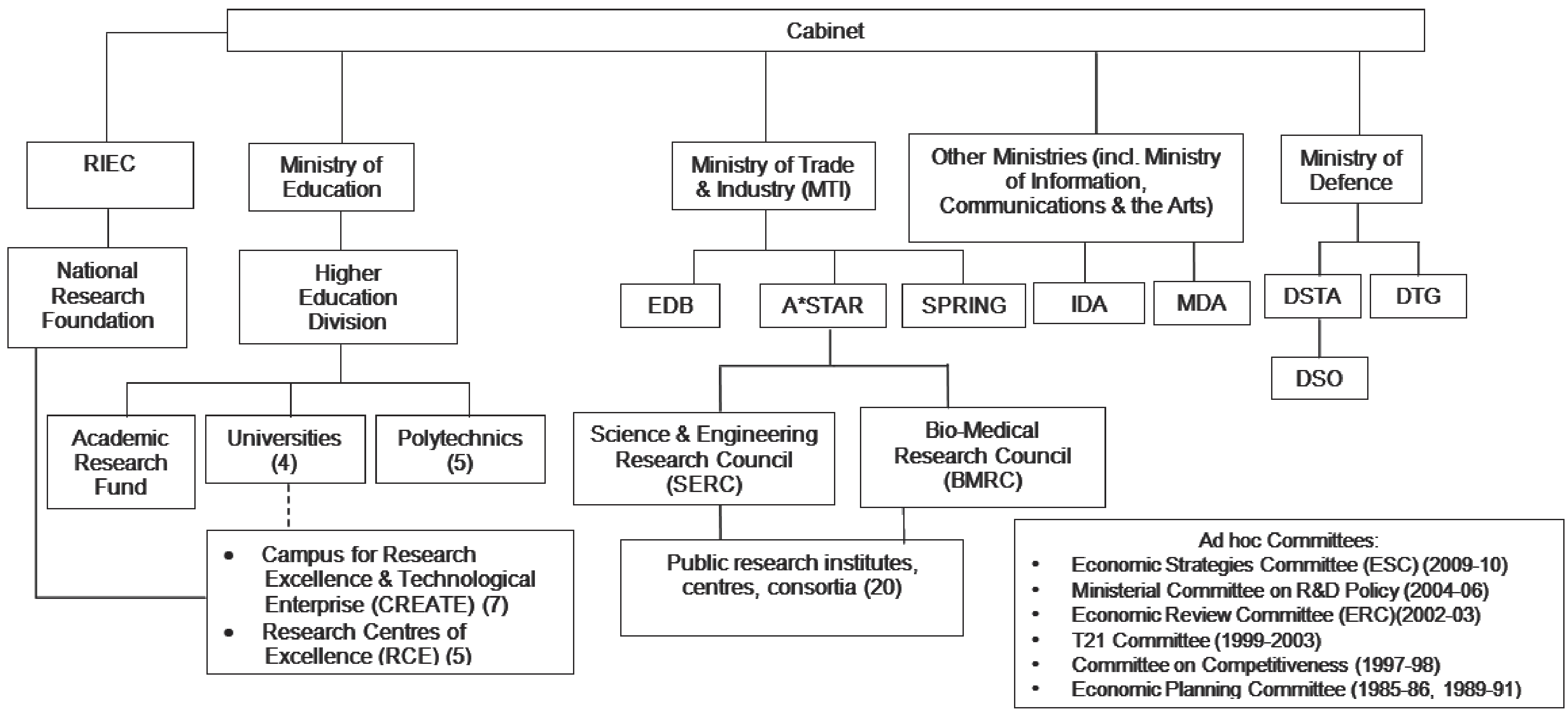
An outline of the prevailing institutional framework for S&T policy in Singapore is shown in Figure 8.7. Of particular note is the RIEC (Research, Innovation and Enterprise Council) established in 2006 and chaired by the Prime Minister. It is intended to strengthen co-ordination of different programmes and initiatives by different ministries and agencies. The NRF was established as a department in the Prime Minister's Office to support the RIEC and to implement national research, innovation and enterprise strategies approved by the RIEC. NRF oversees the strategic overview of national R&D of Singapore (Yeo, 2006). To this end, NRF is responsible for developing policies, plans and strategies for research, innovation and enterprise; funding strategic initiatives; building up Singapore's R&D capabilities and capacities by nurturing local and attracting foreign talent; and co-ordinating the research agenda of different agencies. A five-year budget of SGD 5 billion has been allocated to the NRF to achieve its mission. Through the NRF, the Singapore government is undertaking a fairly holistic approach to the development of domestic capabilities in the Singapore NIS; over and above the financing of R&D, NRF's tasks include developing linkages among actors in the NIS and facilitating technology commercialisation and the growth of high-technology start-ups (Wong and Singh, 2011).

Furthermore, SGD 1.55 billion has been allocated to the NRF for the development of three strategic sectors in which Singapore is seen to have a competitive advantage and which are critical for future economic growth:

- Biomedical sciences (BMS): focusing on building on Singapore's basic R&D discovery capabilities to translate basic science into better medicines and treatments to improve patient care.
- Environmental and water technologies (EWT) including clean energy: leveraging Singapore's foundation in water technologies and management and its competitive advantages in other environmental technology sectors. This is complemented by the clean energy initiative, which will focus on solar and fuel cells, in which Singapore also has a competitive advantage. As a compact city-state, Singapore is also an ideal test-bed for new technologies in these areas.
- Interactive and digital media (IDM): building on Singapore's multicultural, multilingual identity and its strong ICT infrastructure to create new innovative niches in IDM including animation, games and effects, education and edutainment, "on-the-move" media services and media intermediary services.

Attention will be given to commercial development – bringing scientific knowledge from the lab to the market. The target is for these sectors to provide a total of 86 000 jobs with value added of SGD 30 billion by 2015. This underscores the government's aim for R&D efforts to result in economic benefits rather the development of science and technology per se (Wong and Singh, 2011).

Figure 8.7. Emerging institutional framework for S&T policy: Singapore as of 2011



EDB – Economic Development Board
A*STAR – Agency for Science, Technology & Research
SPRING – Standards, Productivity and Innovation Board
IDA – Infocomm Development Authority
MDA – Media Development Authority

DSTA – Defence Science & Technology Administration
DTG – Defence Technology Group
DSO – Defence Science Organisation
RIEC - Research, Innovation and Enterprise Council

For its part, the Ministry of Education (MOE) oversees the three public universities and five polytechnics in Singapore. The Academic Research Fund (AcRF) under MOE was established in 1994 to support academic research in Singapore's universities. Starting with a budget of SGD 96 million in the early years, the AcRF has increased to approximately SGD 250 million a year in 2010s (Wong, 2011; MOE website).

8.4. Actors of the national innovation system

8.4.1. Business sector

Singapore's BERD reached SGD 3.8 billion, or 61.6% of GERD in 2009. Manufacturing firms constituted the lion's share of R&D spending, peaking at 88% of total private-sector R&D in 1996 before declining to 62.2% by 2009 (Table 8.11). Manufacturing R&D remains highly concentrated, with two-thirds in the electronics sector alone in 2009, followed by engineering (19.4%). This is consistent with the fact that electronics and information technology (IT) have been the most important and dynamic sectors in the Singapore economy since the 1980s and have stimulated a certain amount of R&D in the precision engineering industry (Wong, 2003). Private-sector R&D in the life sciences remains small (3.6%). There has also been a noticeable increase in the share of private-sector R&D going to services sector in the early 2000s, with the growing sophistication of Singapore's knowledge-intensive business services (KIBS).

Table 8.11. Distribution of private-sector R&D expenditure by industry: Singapore 1993-2009

Percentage

	1993	1998	2005	2009
Primary industries & construction	n.a.	n.a.	0.1	0.1
Manufacturing	81.1	86.9	65.2	62.2
Electronics	51.4	48.3	39.0	41.8
Chemicals	5.6	10.8	4.7	2.1
Engineering	16.8	22.7	10.6	12.1
Precision engineering	11.2	19.2	8.1	7.8
Process engineering	1.2	0.6	n.a.	n.a.
Transport engineering	4.3	2.9	2.5	4.2
Life sciences	4.0	4.2	3.0	3.6
Light Industries/other manufacturing	3.4	1.0	7.9	2.7
Services	18.9	13.1	34.8	37.8
R&D	n.a.	n.a.	10.9	14.6
IT and communications[1]	3.2	9.2	4.9	3.7
Finance & business	4.3	1.4	8.6	1.1
Other services	11.3	2.5	10.3	8.5
All industry groups	*100.00*	*100.0*	*100.0*	*100.0*

1. Part of ICT has been reclassified to "other services" since 2001.

Source: National Survey of R&D Expenditure and Manpower (various years); Science Council of Singapore (prior to 1990); National Survey of R&D in Singapore (various years); National Science & Technology Board (1990-2000); Agency for Science, Technology & Research (2001-09).

Table 8.12. High-technology vs. non-high-technology sectors, Singapore, 2008

	High-technology sectors			All sectors		
	Total	% local	% foreign	Total	% local	% foreign
Establishments	13 137	77.0	23.0	158 796	83.7	16.3
Employment	426 143	60.3	39.7	1 788 913	70.6	29.4
Value added	SGD 52.9 bn	39.1	60.9	SGD 205.1 bn	50.8	49.2
	High-technology manufacturing[1]			**All manufacturing**		
	Total	% local	% foreign	Total	% local	% foreign
Establishments	3 597	86.3	13.7	8 640	84.0	16.0
Employment	308 769	57.7	42.3	435 154	62.3	37.7
Value added	SGD 39.1 bn	30.2	69.8	SGD 47.2 bn	36.0	64.0
	High-technology services[2]			**All services**		
	Total	% local	% foreign	Total	% local	% foreign
Establishments	9 540	73.5	26.5	149 822	83.7	16.3
Employment	117 374	67.2	32.8	1 351 605	73.3	26.7
Value added	SGD 13.8 bn	64.5	35.5	SGD 157.8 bn	55.2	44.8

1. High-technology manufacturing comprises: coke and chemical products, rubber & plastics, machinery & equipment, electrical & electronics products, precision instruments and transport equipment.
2. High-technology services comprises ICT services, architectural and engineering activities, technical testing and R&D.

Source: Wong et al. (2011), based on unpublished data compiled from Singapore Department of Statistics.

Table 8.13. Foreign firms' share of industry R&D expenditure, Singapore, 1996-2009

	Foreign firms' share of private sector R&D (%)			
	1996	**2001**	**2005**	**2009**
Manufacturing	69.1	61.9	72.2	77.9
Biomedical sciences	71.6	59.6	97.5	92.2
Electronics	68.8	67.6	66.9	84.4
Chemicals	90.9	74.5	89.4	83.5
Engineering	51.1	37.9	63.0	62.9
General manufacturing	12.7	17.9	91.3	20.7
Services	51.8	41.1	57.0	64.3
R&D	n.a.	n.a.	54.8	62.1
IT and communications[1]	54.7	43.6	31.2	40.5
Logistics	n.a.	n.a.	0.1	14.3
Finance & business[2]	67.1	46.9	48.6	66.6
Other services	16.2	36.9	80.4	80.3
All industry groups	67.0	57.6	*66.8*	*72.7*

1 Post & telecommunications; IT and related services.
2 Financial intermediation and other business activities.

Source: National Survey of R&D Expenditure and Manpower (various years); Science Council of Singapore (prior to 1990); National Survey of R&D in Singapore (various years); National Science & Technology Board (1990-2000); Agency for Science, Technology & Research (2001-09).

Table 8.12 shows the extensive role played by foreign firms in Singapore. In 2008 foreign firms comprised 16% of enterprises and contributed almost one-third of employment and half of value added. In the high-technology sectors, dependence on foreign firms was even greater: almost one-quarter of the total number of enterprises, 40% of employment and 61% of value added. In the high-technology manufacturing sector in which many MNCs operate, the contribution of foreign firms is larger still: although they only comprise 13.7% of enterprises, they account for 42.3% of employment and 70% of value added. Foreign firms also account for a larger proportion of R&D activities in Singapore than local firms; in 2009, MNCs accounted for almost three-quarters of private R&D expenditure (Table 8.13).

Among the local firms that engage in R&D activities, three different groups can be distinguished. The first group consists of the more technically advanced SMEs operating in the various supporting industries to MNCs, particularly precision engineering. Good examples include Amtek (metal stamping), Spindex (precision engineering), Meiban (precision plastic moulding), Gul technology (printed/flexible circuit board), and Venture Manufacturing and JIT (contract manufacturing). The major focus of their technical efforts is in improving their manufacturing process capability to meet the stringent quality, cost and delivery requirements of their large MNC customers, although a small number of these firms have also started to diversify into own product innovation activities (Wong, 2003).

The second group consists of the various state-controlled enterprises established by the Singapore government with the specific aim to spearhead local participation in high-technology industries. Called government-linked companies (GLCs), they have strong financial backing from holding companies established by the government and hence have been able to commit significant investment to innovation activities. Among the more significant players include the companies within the Singapore Technology (ST) Engineering Group, Sembawang Group, Keppel Group and Natsteel Group. The ST Engineering Group, for example, has subsidiaries engaged in aerospace repair/maintenance engineering (ST Aerospace), semiconductor fabrication (Chartered Semiconductor Manufacturing), electronics systems integration (ST Electronics) and computer software systems (SCS). Both Keppel and Sembawang started as shipyards, but have since become diversified conglomerates; at the same time, their core shipbuilding and repairing operations have become global leaders in offshore rig building. The Natsteel group started as a national steel manufacturer, but has since diversified into electronics contract manufacturing (Natsteel Electronics, later acquired by Solectron, and Natsteel Broadway); its steel operations were acquired by the Tata Group in 2004.

The third and last group of local enterprises consists of a small but rapidly increasing number of entrepreneurial high-technology start-ups that seek to pioneer innovative products through their own R&D and brand development. The first wave of such firms in the late 1980 and early 1990s included PC (personal computer) firms such as IPC and GES, audio-cards firms such as Creative and Aztech, industrial electronics firms such as Powermatics and Teledata, machine tools makers and industrial machinery makers such as Excel Machine Tools and Falmac, and software companies such as CSA and Systems Access. However, despite some early success, including listing on the local stock exchange, many of these early independent high-technology start-ups either failed (*e.g.* Excel) or exited (IPC), or became absorbed by larger firms (both CSA and Systems Access were acquired by larger American software firms) by the early to mid-2000s. From the late 1990s to early 2000s, a second wave of new start-ups emerged, mainly Internet-/e-commerce-related, as part of the dotcom boom. Most of these also died in the ensuing dotcom crash. From the mid-2000s, a third wave has emerged. Unlike the first wave of local start-ups, whose founders had typically worked previously in industry (especially MNCs), the new wave of entrepreneurs tends to come more from tertiary and public R&D institutions. They are increasingly being funded by venture capital firms and an emerging angel investment community. These new entrants include companies founded by university professors (*e.g.* Semicaps, an IC failure analysis equipment maker founded by a professor from the National University of Singapore); researchers at public research institutes (*e.g.* Muvee, a video-editing software technology spin-off from I2R); and university students (*e.g.* tenCube, a mobile security company founded by NUS students, recently acquired by McAfee).

8.4.2. Higher education institutes

Prior to the establishment of the public research institutes, public-sector R&D was mainly conducted in the higher education sector. Higher education R&D (HERD) accounted for almost one-third of GERD in the mid-1980s. Subsequent to the formation of the PRIs, HERD's share of GERD almost halved, to 15.8% in 1995. Although the absolute amount of R&D expenditure in the higher education sector continued to rise, from SGD 193.4 million in 1995, to SGD 338.3 million in 2000, to SGD 478.0 million in 2005, HERD's share of GERD continued to fall to 11.2% in 2000 to 10.4% in 2005. In recent years, however, the higher education sector's share of national R&D expenditure rose, with HERD reaching SGD 968.1 million in 2010 (14.9% of GERD). The shift towards basic research with the implementation of recent government strategic plans is also evident, with expenditure on basic research in the higher education sector increasing from SGD 115.1 million (34% of HERD) in 2000 to SGD 544.5 million (56.2% of HERD) in 2010 (Table 8.14).

Table 8.14. Higher education R&D expenditure and manpower, Singapore, 1995-2009

Year	Total R&D expenditure (SGD million)	RSEs (FTE)	Basic R&D expenditure (SGD million)	% share of HE basic R&D expenditure
1995	193.4 (15.8)	1 543.8 (18.5)	67.2	34.7
2000	338.3 (11.2)	1 741.3 (15.4)	115.1	34.0
2005	478.0 (10.4)	2 418.9 (13.8)	254.5	53.2
2009	854.3 (14.1)	4 365.6 (19.0)	462.4	54.1
2010	968.1 (14.9)	4 825.0 (20.0)	544.5	56.2

RSEs (FTE) – R&D scientists and engineers (full-time equivalent).
Note: Figures in brackets are percentages of national total.

Source: National Survey of R&D in Singapore (various years); National Science & Technology Board (1990-2000); Agency for Science, Technology & Research (2001-10).

NUS has the most publications of local universities (173.2 per 100 faculty vs. 139.6 for NTU and 36.4 for SMU). The publication output of NUS per 100 faculties compares favourably with that of other universities in the region. It is on par with Japan's Kyushu University (170.8 per 100 faculty), and somewhat higher than Tohoku and Tokyo University, China's Tsinghua University, Mahidol University (Thailand) and Multimedia University (MMU, Malaysia); it was out-performed by Hong Kong University of Science & Technology (HKUST), the National Taiwan University and the Korea Advanced Institute of S&T (KAIST). NTU's publications per 100 faculty is somewhat below that of

Tsinghua University, while SMU's is on par with MMU. In terms of quality of papers, NUS, with 10.6 citations per paper between 2000 and 2010, is outperformed by Tokyo University (15.1 citations per paper), but is generally on par with the other Japanese universities and HKUST. NTU, with 6.7 citations per paper for the same period, performs less well in comparison with the other universities; it is comparable with Tsinghua University.

A total of 316 US-issued patents have been granted to Singapore universities, or 5.2% of the national total. Of these, the majority come from the NUS (a total of 266 patents, or 4.3% of the national total). Patenting is a relatively recent activity in the universities, with the bulk (87%) issued since 2000. This reflects in large part the government's emphasis on the "third mission" of universities and the increasing prominence that has been given since the early 2000s to their role in stimulating economic growth through industrially relevant research, technology commercialisation, high-technology spin-offs, attraction of foreign talent and the task of inculcating entrepreneurial mind-sets in their graduates. Among the local universities, NUS has come nearest to fulfilling these roles. In 2001, NUS created a new division called NUS Enterprise. Tasked with giving NUS education and research a more entrepreneurial dimension, the head of the university set out to make the division the primary organisational vehicle for co-ordinating and managing all major university activities related to technology commercialisation and entrepreneurship promotion within NUS (Wong et al., 2007).

8.4.3. Public research institutes

The main group of public research institutes (PRIs) in Singapore are those managed by A*STAR. In addition to these, STI activities are carried out in various other government agencies. In total, PRIs and the government sector accounted for SGD 1.5 billion of GERD in 2009 (24.2% of the national total), just over half of which (SGD 780.9 million) was accounted for by the A*STAR PRIs (Table 8.15). In terms of S&T manpower, PRIs employed 4 460 RSEs (FTE), or 19.4% of the national total in 2009, of which 60.5% (2 700 RSEs) are in the A*STAR PRIs. PRIs have generally performed about one-quarter of the R&D in Singapore over the last decade (about 13% for the A*STAR PRIs), and employed about one-fifth of the RSEs since 2005 (down from about one-quarter in 2000) (around 12% for the A*STAR PRIs).

Table 8.15. Public research institutes' R&D expenditure and manpower: Singapore 2000-09

		1995	2000	2005	2009
Total R&D expenditure (SGD million)	Govt+PRI	291.8 (21.4)	805.2 (26.8)	1 072.9 (23.4)	1 464 (24.2)
	PRI	181.4 (13.3)	381.4 (12.7)	630.1 (13.8)	780.9 (12.9)
R&D scientists and engineers (full-time equivalent)	Govt+PRI	1 208.5 (14.5)	775.8 (24.5)	3 297.1 (18.8)	4 457.1 (19.4)
	PRI	773.9 (9.3)	1 618 (14.3)	2 009.0 (11.5)	2 698.2 (11.7)
Basic R&D expenditure (SGD million)	Govt+PRI	83.2	147.9	326.8	365.1
	PRI	60.9	139.1	307.0	318.1
Basic R&D as % of sectoral expenditure	Govt+PRI	28.5	18.4	30.5	24.9
	PRI	33.6	36.5	48.7	40.7

Note: Figures in brackets are percentages of national total.

Source: National Survey of R&D in Singapore (various years); National Science & Technology Board (1990-2000); Agency for Science, Technology & Research (2001-09).

In total, A*STAR oversees 21 research institutes, centres and consortia. The initial missions of the PRIs were to develop the applied technological capabilities deemed critical to support Singapore's existing major industries. In addition, some of the institutes were given the task to develop core competencies in new generic technologies (*e.g.* molecular and cell biology and wireless communication technologies) which are needed to attract and grow the new high-technology industries that did not exist in Singapore at the time. Despite this, and the fact that most PRIs had begun to shift their R&D portfolios from more downstream applied R&D to more upstream R&D, the focus on applied R&D continued into the late 1990s. As can be seen in Table 8.15, the share of expenditure on basic R&D increased from about one-third in 1995 to almost half in 2005, before falling to 40.7% in 2009. Similarly, there was increased patenting over this period, with the average annual patents increasing ten-fold between 1995-1999 (average of three patents issued a year) and 2000-04 (average of 32 patents issued a year), before increasing again in 2005-09 (average of 42 patents issued a year).

While the rapid growth of the PRIs did result in increasing public R&D spending and manpower, their changing role over time may have led to a number of problems. First, with the new T21 initiative, the PRIs were asked to spin off high-technology start-ups as well. This new objective appears to have been hastily implemented without sufficiently working out the potential conflicts with the prior objective of licensing technologies to existing companies: some PRIs began to focus on keeping the technologies they developed from being licensed, and instead encouraged their own R&D staff to start companies to commercialise the technologies. Second, there was limited co-operation between individual PRIs. While the linkages between the public R&D sector and the tertiary manpower development sector were generally quite strong – most of the PRIs are housed within the universities, and many of the principal investigators of R&D programmes at these PRIs are drawn from the academic staff of the universities – there were no incentives for PRIs to co-operate among themselves, either in research or in management functions such as gathering technology/market intelligence and intellectual property management.

These gaps have been addressed somewhat, first with the establishment of a number of research partnerships and research consortia to facilitate co-operation among research groups, such as the Singapore Bioimaging Consortium and the Singapore Stem Cell Consortium. Second, a central marketing and commercialisation arm was established within A*STAR. Exploit Technologies was created to identify, protect and exploit promising IP created by A*STAR's research institutes. Its responsibilities include facilitating the IP management process (*i.e.* the protection of inventions through patents and copyrights, etc.), analysing the strength of resulting IP and the markets in which they can be commercialised, and working with companies to commercialise the technologies. Further, a Commercialisation of Technology Fund (COT) administered by Exploit was launched in 2003 to bridge the gap between technologies invented at the research laboratories and enterprises' needs. COT is an internal gap funding mechanism to allow A*STAR's research institutes to carry out technology development and refinement based on their inventions and proof-of-concept prototypes over a period of three to 12 months in order to translate technology disclosures into licensable IP. Companies have the option to license when technology is proven but no obligation if the project fails.

8.4.4. Linkages between innovation actors

Linkages between MNCs and local firms (especially those in industries supporting the MNCs) improved rapidly from the late 1980s. A number of studies (Wong, 1992, 1999) indicated that the supplier-buyer relationship between the local industries and their MNC buyers had contributed significantly towards inducing technological development among the former. This happened less through the unilateral efforts of the MNCs to transfer technology to their vendors and suppliers than through processes of indirect exposure and disclosure of technological information to suppliers. Moreover, the existence of a long-term supplier-buyer relationship helped to reduce the suppliers' perceived market risks of investing in new technology, and thus helped to induce a higher propensity to invest in new technologies among the local supporting industries. Various studies (Wong, 1999; Soon, 1992) indicate that the government has played an effective role in facilitating the innovation links between MNCs and their local supporting industries, through programmes such as the Local Industry Upgrading Programme (LIUP). For example, Wong (1999) documented how the LIUP programme implemented by EDB contributed to the rapid technological development of local precision engineering firms that supplied the major magnetic hard disk drive MNCs. More recently, through the strategy of developing industry clusters, EDB has facilitated the formation of joint ventures and technology strategic alliances between Singaporean firms and major foreign MNCs in a number of high-technology industries, including semiconductor wafer fabrication and chemicals (Wong, 2003).

Inter-firm innovation linkages among local firms appear to be weak, however, and there are few reported cases of joint R&D among local firms. The kind of industry-wide R&D consortia found in Chinese Taipei and Japan are largely absent in Singapore. There have also been few reported cases of industry-wide collaboration in technology deployment. Overall, there appears to have been little policy attention given to promoting collaboration on innovation among local enterprises in Singapore, compared to Chinese Taipei and Finland (Wong and Singh, 2008). The dominance of inter-firm innovation linkages with MNCs has no doubt contributed to this situation.

Linkages between the universities/PRIs and the enterprise sector were relatively weak until the late 1990s, primarily owing to the long gestation time needed for the PRIs to establish core capabilities relevant to industry and the previous lack of focus on industrially relevant research at the universities. Moreover many MNCs looked to their headquarters and associate companies rather than local PRIs/universities for their technological needs. They also preferred to tap public R&D subsidies offered for in-house R&D, so that they would own the intellectual property. As for local firms, many are SMEs that lack the resources and capabilities to take upstream technologies from universities and try to commercialise them (Wong, 1999). However, linkages between universities and enterprises have strengthened since the early 2000s, with universities' increasing emphasis on commercialising technologies and on collaborative R&D with industry, particularly with MNCs. The 2005 IP and Innovation Survey found that, among innovating firms engaged in innovation collaboration, the most common local partners were higher education institutions (HEIs) and government/PRIs (52.5% and 50.8% of such firms had collaborated with HEIs and government/PRIs, respectively) (Table 8.16) (Wong et al., 2007, 2006). Moreover, by 2010, Singapore ranked sixth in the world on the indicator used to measure university-industry R&D collaboration in the 2010-11 *Global Competitiveness Report* (Table 2.1).

Table 8.16. Innovation collaboration partners in Singapore

Innovation collaboration partners	% of innovating firms with innovation collaboration		
	Manufacturing	Services	All sectors
Universities or other HEIs	58.1	46.4	52.5
Government/public research institutes	51.6	50.0	50.8
Suppliers of equipment, materials, components or software	41.9	21.4	32.2
Clients or customers	22.6	32.1	27.1
Other enterprises within enterprise group	29.0	3.6	16.9
Commercial laboratories/R&D enterprises	25.8	7.1	16.9
Consultants	12.9	17.9	15.3
Competitors and other firms from same industry	9.7	3.6	6.8

Source: Wong et al. (2006).

Nevertheless, by tracing the backward citations of patents granted to local firms, Wong et al. (2009a) found that local universities/PRIs played a relatively small role as scientific and technological knowledge sources of invention. Only 0.1% of citations from local Singapore firms were made to patents owned by local universities/PRIs. Similarly, only 2.8% of publications cited in local firms' patents were authored by researchers in local universities/PRIs.

8.5. Human resources

A distinctive feature of the development of Singapore's NIS is the early and sustained emphasis on building human resource competencies geared to absorbing and assimilating new technologies. While the expansion of education at all levels has been a priority public expenditure focus of the government throughout the years, the relative emphasis has changed over time. In addition, the government has played critical roles in promoting industrially relevant workforce development. This has included the establishment of vocational and technical training institutes, polytechnic education and the setting up of specialised technical training programmes, many of them collaborative ventures between the government and reputable overseas partners (MNCs and highly regarded foreign industrial training institutes).

Singapore has a well-developed tertiary education system, composed of universities, polytechnics that were set up to train middle-level professionals to support the technological and economic development of Singapore, and a network of ITEs (institutes for technical education) with a host of industrially relevant vocational training programmes (Wong, 2003; MOE website). There are currently three universities, two of which are public (the National University of Singapore and the Nanyang Technological University, NTU) and one is private (Singapore Management University, SMU). A fourth, the Singapore University of Technology and Design (SUTD), which will involve collaboration with MIT and Zhejiang University, will commence classes in 2012. There are also currently five polytechnics and three ITEs. In addition, the Singapore government has actively attracted several leading universities to operate branch campuses in Singapore (Olds, 2007), including INSEAD, University of Chicago Business School, James Cook University, and the New York TischAsia School of the Arts. There are also a large number of part-time tertiary diploma and degree programmes operated in Singapore by various overseas universities on a distance learning basis, although most of these programmes concentrate on non-technical fields; the aggregate number of technical graduates from these private programmes is still relatively small and confined largely to IT-related fields.

Overall, Singapore appears to have done well in increasing the supply of technical graduates over the years. The annual flow of graduates with S&T qualifications increased from about 8 000 polytechnic students and 4 500 university students a year in the mid-1990s to close to 16 000 polytechnic students and 10 000 university students in 2009 (*i.e.* 68.4% and 52.8% of polytechnic and university graduates, respectively) (Table 8.17). The proportion of S&T graduates who hold university degrees also increased slightly from about 35% to 39% curing the same period.

Table 8.17. Graduates from S&T courses in local institutes of higher education, Singapore, 1995-2009

Year	Polytechnics				Universities			
		S&T courses				S&T courses		
	Total number of graduates	Total in S&T courses	With advanced diploma	% in S&T	Total number of graduates	Total in S&T courses	With postgraduate degree	% in S&T
1995	11 851	7 934	572	66.9	9 029	4 376	597	48.5
1996	12 759	8 755	489	68.6	9 706	4 513	709	46.5
1997	13 875	9 437	569	68.0	10 474	5 062	999	48.3
1998	15 132	10 115	594	66.8	11 496	5 636	1 190	49.0
1999	15 781	10 836	747	68.7	12 051	6 155	1 495	51.1
2000	16 371	11 046	816	67.5	13 020	6 892	2 100	52.9
2001	17 524	12 182	1 042	69.5	14 098	7 563	2 457	53.6
2002	18 306	12 785	1 217	69.8	14 901	8 189	2 814	55.0
2003	17 675	12 088	1 088	68.4	14 658	8 664	2 602	59.1
2004	19 203	13 587	914	70.8	14 944	9 372	2 833	62.7
2005	19 374	13 917	894	71.8	15 559	9 413	3 275	60.5
2006	19 107	13 753	751	72.0	15 794	9 271	2 977	58.7
2007	19 548	13 676	707	70.0	17 061	9 769	2 965	57.3
2008	21 493	15 158	808	70.5	17 707	9 793	3 125	55.3
2009	22 924	15 689	1 231	68.4	18 629	9 829	3 190	52.8

Data classified according to SSEC2000. S&T courses include:

- For polytechnic courses: science & related technologies; health sciences; IT and engineering sciences.
- For university courses: natural, physical & mathematical sciences; medicine; dentistry; health sciences; IT and engineering sciences.

Data includes both full-time and part-time diploma/degree courses, as well as advanced diploma and higher degree.

Source: Wong et al. (2009b), *Yearbook of Statistics 2010*.

Nevertheless, Singapore still lacks a sufficient number of highly skilled knowledge professionals, especially RSEs. Among RSEs engaged in R&D activities in Singapore, the proportion with Masters/PhD degrees remained relatively low (around 40-44% during the 1990s and early 2000s, though it subsequently increased to 49.4% in 2009. The IMD World Competitiveness Yearbook (WCY) has generally rated the availability of skilled technical labour in Singapore as behind most of the advanced OECD countries, although its ranking has improved from the mid-2000s. In some ways this relative lack of RSEs is to be expected given Singapore's small size and thus limited manpower pool. However it is a major constraint to the future development of its NIS, given the critical mass of science and technology manpower needed for its high-technology industrial drive, especially in the life sciences (Wong and Singh, 2008).

One means by which the government is trying to address this issue is by giving greater emphasis to the PRIs' role in training the workforce. Especially since the Third National Science and Technology Plan (2001-05), various new programmes have been launched which emphasise human resource development, including new scholarship schemes for postgraduate education at leading universities overseas, a scheme for postgraduate research students to undertake internships at various local research institutes, and the funding of PRI researchers attached to local high-technology firms to develop their technology commercialisation experience.

Another key aspect of Singapore's competence-building policy is its policy towards attracting foreign talent. To supplement the local supply of skilled labour, the government has consistently adopted a liberal immigration policy to attract overseas skills. In 2006, foreigners comprised 30.9% of the total employment pool (Committee on Global Science and Technology Strategies and their Effect on US National Security 2010). While precise statistics on the in-migration of qualified technical labour are unavailable, the annual R&D surveys indicate that foreigners typically account for almost one-fifth of the total pool of RSEs in Singapore in recent years (A*STAR, various years). Even this, however, is a gross under-estimate, as it does not include the sizeable number of people offered permanent residence who were not counted separately. Similarly, over one-third of Singapore's IT workforce in the late 1990s was found to consist of foreigners. The proportion is even higher in the emerging life sciences. While Malaysia was a major source of foreign talent in the early years, China and the Indian sub-continent have provided the bulk of the foreign technical professionals working in Singapore since the mid-1990s (Wong and Singh, 2008).

8.6. SWOT analysis

Based on the foregoing analysis, several strengths and weaknesses of Singapore's NIS can be identified, along with future opportunities and threats. These are summarised in Table 8.18.

In terms of its strengths, Singapore's national innovation system is relatively well endowed. The country is politically stable and long-term policy is oriented to the development and exploitation of science, technology and innovation and it has attracted foreign investment and talent. It has a high-quality education system and internationally recognised universities that have recently strengthened their links with industry. It has an excellent logistics infrastructure and its ICT infrastructure is better developed than in most of its regional competitors and is improving rapidly. A strong intellectual protection regime is also now in place. There is a notable MNC presence, with some firms increasingly conducting advanced R&D activities. These include a strong base of electronics and ICT manufacturing companies and a growing core of pharmaceutical and biomedical firms, around which there are emerging clusters of supporting engineering and service firms. Trade links with countries such as the United States, Japan and Malaysia have dominated historically, but China (including Hong Kong) is now its leading trade partner.

Although Singapore is strong compared to many of its regional neighbours, it still lags behind leading-edge competitors such as Korea, Chinese Taipei and Hong Kong because of relatively late investment in advanced R&D and the slower development of domestic innovation capabilities and advanced ICT infrastructures. There is a small base of local high-technology firms compared to its leading competitors, and expansion is limited by a small domestic market, a fragmented regional market and lack of a critical mass of advanced lead-user firms willing to trial the products of new start-ups. Moreover, despite the quality of Singapore's education system, there is still an insufficient supply of scientific and technical manpower. Attractive employment prospects in MNCs and government also provide potential entrepreneurs with strong alternative career paths.

Opportunities nevertheless exist for Singapore to catch up and even surpass its strongest competitors, especially in terms of developing and strengthening its role as regional innovative hub in emerging technologies such as interactive and digital media (IDM), clean technologies, water technology and biomedical technologies. Its universities have a global orientation and are in a good position to attract leading talent from overseas and to forge strong links both with researchers abroad and, increasingly, with locally based firms. Universities and public research institutes look set to become important providers of cutting-edge technologies capable of being commercialised by Singapore-based firms and entrepreneurs, and burgeoning markets in China, India and elsewhere in Southeast Asia offer considerable opportunities for innovative products and services adapted to their cultural needs and tastes.

Threats to future development are both internal and external. Internally, growing income inequality could create political instability and affect both continued opening up of the economy and expansion of public support for cluster developments designed to attract foreign talent and investment. Externally, new, expanding markets in China and India offer not only opportunities but also the threat of increased competition from leading-edge suppliers, especially in some of the niche technology areas that Singapore is targeting. Continued fragmentation of Southeast Asian markets could also prevent Singapore from playing its role as an innovation hub in an integrated Southeast Asian market.

Table 8.18. Summary SWOT (strengths, weaknesses, opportunities, threats) analysis

Strengths	Weaknesses
• Clean, stable government, rule of law, business-friendly environment, and long-term strategic vision to develop STI • Well-regarded primary and secondary education system, with high English and regional language capability Relatively high-quality university education system with global orientation and growing research capabilities • Recently improved linkages between firms and universities • Sound infrastructure and policy incentive framework for rapid exploitation of new technology • Strong IP protection regime and improving supporting IP services • Broadband ICT infrastructure deployment has been faster than in most regional competitors • Openness to foreign investment and environment conducive to attract foreign talent from elsewhere • Strong base of foreign MNCs conducting increasingly advanced R&D activities • Strong base of advanced electronics and ICT manufacturing by foreign MNCs creating a strong cluster of supporting engineering and services industries • A growing base of pharmaceutical and biomedical manufacturing and water technology companies • Strong business and cultural links to the two giant emerging markets in Asia – China and India	• Insufficient scientific and technical manpower • Relatively late investment in advanced R&D; • Small base of local high-technology firms compared with economies like Chinese Taipei and Korea • Small domestic market and lack of critical mass of advanced lead-user firms • Relatively poor linkages within private sector and, until recently, between private sector and universities/ PRIs • Underutilisation of the IP protection regime • Broadband ICT infrastructure deployment has been slower than in leading regional competitors • Social and cultural norms and high opportunity costs of foregoing alternative careers can discourage entrepreneurial pursuits among the highly educated; • Fragmentation of Southeast Asian markets reducing the ability of local high-technology firms to grow by scaling to the regional markets

Opportunities	Threats
• Opportunities to strengthen role as regional innovation hub in emerging technologies such as IDM, clean technologies, and biomedical technologies through continuing public funding support • Strategic cluster development policies to attract foreign R&D investment • World-class, globally oriented universities are in position to attract top talent from overseas and to develop collaborative R&D and educational links with leading universities in the world • Rapidly growing volume of cutting-edge technology from HEIs and PRIs • Potential to leverage proximity and cultural links to major, fast-growing regional emerging markets (China, India, ASEAN) Potential role to become a leading regional education and training, venture financing, and IP services hub	• Cost pressures due to growing competition from other emerging markets, especially China and India • Vulnerability to volatility in the global economy, given Singapore's openness • Increasing competition from China and India in developing hubs for high-technology sectors such as biomedical technologies • Continuing fragmentation of Southeast Asian markets, coupled with protectionist tendencies by some regional economies that hamper pan-Southeast Asian market integration High dependence on foreign S&T professionals, many of whom may be lured back to their home economies as these become more attractive • Growing income inequality and potential political backlash against continuing opening up of economy to foreign talent

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Chapter 9

Thailand innovation profile

Thailand has joined the ranks of middle-income countries, but further growth will have to come from innovation and efficiency improvements in the manufacturing and services sectors. Since the 1980s, economic performance has depended on foreign investment and exports. Thailand has become a key production base for global automotive and electronics firms from Japan, the United States and Europe. The agricultural sector employs over 40% of workers and Thailand continues to be one of the world's largest rice exporters. Services carry great potential for growth, but tourism has been threatened by political instability. Economically, Thailand is in a "middle-income" trap. On the one hand it is under pressure from lower-cost but more dynamic economies such as China, India, Viet Nam and Indonesia; on the other, it is threatened by the more technological, learning-intensive economies of the original four Asian Tigers (Singapore; Korea; Hong Kong, China; and Chinese Taipei).

The government has adopted a dual track policy to enhance the capabilities of Thai firms while increasing international competitiveness by expanding foreign investment, exports and tourism. The cluster concept, focused on automobiles, food, fashion and software, underpins industrial and innovation policy. Programmes to encourage R&D and technology development have had limited results. Thailand has derived few technological capabilities from multinational firms, which primarily transfer technology embodied in equipment. Levels of R&D spending, S&T workers and patents are below those of Thailand's principal competitors.

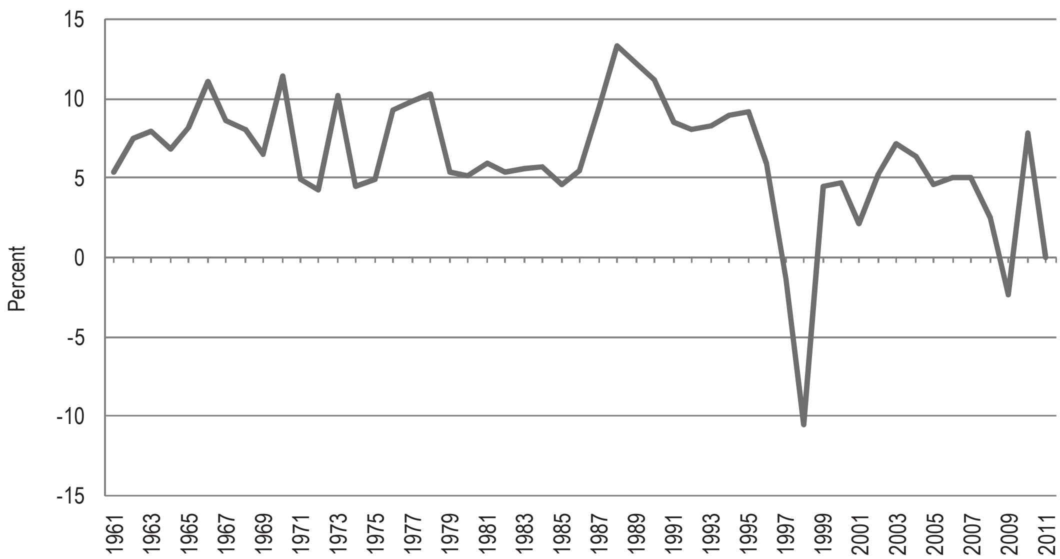
Thailand can boost performance in the long term by improving the skills level of the labour force, investing in ICT infrastructure, and better co-ordinating and implementing S&T policies. Upgrading the country's innovative capabilities depends, in part, on enhancing the quality of teaching and research at Thai universities, investing in targeted public research facilities, and providing R&D incentives to foreign and local firms. To move beyond labour-intensive parts production and assembly, firms in Thailand's manufacturing sector will need to strengthen collaborative innovation linkages.

9.1. Macroeconomic performance and framework conditions for innovation

9.1.1. Performance and structure of the economy

Thailand is the second largest economy in Southeast Asia after Indonesia and is now a middle-income country. Growth in gross domestic product (GDP) averaged 7.7% between 1961 and 1996 (Figure 9.1). The Asian financial crisis of 1997/98 led to a sharp recession and thereafter Thailand experienced a slowdown in economic growth compared to the pre-crisis years, with annual growth averaging less than 5% a year between 1999 and 2008. Then the global economic crisis contributed to a contraction in GDP of 2.3% in 2009. A resurgence of economic activity led to 7.8% growth in 2010, but in 2011 the economy suffered as a result of severe flooding which caused widespread damage and economic output collapsed in the fourth quarter. As a result, growth was 0.1% in 2011 but is predicted to rebound to 4.5% in 2012 (World Bank, 2012a).

Figure 9.1. Thailand annual GDP growth, 1961-2011

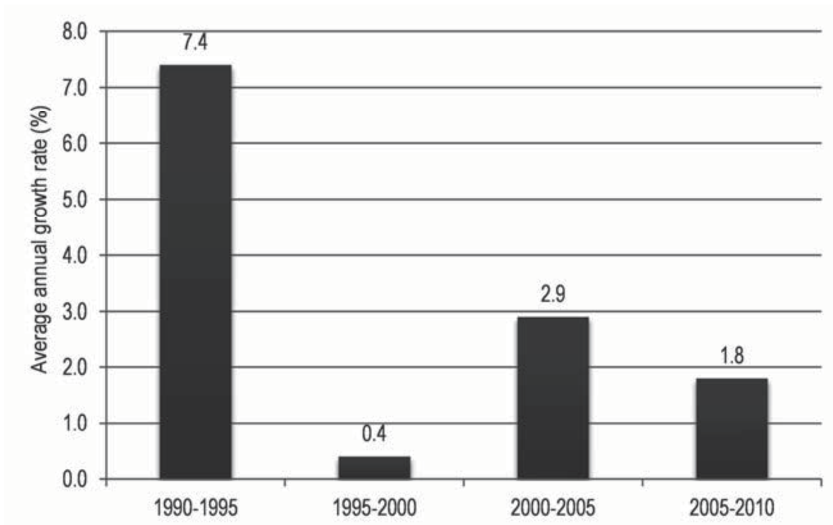


Source: World Bank World Development Indicators.

Thailand's growth has been driven by increasing foreign investment and the re-allocation of resources among economic sectors. Modest improvements in labour productivity since 1995 (Figure 9.2) and total factor productivity (TFP) since 1990 (Figure 9.3) have stemmed largely from the reallocation of labour and capital inputs from the agricultural sector to manufacturing and services. However, productivity has grown slowly in the manufacturing sector and foreign technology spillovers embodied in international trade and investment have played a limited role. Weak productivity growth in services is linked to the lack of competition (World Bank, 2010a).

Beginning in the 1980s, Thailand's economy was built on open foreign investment policies and encouragement of the private sector. Prior to the Asian financial crisis, economic growth was led by manufacturing, based on abundant and inexpensive labour and natural resources. However, output fell sharply in 1997-98, leaving millions unemployed. Thailand sought to regain economic momentum in 2001 by embracing a "dual track" economic policy that combined increased domestic activity with traditional promotion of open markets and foreign investment (Intarakumnerd, 2010). The 11th Economic and Social Development Plan (2012-16) focuses on creating a knowledge economy and sustainable society.

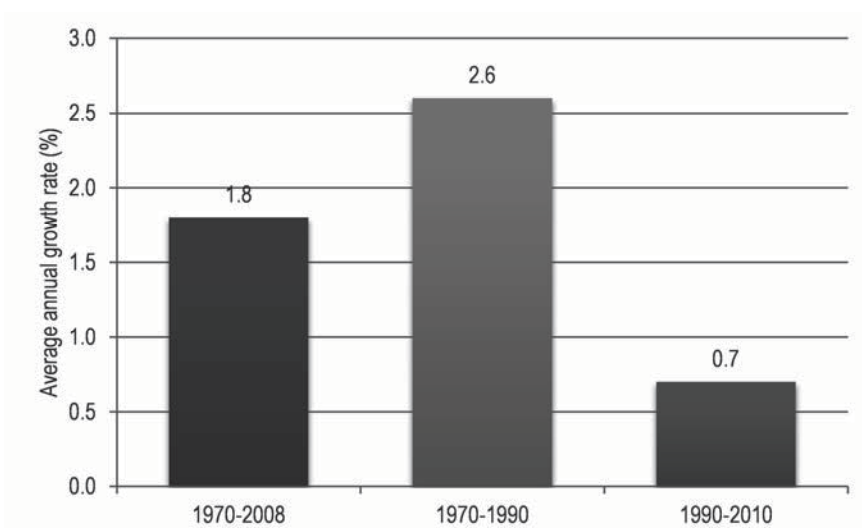
Figure 9.2. Trends in labour productivity growth, Thailand, 1990-2010



N.B. Average annual growth rate of GDP at constant basic prices per hour, using 2005 PPPs.

Source: APO (2012).

Figure 9.3. Trends in total factor productivity (TFP) growth, Thailand, 1970-2010



Source: APO (2012).

Poverty levels have decreased markedly in the past quarter century, although poverty remains high in the northern provinces. Vulnerable households suffered from the global economic crisis through a decline in agricultural prices and softer labour markets, and the percentage of the population below the national poverty line increased in 2008. There is more poverty among the elderly, who work primarily in agriculture and will represent over 17% of the population by 2020. Safety nets can help ensure that the benefits of growth are shared more equally across the population. The Thai government has an ambitious plan to double the household income of the poor in nearly 3 000 villages by 2012. Further land reform, combating political and economic elitism and corruption, and steps to ensure a more equitable distribution of wealth are needed as a foundation for growth (World Bank, 2010a).

Thailand's development has been accompanied by sizeable changes in the structure of the economy. From being a major rice exporter it has become a main production hub of multinational corporations in the automotive and electronic industries. The share of value added accounted for by industry has more than doubled, from 21% in 1970 to 44% in 2011, while the share of the agricultural sector fell from 23% to 12%, with services accounting for the remaining 44% (World Bank, 2012c).

Thailand's recovery from the 1997 Asian financial crisis relied mainly on increasing exports, which now account for more than two-thirds of GDP. Since the 1970s, the share of primary products in exports fell by 70% while that of electronics, automotive and other manufactures increased by 57%. Export growth has been driven primarily by demand from Thailand's regional trading partners. In 2010, export values in US dollars surged by over 40%, mainly in motor vehicles and parts, electronics and electrical appliances. The United States and Japan continue to be major export destinations, but growth in trade with China (both imports and exports) grew substantially in nominal terms from 2000 to 2010 (Table 9.1) with China becoming the lead export destination by the end of the period.

The electronics industry is the largest exporter, and hard disk drives contribute 32% of the sector's total production value. Most firms are original equipment manufacturers (OEMs) for multinational enterprises. In 2006, Thailand led world rankings of hard disk drive exporters with 48% of the global market. However, the industry's domestic value added remains low (AIT/Asia Policy Research, 2003). Other main exports are automobiles and automotive parts, which account for 12% of GDP. Rather than developing indigenous brands, Thailand is a key production base for global automotive firms from Japan, the United States and Europe. It ranks 13th among countries producing motor vehicles and is predicted to be one of the top ten producers by 2015 (World Bank, 2010a).

Around 42% of Thailand's labour force was still employed in agriculture in 2009, a decrease from around 70% in 1980. The agricultural sector has shifted from labour-intensive and traditional methods to more modern production techniques. Rice remains the country's most important crop. Other agricultural commodities produced in significant amounts include fish and fishery products, tapioca, rubber, grain and sugar. Exports of processed foods such as canned tuna, pineapple and frozen shrimp are on the rise.

Thailand's services sector is also growing, particularly tourism, which contributes about 6% of GDP. Europeans constitute the largest percentage of visitors from high-income countries. Although tourism decreased in 2009, estimates were revised upwards for 2010 and beyond owing to the easing of the global financial crisis, the vigorous growth of the Chinese economy, the relatively stable political situation following the 2008-09 political crisis, and a lesser impact than feared from the 2009 flu pandemic. Thailand remains a competitive tourist destination and a recovery in consumer spending in advanced economies will drive growth in this sector (Intarakumnerd, 2010), even though the volatility of the global financial situation once again threatens all economic development.

In terms of firm size and ownership, the economy is dominated by large multinationals, primarily Japanese, large state-owned domestic firms, and large family-owned domestic conglomerates, which together are the primary contributors to GDP. At the same time, Thailand has a sizeable number of small and medium-sized enterprises (SMEs), which account for 78% of employment, 43% of non-agricultural GDP and 30% of exports. Thailand's medium-sized enterprises account for a much smaller proportion of the SME population than in other Asian countries, an indication of barriers to growth (OECD, 2011).

Thailand's economic performance, which is based on manufacturing for export, has lagged behind competitors in the Southeast Asian region. In 2010, Thailand ranked 39th out of 142 countries on the World Economic Forum Global Competitiveness Index (WEF, 2011). Thailand's economic success is most directly threatened by competition in labour-intensive manufactured goods from countries such as India, China, Viet Nam and Indonesia. To compete in international markets, it must move to higher value-added activities while attracting foreign investment, increasing exports and improving the capabilities of domestic firms.

Table 9.1. Thailand's top trading partners, 2000-10

Rank	Thailand's top 10 export partners in 2000	USD million	Thailand's top 10 export partners in 2010	USD million
1	United States	14 725	China	21 473
2	Japan	10 105	Japan	20 416
3	Singapore	6 013	United States	20 231
4	Hong Kong, China	3 475	Hong Kong, China	13 132
5	China	2 816	Malaysia	10 567
6	Malaysia	2 805	Australia	9 370
7	Chinese Taipei	2 390	Singapore	9 009
8	United Kingdom	2 363	Indonesia	7 347
9	Netherlands	2 251	Viet Nam	5 845
10	Germany	1 639	Philippines	4 886
Rank	Thailand's top 10 import partners in 2000	USD million	Thailand's top 10 import partners in 2010	USD million
1	Japan	15 285	Japan	37 856
2	United States	7 292	China	24 239
3	Singapore	3 402	United States	10 751
4	China	3 369	Malaysia	10 709
5	Malaysia	3 342	United Arab Emirates	8 655
6	Chinese Taipei	2 890	Korea	8 057
7	Korea	2 164	Chinese Taipei	6 815
8	Germany	1 947	Singapore	6 294
9	United Arab Emirates	1 781	Australia	5 896
10	Indonesia	1 290	Indonesia	5 676

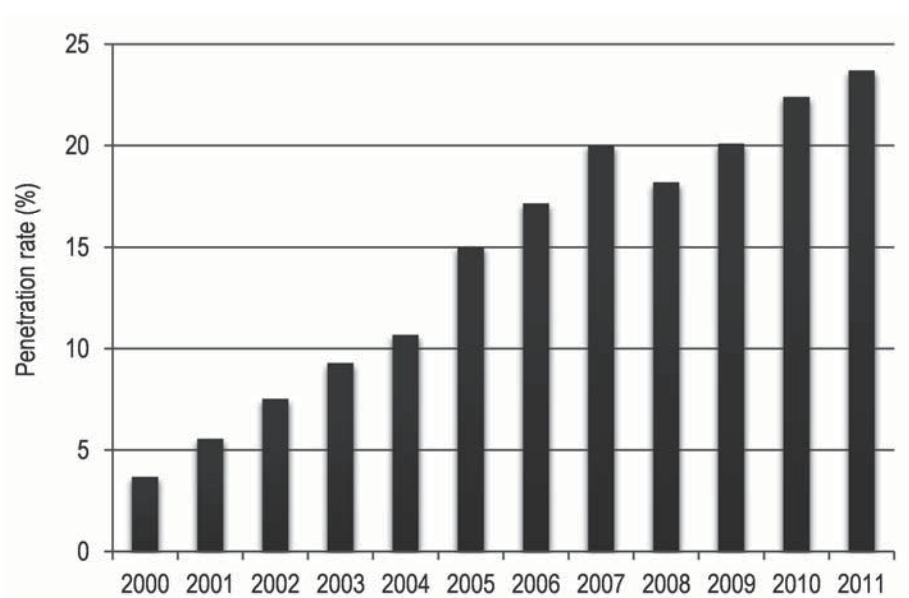
Source: UN Commodity Trade (Comtrade) Statistics Database.

9.1.2. Framework conditions for innovation

Increases in productivity and efficiency of resource use, which underpinned Thailand's transition to middle-income country status, are now less important than investments in education, infrastructure and entrepreneurs. Thailand's growing shortage of engineers and skilled technical personnel will limit future productivity growth. Secondary and tertiary education systems are not highly ranked and there are serious deficiencies in the training of workers in the private sector. Thailand has a substantial diaspora of skilled workers in other countries, but they have not been a source of local entrepreneurship or technical improvements (Liefner and Schiller, 2008).

Infrastructure for telecommunications, transport and electricity generation has been increasingly strained during the period of sustained economic growth. Thailand has not invested sufficiently in telecommunications infrastructure, and while broadband penetration (5.4 fixed broadband subscriptions per 100 inhabitants in 2011) and Internet use by business rose steadily over the last decade, with overall Internet penetration rising to nearly 24% of the population in 2011 (Figure 9.4), Thailand lagged considerably behind other countries in the region. In 2011 Singapore had an Internet penetration of 75% and Malaysia of 61% (ITU, 2011). The challenges appear to be institutional as well as technological. Legislation governing radio spectrum licensing in Thailand originally envisaged that information and communication technology (ICT) decisions would be made jointly by the National Telecommunications Commission (NTC) and the National Broadcasting Commission (NBC), but internal disagreements over relative authority have slowed investments (World Bank, 2010a).

Figure 9.4. Internet users per 100 inhabitants, Thailand, 2000-11



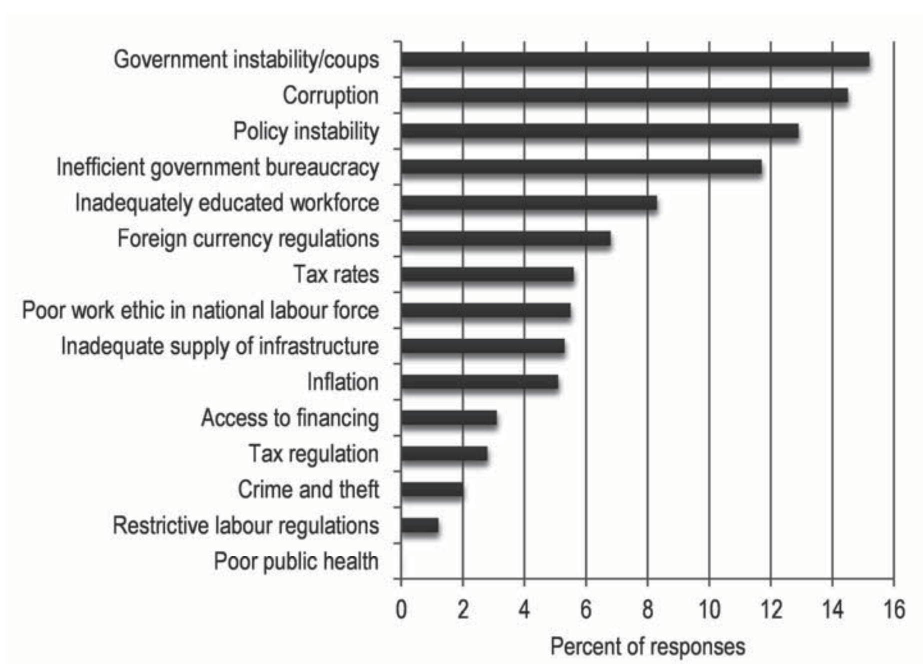
Source: ITU (2012), “World Telecommunications and ICT Database”, International Telecommunications Union, *www.itu.int/ITU-D/ict/statistics/.*

The current ICT master plan (2009-13) aims to strengthen ICT governance as well as ICT professionals and infrastructure. The Software Industry Promotion Agency (SIPA) was created in 2003 to support the small software industry and increase the ICT literacy of the Thai population. SIPA is currently co-operating with the Japan Industrial Promotion Agency and the Japanese Software Association to upgrade Thai programming resources and capabilities.

Barriers to entrepreneurship and the creation of innovative small firms persist. Recent political instability coupled with concerns about corruption and bureaucratic inefficiency have had a major impact on the contemporary business climate (Figure 9.5), but this should not overshadow structural problems: an inadequately educated workforce, limited access to capital and sub-standard infrastructure for further development.

The large number of SMEs in Thailand is mainly due to a lack of alternative job opportunities and deep labour market segmentation. Their distribution is very unequal across regions, with about two-fifths in the more prosperous Bangkok region, which has only one-tenth of the population. Most are not linked to multinational enterprises or integrated into global supply chains. There are large developmental gaps between SMEs in the centre of the country and those in the regions. The creation of innovative SMEs is hindered by inadequate education and training systems and limited access to financing (OECD, 2011). Thailand also compares unfavourably with countries such as Singapore in terms of the administrative hurdles facing prospective start-ups. However, Thailand ranks 17th overall on the World Bank's Doing Business index, ahead of Viet Nam, Malaysia and Indonesia, although it is only in 55th position on the indicators relating to starting a business (World Bank/IFC, 2012).

Figure 9.5. The most problematic factors for doing business in Thailand



Source: World Economic Forum (2012. Percentages represent the weighted results of a ranking of the five most problematic factors from a list of 15 by respondents to the WEF survey.

Thailand's financial support for industrial development is bank-based, but the commercial banks that finance most private-sector investment are reluctant to lend to risky start-ups. Industrial development banks set up by the government – the Industrial Finance Corporation of Thailand (IFCT), the SME Bank, and the Small Industry Credit Guarantee Corporation (SICGC) – have been largely ineffective in providing venture finance owing to overly bureaucratic procedures. Application processes are complicated and time-consuming, so that SMEs seek loans from informal sources where they can get credit more quickly. In addition, the maximum loan from these financial institutions is small and interest rates do not differ significantly from those of commercial banks (Intarakumnerd, 2010).

The Thai Venture Capital Association (TVCA) was set up in 1994. Half of its members are domestic and international private equity management firms; the other half give financial, accounting and legal advice. However, the venture capital market in Thailand primarily finances firms at the expansion or mezzanine stage rather than early start-up (Chairatana, 2006). The government has provided funding for the SME Venture Capital Fund, the Thailand Equity Fund and the Thailand Recovery Fund, and it is now considering tax incentives to promote more venture capital investment in Thailand.

The Market for Alternative Investment (MAI), a business unit of the Stock Exchange of Thailand (SET), was established in 1999 as a secondary market for trading SME shares. Although MAI requirements for initial public offering have been adjusted to promote SME entry, most small firms are below the minimum capitalisation level. In addition, the founding shareholders in family-controlled SMEs are reluctant to enact common stock issues that would dilute levels of ownership. The capacity of the MAI as a conduit for small business is limited, particularly in promoting knowledge-intensive start-ups (Intarakumnerd, 2010).

9.2. Innovation performance

Thailand's innovation performance is considerably below that of the leading high-income countries and increasingly weaker than that of other middle-income countries in Southeast Asia. It has one of the lowest levels of research and development (R&D) spending and R&D workers in the region, and continues to fall behind other middle-income countries. Thailand's gross expenditure on research and development (GERD) was 0.21% of GDP in 2007 (see Table 9.2), a decline on the figure in previous years and significantly less than Singapore's (2.61% in 2007) and Malaysia's (0.64% in 2006 and 0.82% in 2008). Thailand also has a much lower share of R&D financed by the private sector than other middle-income countries in the region, with just over 40% contributed by industry in 2006, mostly the large multinationals, compared to over 80% in Malaysia in the same year and over 60% in the Philippines in 2005. Public and private tertiary institutions and government research institutes account for 35% and 23% of R&D expenditures, respectively. The government's target is to increase R&D spending to at least 0.5% of GDP.

Table 9.2. Thailand's R&D performance: selected R&D indicators

Indicator	Year	Value
GERD as % of GDP	2001	0.25
	2007	0.21
GERD per capita (USD PPP)	2001	13.2
	2007	16.5
GERD by business sector (%)	2001	39.2
	2007	45.0
GERD by business sector source of funds (%)	2002	36.8
	2005	48.7
Total researchers (FTE)	2001	17 710
	2007	21 392
Researchers per million	2001	277
	2007	316
Technicians per million	2001	111
	2007	140
Female researchers (%)	2009	50.3
Female professionals & technical workers (%)[1]	2009	53.0

1. Calculated from UNDP Human Development Report, 2009.

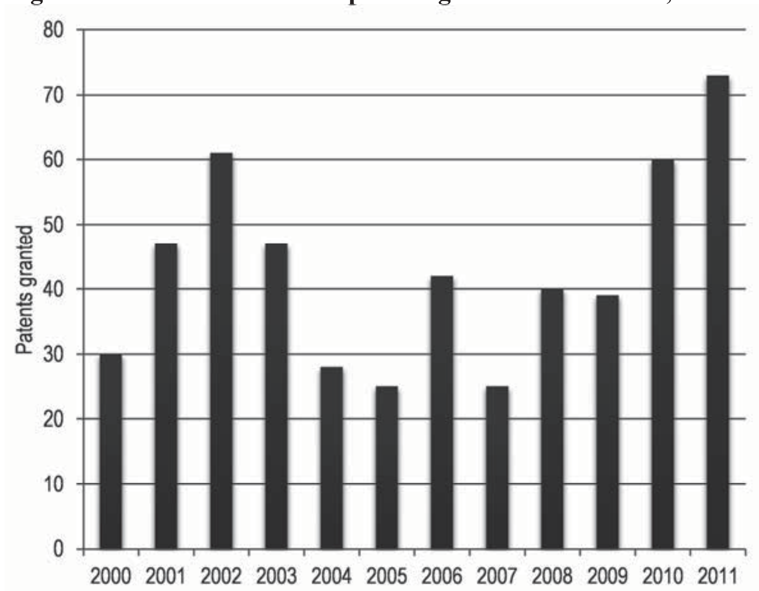
Source: UNESCO Statistical Unit, 2011.

An innovation survey by the National Science and Technology Development Agency in 2003 found that only 6% of domestic firms invest in R&D, primarily to improve production processes rather than to engage in product innovation. Thai firms in the automotive, electronics and food processing industries focus on labour-intensive and lower-technology areas and rely more on labour-cost advantages and lower overheads to compete in the Southeast Asian region. Few firms are attempting to move up the value chain by investing in R&D to stimulate innovation and enhance their technological capability (Abhinorasaeth, 2007).

Partly as a result of its low R&D intensity, Thailand has a relatively low patents per capita ratio, about half that of Malaysia. From a very low base in the 1980s, the total number of domestic patents granted has risen to over 2000 per annum (DIP, 2012). Around two-thirds of the patents issued by the Thai Department of Intellectual Property (DIP) in 2011 were to foreign firms, although that has fallen from an average of 83% in the 1990s. In terms of patents registered at the US Patent and Trademark Office (USPTO), numbers fluctuated around a low mean over the period 2000-11 (Figure 9.6), considerably behind Singapore and Malaysia. In the electronics sector, Thai firms that are second- or lower-tier suppliers do not produce patented products or processes and less than 1% of domestic patents are awarded to Thai nationals, mostly in universities. In the automotive sector, most patents are awarded to Japanese carmakers and their subsidiaries. About 12% of automotive patents were awarded to Thai nationals in recent years, mostly for non-functional accessories. Domestic patents are mainly granted for consumer goods and equipment, food processing, medical technology and chemical engineering (Intarakumnerd, 2006a).

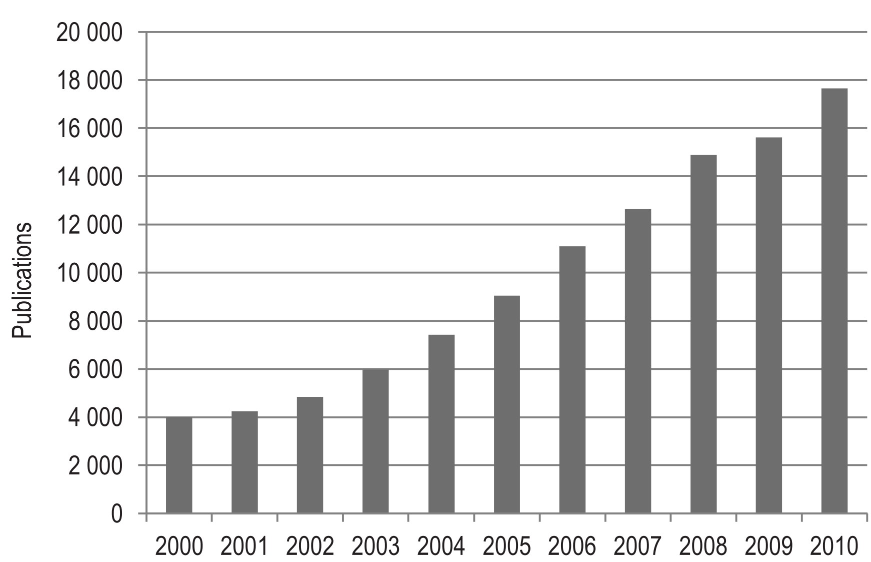
Thailand performs better in terms of scientific publications. The number of scientific publications increased from 4 008 in 2000 to 17 646 in 2010, more than a four-fold increase (Figure 9.7). However, from a similar base Malaysia overtook Thailand in terms of total publications in 2009. Publications have grown across the board but nanosciences have been the fastest growing field in recent years. In terms of international collaboration, 43% of papers from 2000-2010 were co-authored with foreign authors, with the United States, Japan and the United Kingdom being the most common partners.

Figure 9.6. Trends in USPTO patents granted to Thailand, 2000-11



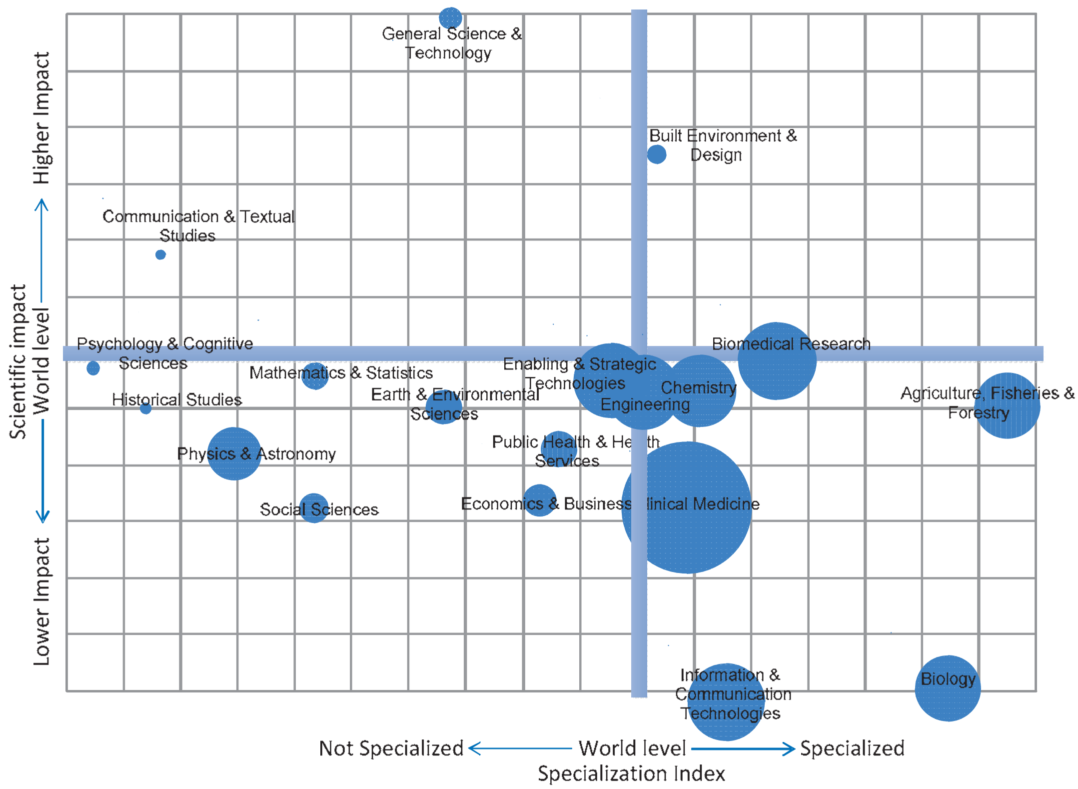
Source: US Patent and Trademark Office (USPTO).

Figure 9.7. Trends in scientific publications in Thailand, 2000-10



Source: Science Metrix analysis of Scopus (Elsevier) database.

Figure 9.8. Positional analysis of Thailand's scientific publications, 2000-10



Source: Analysis of Scopus (Elsevier) database by Science Metrix. This combines the number of publications by scientific field (area of circles), the specialisation index (a measure of relative intensity in a field compared to the World average) and the average of relative citations (citations relative to the World average controlling for age and field).

The impact of Thai scientific publications in terms of citation rates is still relatively low by world standards, though similar to countries in the region. Figure 9.8 shows that in terms of citation impact, all but three subfields were below the world average in relative terms. Thailand is relatively specialised in agricultural and life sciences, with biomedical research and chemistry being close to average global impact in terms of citations. ICTs and biology record the lowest impact scores. About 43% of scientific articles published by Thai nationals have international co-authorship – with the United States, Japan and the United Kingdom being the primary sources of collaboration, indicating some integration into international research networks. Over the last decade, the number of papers co-authored with collaborators in the United States, the European Union and Japan more than doubled, with co-authorship with the United States rising most steeply.

Thailand ranks 66th, behind Malaysia and Singapore but ahead of Indonesia, on the World Bank's Knowledge Economy Index (KEI), based on scores averaged across the four pillars of the knowledge economy, including education and innovation (Table 9.3). When controlling for GDP per capita, Thailand's rank on the 2011 version of the innovation sub-index, which focuses on outcomes such as royalty payments, patents and journal publications, was similar to that of China, although it trailed Malaysia (World Bank, 2012b).

Table 9.3. Knowledge Economy Index and Knowledge Index, Thailand, 2012

Indicator	Value
Knowledge Economy Index (KEI)[1]	5.21
Knowledge Index (KI)[2]	5.25
Economic incentive and institutional regime	*5.12*
Innovation	*5.95*
Education	*4.23*
ICT	*5.55*
Position in world rank	66
Change in rank from 2000	-6

1. The Knowledge Economy Index (KEI) is based on the average of the normalised scores of a country on all four pillars related to the knowledge economy: economic incentive and institutional regime; education; innovation; and ICT.

2. The Knowledge Index (KI) measures a country's ability to generate, adopt and use knowledge. The index is based on key variables in the three knowledge pillars: education, innovation and ICT.

Source: World Bank (2012b).

In Thailand, the number of R&D personnel relative to population has grown from a low base in the 1990s but remains low when compared internationally. PhD graduates make up a very low proportion of the labour force and only 10% of PhDs studied engineering. The ratio of science and engineering to social sciences graduates has decreased in recent years, resulting in skilled labour shortages. Around one million S&T graduates do not work in technology-related fields; this may indicate a mismatch between the qualifications and skills of graduates and market demands (Intarakumnerd, 2006a).

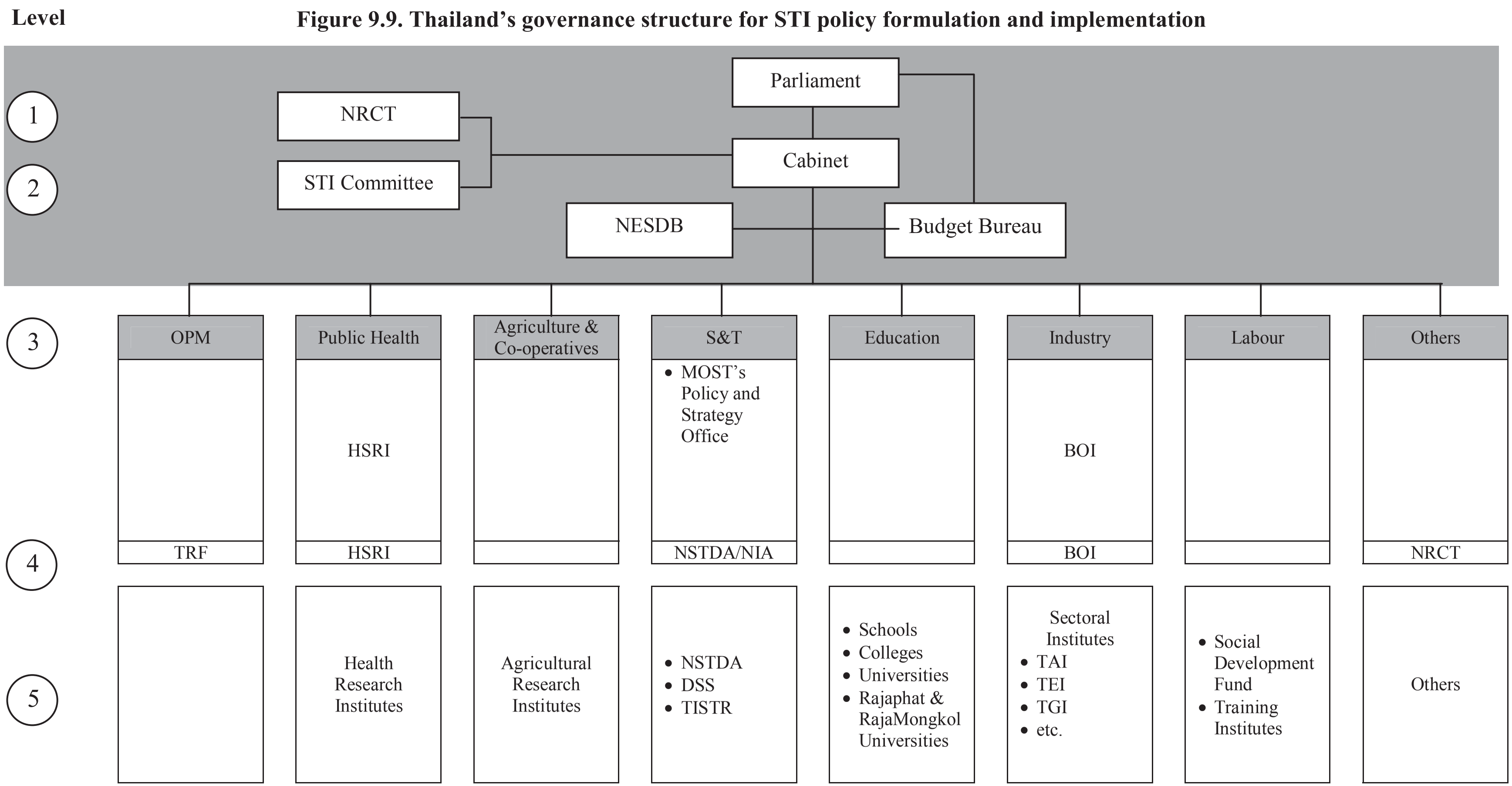
9.3. Innovation policy: Institutional frameworks and policy orientations

Traditionally, Thailand's science and technology policy focused on research and development, based on the view that private firms are "users" of knowledge produced mainly by government agencies and universities. Although innovation was mentioned in several national plans, there was no articulated national innovation policy and innovative capabilities were not part of the scope of S&T policies. Nor were S&T elements integrated into broader economic strategies or industrial, investment, trade and education policies (Intarakumnerd, 2006b).

Thailand's industrial policy, which is under the responsibility of the Ministry of Industry, prioritised attracting foreign direct investment and promoting exports. This tended to overshadow the need to develop Thailand's own technological capabilities. There were no explicit links between promoting foreign investment and upgrading the abilities of local firms (Vongpivat, 2003). Trade policy focused on reducing domestic demand for imports because of balance of payment deficits rather than on technology transfer.

For many years, Thailand concentrated on infrastructure, general education and exports and had no measures targeting the development of particular sectors. The exceptions were technological upgrading targets and local content requirements in the automobile industry. These raised the local content of passenger vehicles to over 54% by 2008 (Lauridsen, 2008).

Figure 9.9. Thailand's governance structure for STI policy formulation and implementation



Source: Updated from Bell (2002), "Knowledge Capabilities, Innovation and Competitiveness in Thailand: Transforming the Policy Process", report for National Science and Technology Development Agency (Thailand), World Bank. See Table 9.4 for a description of functional responsibilities at different levels.

In 2001, a "dual track" policy was adopted to enhance the capabilities of Thai firms while increasing international competitiveness by strengthening the external side of the Thai economy, *i.e.* exports, foreign direct investment and tourism. A National Competitiveness Committee was created to develop specific industrial clusters: automobiles, food, tourism, fashion and software. The cluster concept became the main plank of industrial and innovation policy at the national, regional and local levels. The National Economic and Social Development Board (NESDB) conducted a cluster mapping of the country to identify significant agglomerations of firms in various locations. At the regional level, Thailand was divided into 19 areas which were encouraged to implement cluster strategies focused on a few strategic products or services (Chairatana and Intarakumnerd, 2007).

The Board of Investment (BOI) extended investment packages for strategic clusters, such as hard disk drives and semiconductors, and gave Thai firms incentives to participate in global value chains. Other government agencies supporting the cluster strategy included the Department of Industrial Promotion and sector-specific institutes under the Ministry of Industry such as the Thai Automotive Institute, the Thailand Textile Institute, the National Food Institute, and the Electrical and Electronics Institute (Intarakumnerd, 2006b).

Table 9.4. Functions of key STI policymaking and implementation bodies in Thailand

Level	Responsibility	Organisations
Level 1	National budget approval	*Parliament.* Both houses of parliament have S&T committees. No special organisation advises the parliament regarding STI policy.
Level 2	High-level, cross-cutting policy formulation and development	*Cabinet*. The National Research Council of Thailand (NRCT) and the National Science Technology and Innovation Policy Committee (STI Committee) are the cross-cutting policy formulation bodies for research and STI, respectively. The National Economic and Social Development Board (NESDB) is the main governmental policy advisor and project evaluator, including S&T policies and projects. The Budget Bureau is responsible for budget allocation. These two agencies also play very significant roles in the cross-cutting policy formulation process.
Level 3	Ministerial-level policy formulation	Apart from the Ministry of Science and Technology, several other ministries are involved in STI policies. These include the Ministry of Industry, Ministry of Agriculture and Co-operatives, Ministry of Labour and Social Welfare, Ministry of Education, Ministry of Public Health and the Office of the Prime Minister.
Level 4	STI funding and promotional incentives	There are several specialised agencies in several ministries. The National Science and Technology Development Agency (NSTDA), the Thailand Research Fund (TRF) and the Health System Research Institute (HSRI) are funding agencies, mostly for R&D activities. The National Innovation Agency (NIA) is responsible for providing funding and interest-free loans for private firms' innovation projects. The Board of Investment (BOI) and the Revenue Department provide tax incentives for R&D investment.
Level 5	Policy implementation	Policy is implemented by national centres, governmental departments such as sectoral development institutes under the Ministry of Industry, universities, and research and technology organisations (RTOs).

Source: Updated from Bell (2002), "Knowledge Capabilities, Innovation and Competitiveness in Thailand: Transforming the Policy Process", report for National Science and Technology Development Agency (Thailand), World Bank.

The ten-year Science and Technology Action Plan (2004-14) enacted further measures to strengthen industrial clusters and their innovation capabilities. The National Science and Technology Innovation Policy Committee (NSTIC) and the National Research Council of Thailand (NRCT) co-ordinate the work of the core ministries in implementing the plan (Figure 9.9 and Table 9.4). The *National Science, Technology and Innovation Act*, enacted in 2008, aims to strengthen S&T manpower and infrastructure. It is being implemented by a new supra-ministerial structure, the National Science, Technology and Innovation Policy Committee chaired by the Prime Minister, which will monitor and report the results of the national plan, including the performance of government agencies (NSTIPO, 2010).

The Ministry of Science and Technology (MOST) remains central to Thailand's innovation efforts, particularly through the National Science and Technology Development Agency (NSTDA), which has overlapping and sometimes conflicting technical and funding responsibilities with the NRCT. To promote specific industrial clusters, the NSTDA emphasises increasing R&D investments, enhancing private-sector access to knowledge and information, promoting English as a second language, and upgrading S&T education and training (World Bank, 2010b).

The National Innovation Agency (NIA), formerly the Innovation Development Fund (IDF), provides financing in the form of grants and soft loans for innovative projects in firms primarily in the areas of bio-business, eco-industry and design solutions. The NIA has four financing schemes: *i)* technology capitalisation for testing prototypes; *ii)* zero-interest innovation projects to secure low-cost loans from banks for technology development; *iii)* cluster-based innovation projects primarily in biotechnology fields; and *iv)* venture capital to initiate production (this programme has been discontinued). The NIA has also established an Innovation Management School, which provides training for executives (Intarakumnerd, 2010).

The government has extended larger R&D tax incentives if investments by companies in R&D or design amount to 1-2% of sales; if scientists or engineers with a bachelor's degree comprise at least 5% of the workforce; if spending on employee training is at least 1% of the total payroll; or if similar amounts are spent on training the personnel of local suppliers. However, a survey showed that only 2-3% of firms knew about these fiscal incentives, which are often too narrowly defined for Thai firms to take advantage of them. Because of the complexity and rigidity of the system, only a handful of firms have availed themselves of R&D tax credits in recent years. Moreover, less than 4% of firms received grants for innovative investments from the Ministry of Science and Technology (World Bank, 2010b).

In 2009, the new government decided to focus on making Thailand a creative economy based on the talent and unique culture of the Thai people. It emphasises developing industries such as Thai food and cuisine, crafts, massage techniques and spas, films, and multimedia software (Intarakumnerd, 2010). However, related efforts have so far had limited impact owing to a lack of links between creative industries and overall innovation programmes.

Despite substantial policy efforts, industrial upgrading in Thailand has been limited, owing in part to the failure to co-ordinate agencies and policies and to disburse funds effectively. Projects tend to be captured by particular public interests and public perceptions of government inefficiency and corruption are high (see Figure 9.5). Further improvements are needed, specifically in institutional arrangements for co-ordinating national science and technology policies and in fostering greater involvement of the private sector in policy formulation. In addition, fiscal incentives and grants for enterprises to engage in innovative activities need to be streamlined and better co-ordinated and implemented (Lauridsen, 2008).

9.4. Actors of the national innovation system (NIS)

9.4.1. The business sector

Firms in Thailand tend to lag behind firms in other Southeast Asian countries in innovation performance whether they are multinational enterprises, state-owned enterprises, family-owned conglomerates, or SMEs. For instance, only 12% of multinationals in Thailand conduct R&D, although a greater share than domestic firms (Intarakumnerd, 2010). In 2008, the electrical machinery and electronics sector accounted for 35% of R&D-performing firms, followed by chemicals (16%), and R&D services (11%). Among multinationals, most R&D is performed by the electrical machinery sector, including electronics (56%), followed by food, motor vehicles and chemicals (Intarakumnerd, 2010).

Surveys indicate that the most innovative Thai manufacturing sectors in terms of product and process initiatives are automobiles, wood products and food. The majority of Thai firms do not invest in R&D but in technological learning through acquisition of existing technology, reverse engineering, design, testing and quality control. Government efforts have generally done little to strengthen the innovative or absorptive capabilities of Thai suppliers, as most do not avail themselves of government programmes, whether R&D tax incentives, subsidies and grants, or technical and consulting services (Intarakumnerd et al., 2002).

Although the products exported have grown more sophisticated over time, the tasks performed in Thailand, primarily assembly manufacturing, have remained relatively basic and create little value added. Thai-owned first-tier suppliers in the automotive sector, for example, generally manufacture labour-intensive parts and establish technical agreements or project-specific joint ventures with foreign suppliers to acquire technology. Furthermore, the research, design, development and branding of the export products of multinational enterprises still takes place outside of Thailand. As value added in manufacturing has increased, average wages and employment have stagnated, with capital rather than labour inputs spurring productivity growth. Increases in the level of technology of export products reflect technology embodied in imported production equipment rather than domestic efforts (Abhinorasaeth, 2007).

In addition to little investment in research in Thailand, multinational enterprises (MNEs) have few links with domestic firms. Technology transfer is limited to the operational level, as MNEs tend to train workers to produce goods efficiently rather than equip them with design and engineering skills. MNEs have not been active in developing subcontractors or giving technical assistance to local suppliers. However, in recent years they have begun upgrading research and technological capabilities, particularly in electronics and automobiles, and have invested in efforts to boost the country’s infrastructure and human resources for industrial needs (Intarakumnerd, 2010).

Large MNEs in the automotive sector have begun to invest in more R&D in Thailand. Toyota Motor set up the Toyota Technical Centre Asia Pacific Thailand and invested almost USD 100 million in technical development facilities. The emphasis of the centre is on materials development, vehicle testing for reliability, durability and comfort as well as design and engineering to fit regional needs. As Thailand improves its competitiveness in passenger cars, which have higher technological requirements than pickups, this may lead to structural changes in the innovation capabilities of domestic firms. By 2015, the eco-car segment is expected to account for up to 20% of automobile production in Thailand, providing opportunities for local assemblers and suppliers (World Bank, 2010a).

Historically, Thai firms have been notoriously slow to develop technological capabilities (Tipton, 2009). There is some indication, however, that firms owned by ethnic Chinese interests, mostly located in Thailand for generations and well integrated into the social and cultural fabric of the country, are in a better position to absorb and exploit technologies developed in other parts of the world. Such firms have played an important role in the economic development of Thailand. By the late 1990s, 90% of manufacturing and 50% of services in Thailand were controlled by firms owned by ethnic Chinese interests (Weidenbaum and Hughes, 1996; Yeung, 1999), some of which have become significant transnational conglomerates. Driven initially by the lack of sizeable domestic markets free from state intervention and monopolistic interests, and by the opening of domestic markets to foreign competition, these firms expanded and diversified into foreign operations. Many exploited their links with China to establish trade links and explore investment opportunities in Asia (Yeung, 1999). Some also began to penetrate markets in North America and Europe, establishing not only trade links but also tapping into centres of technological innovation via direct investment and the establishment of foreign production plants. By internalising and bringing back to Thailand experience gained through their international operations (Yeung, 2006), *i.e.* by exploiting linkage, leverage and learning effects, these so-called "dragon multinationals" (Mathews, 2006) are well placed to undertake the technological upgrading that will be needed to move up the value chain and take advantage of expanding export markets, especially in mainland China.

A small number of trade and industrial associations support the development of Thai firms. These include the Federation of Thai Industry (FTI) and the Thai Chamber of Commerce (TCC). Their members, however, come primarily from commercial rather than industrial interests and their focus is on negotiating with the government on export quotas, import levies and the tax regime rather than on upgrading local innovation capabilities. Still, these associations provide some services, including management consulting, standards certification, and training in energy saving and sanitary standards (Vongpivat, 2003).

Although firms in the strategic clusters designated by the government are more open to change, co-operative consortiums among firms to research particular technologies or products are rare in Thailand. The intensity of relations between producers and users and between producers and suppliers is weak and customer-supplier links in Thailand are short and fragmented (Arnold et al., 2000).

Recent innovation surveys indicate that many firms in Thailand engage in incremental innovation, particularly to introduce new products in the food processing, automotive and electronics industries. In 2010, the National Innovation Agency initiated an "Open Innovation" activity and brought together 20 large Thai companies to discuss innovation problems and share knowledge to develop new products and services (Intarakumnerd, 2010).

9.4.2. Higher education institutes

At present, there are 165 higher education institutes (HEIs) in Thailand, of which 78 are public. Among the public HEIs, 13 are autonomous in that there is less state control of activities, budget and human resource management. The leading universities are Thammasat University, the Asian Institute of Technology, Bangkok University, Rangsit University and Rajamongkol Thanyaburi. The persistent weakness in the quality of universities in Thailand, especially as regards R&D capacity, and the location of the leading institutions in a few urban areas has made it difficult for universities to serve as nuclei for technological clusters (World Bank, 2007).

Limited interaction between universities and industry in Thailand has exacerbated skilled labour supply shortages. Linkages between Thai universities and industry are mostly limited to consulting and technical services to augment the personal income of researchers. Most linkages are based on personal contacts and operate without an elaborate institutional framework. Firms generally do not regard university and public research institutes as important sources of information and knowledge. Industry has recommended that steps be taken to remedy the shortcomings of university graduates through a redesign of programmes, reform of curricula, revisions of textbooks, investment in laboratories and research centres, and more emphasis on practical skills (World Bank, 2010b).

The spin-off of start-up firms from universities is exceedingly rare, as larger local companies in traditional sectors are more likely to carry out joint activities with universities than with new SMEs. Firms that perform research in science-based sectors have more intense collaboration with local universities, particularly the petroleum, petrochemical, electrical machinery, telecommunications and computer sectors (Schiller, 2006). In recent years, the Thai food processing industry has also started using universities as a knowledge source and to improve production processes.

The Thai Cabinet has approved a 15-year Tertiary Education Framework (2008-22) focused on knowledge and innovation. It includes efforts to improve collaboration between universities and industry and support for faculty attempting to attract external funding for entrepreneurial activities. The establishment of the Thailand Advanced Institute of Science and Technology (THAIST) in 2009 is intended to promote collaboration between domestic research and educational institutions with overseas institutes specialising in R&D, technology transfer and innovation, and S&T manpower development. The Office of Higher Education is setting up technology licensing offices in public universities to spur commercialisation (World Bank, 2010b).

The government's efforts to reform universities include greater targeting of resources on industry outreach. A successful case of university involvement in industry is the Centex Centre of Excellence for Shrimp Molecular Biology and Biotechnology established at Mahidol University with support from the Thai National Centre for Genetic Engineering and Biotechnology (BIOTEC). The aim of the centre is to gain further scientific knowledge of shrimp and fish and find ways of preventing outbreaks of disease. The Shrimp Biotechnology Business Unit was created to help commercialise R&D findings. Other promising cases of university-industry collaboration include the Petroleum and Petrochemical College at Chulalongkorn University, which supplies skilled workers to the petrochemical industry in addition to providing testing and analysis services (Liefner and Schiller, 2008).

9.4.3. Public research institutes (PRIs)

Firms in Thailand consider public research institutes (PRIs) less important as sources of knowledge than universities (Schiller, 2006). The National Science and Technology Development Agency (NSTDA) and the Thailand Institute of Scientific and Technological Research (TISTR) carry out basic research in wide-ranging areas. Institutes conducting technology-specific research include the National Synchrotron Research Laboratory, the National Astronomical Research Institute of Thailand, the Office of Atoms for Peace, and the Geo-Informatics and Space Technology Development Agency. PRIs conducting sector-specific activities include the Agricultural Research Development Agency (ARDA), which works on organic and bio-based production. Other institutes, such as the National Institute of Metrology and the Department of Science Services, are responsible for setting standards and providing technical testing services for companies.

The NSTDA employs 2 000 researchers in four national research centres with fully equipped laboratories: the National Centre for Genetic Engineering and Biotechnology (BIOTEC); the National Metals and Materials Technology Centre (MTEC); the National Nanotechnology Centre (NANOTEC); and the National Electronics and Computer Technology Centre (NECTEC). Their activities focus on research and development or providing technical services such as testing and calibrating to public and private entities. PRIs have few other links with private firms and generally do not help companies build capabilities such as technology assimilation, adaptation, design and engineering (Intarakumnerd, 2010).

In recent years, industry has invested in strengthening local research institutes through cluster management organisations. The Hard Disk Drive Institute (HDDI) was created by IDEMA, an industrial association for hard disk drive firms, with local research institutes and representatives of key government organisations such as the Board of Investment. The institute is engaging in research projects to upgrade the capabilities of the entire hard disk drive industry in Thailand (AIT/Asia Policy Research, 2003).

9.4.4. Linkages between innovation actors

Limited collaborative links among universities, PRIs and the business community have compounded the weaknesses of Thailand’s innovative capacity. Because relational clustering is weak, few Thai firms are involved in the design phase of product development. This makes it harder to acquire the skills and expertise that could help move up the supply chain. Technological upgrading and product development, which could serve as the springboard for relationships with MNEs and the emergence of dynamic industry clusters, are hampered by limited entrepreneurship and the low quality of human capital (Schiller, 2006).

There are two important technology intermediaries in Thailand. The Thailand-Japan Technology Promotion Association (TPA) aims to diffuse knowledge and technologies associated with manufacturing. The Kenan Institute Asia (KI Asia) also provides a bridge for the exchange of knowledge, expertise and information by the government, universities and industry. At a sectoral level, one reason for limited linkages in the automotive sector is a lack of capable intermediaries such as those that exist in the hard disk drive sector. The Thai Automotive Institute (TAI) has been entrusted to assume such a role, but it does not have the legal status of either a government department or an autonomous government agency or a clear mandate as a promoter of industrial collaboration (World Bank, 2010a).

Thailand has invested in science and technology parks to encourage linkages between firms and other actors in the national innovation system. The Thailand Science Park has 60 companies in operation, of which 75% are Thai, together with the public research institutes BIOTEC, MTEC, NECTEC and NANOTEC. Plans are to increase the Thailand Science Park to 200 companies and 4 000 knowledge workers. Software Park Thailand is home to more than 30 firms, mostly Thai, along with IBM, Hewlett Packard, Sun Microsystems, and Oracle. Training and certification are offered jointly by the NSTDA and Carnegie-Mellon University of the United States.

There are also several industrial parks with research capabilities, including those in Navanakorn, Bangkadee, Rojana and Bangpain. Firms in the parks receive a 200% tax credit for R&D expenditures and accelerated depreciation on research machinery and equipment. The Board of Investment grants firms work permit and visa facilitation for foreign specialists and researchers. In addition, it extends tax exemptions to companies for imported machinery, income tax exemptions for eight years, and 50% income tax reduction for five additional years (Intarakumnerd, 2010).

9.5. Human resources

Inadequate human capital constrains innovation. Thailand does well in terms of primary and secondary education, and enrolment rates are high. In 2009, the Ministry of Education launched a Free Education with Quality policy to reduce the financial burden of households and improve children's access to education. National expenditures on education and access to secondary and tertiary education are adequate and in line with regional peers. However, this does not appear to translate into outcomes. Thailand is lagging in mathematics and science scores and innovates less than countries with comparable higher education ratings (World Bank, 2010b).

The major problem in Thailand is educational institutions' inability to produce enough S&T graduates with the skills and of the quality required by the private sector. Thailand's ten-year Science and Technology Action Plan (2004-14) aims to increase the number of Thais entering tertiary education and to attract 150 000 foreign students by 2015. Thailand has shortages of STI manpower with bachelor's degrees in almost all areas, especially in engineering disciplines. The proportion of graduates in natural sciences and engineering to social sciences is about 50%. However, the proportion of graduate students with master's degrees in science is about one-third that for social studies. The lack of skilled workers is the top constraint to innovation identified by industry. More than half of firms indicate that the English language, information technology (IT), and numerical skills of their workers are poor.

Only a quarter of faculty members at Thai universities hold doctorate degrees, and this has hindered the expansion of research and development (World Bank, 2010b). Higher education institutions cannot keep up with technological change in the industrial sector because teaching is academic and does not emphasise creativity and the self-learning abilities that would allow graduates to acquire further knowledge and problem-solving skills. Very little development of university curricula has involved co-operation between industry and educational institutions. In a few exceptional cases, co-operation has taken place between individual institutions and firms rather than industries as a whole.

For vocational manpower, shortages exist in certain areas, but the general assessment is one of over-supply. Since the late 1970s, the number of vocational students in Thailand had risen dramatically, but many remain unemployed, suggesting a disconnect between firms' needs and the supply of human resources at this level (Table 9.5) (Intarakumnerd, 2010).

Table 9.5. Differences in the knowledge and skills required by industry and supplied by educational institutes

Industries	Gap	Educational Institutions
Specific and sophisticated technology and more interdisciplinary knowledge needed	Lack of knowledge and technical information with practical application	Obsolete technology and knowledge too departmentalised
Little participation in curriculum development	Lack of mechanism to integrate academic curriculum with industry needs	Curriculum based on what instructors believe appropriate
Emphasis on analytical skills in problem solving	Lack of encouragement of students to be self-learners	Emphasis on theoretical lessons and examinations more than self-learning
Need knowledge and working skills such as basic statistics and quality management	These areas are not prerequisite or required courses	Statistics and quality management are elective courses; few students choose them
Need literacy skills, such as English and computer programming skills for managing work processes	Lack of important skills for today's globalisation economy, such as skills in other languages and computer management	English is compulsory but not considered important by students. Some courses (*e.g.* computer courses) are not available.

Source: College of Management (2003), "S&T Needs and Production of Manpower in the Manufacturing Sector", June, Draft Final Report submitted to National Science and Technology Development Agency, Thailand (in Thai).

The Thai government has introduced various initiatives to improve the quality of the labour force. At the secondary education level, it has allowed privatisation, encouraged integration of information technology and foreign languages in curricula, and adopted measures to upgrade teacher standards. However, instructional resources and teaching aids remain in short supply, and measures that decentralise authority to schools and raise the profile of vocational schools are needed.

A Science-Based Technology School (SBTS) has recently been established by the National Science and Technology Policy Committee and the Vocational Education Commission. The objective is to increase the number of qualified vocational students by encouraging them to develop technical and creative abilities. Work-integrated learning is being expanded through the Practice Engineering School approach to meet industry demand for engineers. The programme provides work and research experience at industrial sites to students who study for one year and work on industrial projects for the second year at the company (Intarakumnerd, 2010).

Given the lack of innovation infrastructure, Thailand is losing its skilled workforce and worsening the problem of insufficient human resources for economic development. The Reverse Brain Drain Project initiated by the NSTDA in the 1990s to lure back Thai S&T professionals working abroad met with limited success (Chairatana, 2006). Competition for knowledge workers is intensifying regionally and internationally, and Thailand lacks large national research projects or vibrant public research institutes that could provide financial incentives, professional challenges and long-term career paths to encourage skilled nationals to return home. In addition, low private-sector demand for innovation and upgrading does not create the conditions to attract the skills and knowledge of the Thai diaspora. In order to attract foreign skilled labour, Thailand recently increased the length of visas for researchers and technology workers from two years to four years.

9.6. SWOT analysis

On the basis of the material presented above, it is possible to identify several strengths and weaknesses of Thailand's NIS, along with future opportunities and threats. These are summarised in Table 9.6.

The presence of major transnational corporations in fields such as electronics, automobiles and the food processing industry is a notable strength and offers a strong base for future development, especially given the proximity of large export markets in countries such as China and India. There have also been pockets of success in the tourist sector and in creative industries, and the agricultural sector remains an important productive part of the overall economy. Some large firms became more active "learners" after the financial crisis in 1997, especially ethnic Chinese conglomerates, and a few universities have started to become more industrially relevant.

Major weaknesses remain, however. On the supply side, there is still an inadequate supply of qualified STI personnel, low investment in R&D and weak technological learning. The ICT infrastructure is poorly developed and incapable as yet of supporting the development of a fully functioning knowledge society. Although Thailand hosts strong transnational players in technology-based sectors, knowledge linkages and spillovers to local firms and institutions are minimal. The links between local firms and universities are also weak. In policy terms, efforts have been made to revamp governance structures and policy directions following limited success in effective policy formulation and implementation.

Growth opportunities exist owing to the internal growth of sectors such as tourism and the external expansion of export markets in mass-market, higher value-added and niche products, but much greater investment and improved spillovers will be needed to raise domestic innovation capabilities. This will call for a continued focus on cluster policies and "smart specialisation", including the further development of S&T and industry parks. Opportunities also exist for local transnationals to increase their holdings abroad in growth markets.

Threats, apart from the obvious danger of another downturn in the global financial situation and political instability in the region, stem mainly from the increased competition for foreign direct investment from regional rivals, some of which have larger and more active populations of firms keen to learn and adapt to the needs of an innovative economy. Limited competition in many sectors and a continuation of the brain drain that has affected the country historically would also have deleterious impacts.

Table 9.6. Summary SWOT (strengths, weaknesses, opportunities, threats) analysis

Strengths	Weaknesses
• Strong electronics and automotive sectors based on multinational firms • Some large local firms with international interests have become “active learners” • Large regional export markets, particularly China • Productive agricultural sector • Growing food processing industry • Expanding Thai creative industries • Examples of industrial focus amongst a number of universities	• Inadequate supply of skilled personnel • Low R&D investments • Lack of ICT and Internet services reflecting inadequate digital infrastructure • Weak technological learning • Weak links between foreign and local firms restricts technology transfer and spillovers • Weak university-industry links • Ineffective industrial clusters policy • Disjointed S&T governance and limited success in policy implementation
Opportunities	**Threats**
• MNEs investing in local R&D including eco-cars • Greater investment by local transnationals in other countries • Opportunity to expand into higher value-added goods and markets, especially in Asia, exploiting proximity of large export markets • Market niches in Thai food and crafts • Growing tourist destination • S&T and industrial parks may allow future clusters and pockets of specialisation to develop	• Competition from Asian countries for FDI • Lack of competition in many sectors • More competition from imports in some markets • Failure to upgrade technological capabilities and move into higher value-added areas • Increasing brain drain • Political instability • Volatility of global financial situation

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Chapter 10

Viet Nam innovation profile

Starting with economic reforms in 1987, Viet Nam has pursued an export-led growth strategy based on more open markets and increased foreign direct investment. Despite marked economic progress, however, Viet Nam is still a low-income developing country that is ranked lower on competitiveness indices than most of its neighbours in the South-east Asian region. Viet Nam remains the second largest exporter of rice and coffee in the world and its agricultural sector employs 52% of workers, but technology-based exports constitute a small share of total exports. Due to fewer international links, Viet Nam suffered relatively less than other countries in the region from the Asian financial crisis in 1997 and the global economic crisis in 2008.

Government actors dominate all aspects of science and technology and research and innovative activity in both the public and private sectors is limited. There is a strong case for streamlining and clarifying the role of government S&T agencies, while the country would benefit from centres of research excellence focusing on public health and environmental goods. The expanding tourism sector and agricultural niches could also be targeted areas of research and development. Priority sectors such as information and communications technology (ICT) continue to develop well and Viet Nam is now attracting investments from multinational enterprises in information technology.

Along with continued economic reforms and international integration, there is scope for the state's role to change from that of a main innovation actor to that of an innovation catalyst. Continued economic growth in Viet Nam and its ability to compete in global markets will depend on increasing investments in education and technology-based production. The national innovation system (NIS) needs to be strengthened in terms of public research, incentives to private R&D, and technology transfer and linkages between the public and private sectors, particularly with foreign firms.

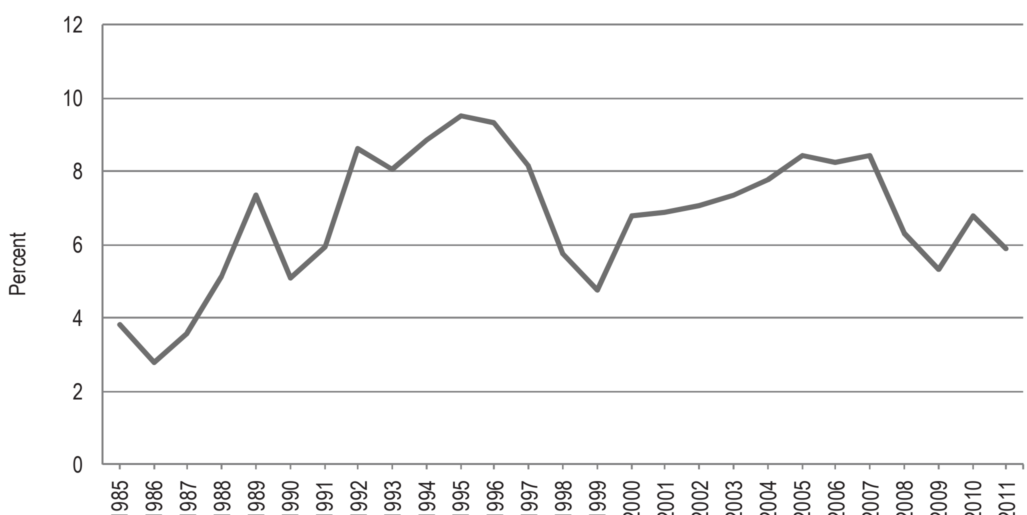
10.1. Macroeconomic performance and framework conditions for innovation

10.1.1. Performance and structure of the economy

Viet Nam's gross domestic product (GDP) has grown at an average rate of 6.7% since 1985 (Figure 10.1). Over the past 15 years the economy has appeared more resilient to shocks than many other countries in the region, although growth since the start of the global financial crisis in 2008 has been lower than that recorded in the preceding decade. GDP growth was 6.8% in 2010 and 5.9% in 2011, accompanied by low levels of unemployment. Despite significant economic progress, however, Viet Nam is still a low-income developing country – GDP per capita was just over USD 3 000 in 2011 (on a 2005 purchasing power parity basis) and Viet Nam's UN Human Development Index score is 0.593, a global ranking of 128^{th}. Inflation has also spiked at times over the past few years – consumer prices rose by nearly 19% in 2011.

The new Socio-Economic Development Plan for 2011-2015 calls for a growth rate of 7-8%. A fiscal stimulus designed to help the country rebound from the economic crisis has been relatively effective, but may have distracted the government from the more basic economic reforms needed to stimulate innovation and business activity, including changes to the legal and banking systems and more stringent anti-corruption measures.

Figure 10.1. Growth of gross domestic product, Viet Nam, 1985-2011



Source: World Bank World Development Indicators.

Viet Nam is a densely populated developing country that in the last 30 years has had to recover from the ravages of war, the loss of financial support from the Soviet Union, and the rigidities of a centrally planned economy. Viet Nam's economic development was spurred in 1987 by the switch from a centralised economy, where the government designated and planned for all socio-economic targets, to a market orientation and integration into global markets. The government implemented structural reforms needed to modernise the economy and to produce more competitive export-driven industries. A lower level of internationalisation meant that Viet Nam was relatively unaffected by the Asian financial crisis in 1997 although GDP growth dipped slightly in 1998 and 1999.

Rapid economic growth has been accompanied by a marked reduction in the population below the national poverty line from nearly 60% in 1993 to less than 15% in 2008 due to a broadly inclusive pattern of development, though poverty levels are higher in rural areas, particularly in regions with substantial numbers of ethnic minorities. Viet Nam is nevertheless making strenuous efforts to create jobs to meet the challenge of a labour force that is growing by more than one million people per year, and some progress has been made in improving labour market efficiency.

Viet Nam's economic structure is gradually shifting from an agricultural base to one more concentrated in industry and services (Table 10.1 and Table 10.2). The share of the agricultural sector in value added decreased from 39% in 1990 to 20% in 2011, while that of industry has increased from 23% in 1990 to 41%. The share of the services sector has remained relatively steady at around 40% of value added. The share of employment in the agricultural sector is still high at over 52% of the labour force in 2008, while the industrial sector absorbed 21% of workers and the services sector 27%. Tourism has increased by 63% since 2000, with most visitors coming from China, followed by the United States, Japan and South Korea. The Viet Nam National Administration of Tourism is following a long-term plan to diversify and strengthen the tourism industry, which brings in much needed foreign exchange.

Table 10.1. Economic structural change in Viet Nam, % of value added, 1990-2011

	Agriculture, forestry and fishery	Industry and construction	Services
1990	38.7	22.7	38.6
1992	33.9	27.3	38.8
1994	27.4	28.9	43.7
1996	27.8	29.7	42.5
1998	25.8	32.5	41.7
2000	24.5	36.7	38.7
2002	23.0	38.5	38.5
2004	21.8	40.2	38.0
2006	20.4	41.5	38.1
2008	22.2	39.8	37.9
2010	20.6	41.1	38.3
2011	19.7	40.6	39.7

Source: World Bank World Development Indicators.

Table 10.2. Structural change in employment in Viet Nam, % change, 2000-08

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Agriculture, forestry and fishery	65.09	63.46	61.91	60.25	58.75	57.10	55.37	53.90	52.62
Industry and construction	13.11	14.40	15.40	16.44	17.35	18.20	19.23	19.97	20.83
Service	21.80	22.15	22.70	23.30	23.90	24.70	25.40	26.13	26.55

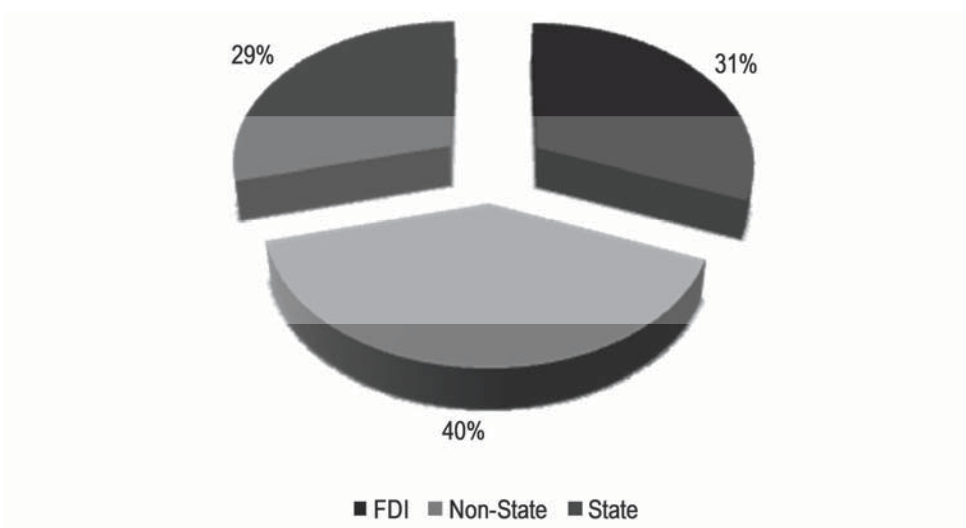
Source: General Statistics Office of Viet Nam.

The agricultural sector continues to play an important role in Viet Nam as the economic reforms starting in 1986 converted it from a country facing chronic food shortages to the second largest rice exporter in the world. Impressive performance in agriculture resulted from substantial reforms, including market liberalisation, land reform, public investments in irrigation, and the promotion of agricultural research activities. Besides rice exports, which account for 13% of the world market, Viet Nam is a leading exporter of cashew nuts (9.5% of the world market), coffee (40%), pepper (23%) and rubber. Viet Nam is the world's second largest coffee exporter after Brazil and is working towards increasing 'Fair Trade' and organic coffee production.

Foreign direct investment (FDI) has played an important role in Viet Nam's growth, accounting for over 30% of total investment capital in Viet Nam in recent years (Figure 10.2). Net inflows of FDI as a percentage of GDP peaked in 1993 before falling back, but represented an average of nearly 9% of GDP from 2007-2010 (Figure 10.3), with more than USD 70 billion invested from abroad in Viet Nam in 2008. However, the impact of FDI on technology transfer appears to be far less than in other Asian countries.

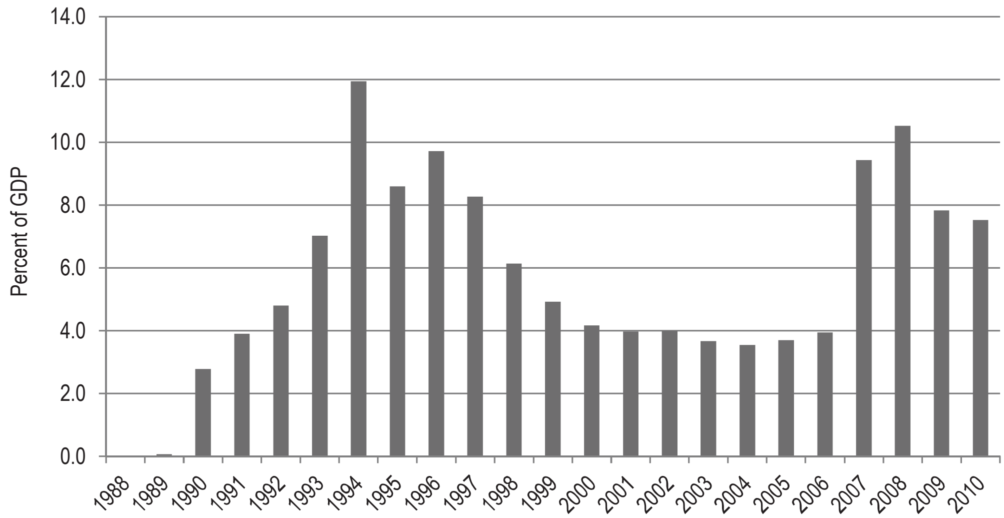
Viet Nam has pursued a trade-led growth strategy, resulting in a steady increase in both exports and imports as a proportion of GDP. In 2000, the top export destinations were Japan, China and Australia, with the United States trailing in 6th position, but by 2010 exports to the United States had increased nineteen-fold in nominal terms, taking it to pole position (Table 10.3). Over the same period, imports from China rose significantly leading it to become the leading import partner, whilst the share accounted for by Japan and Singapore shrank.

Figure 10.2. Main sources of capital investment, 2008



Source: General Statistics Office of Viet Nam.

Figure 10.3. Net inflows of foreign direct investment (FDI) percentage of GDP, 1988-2010



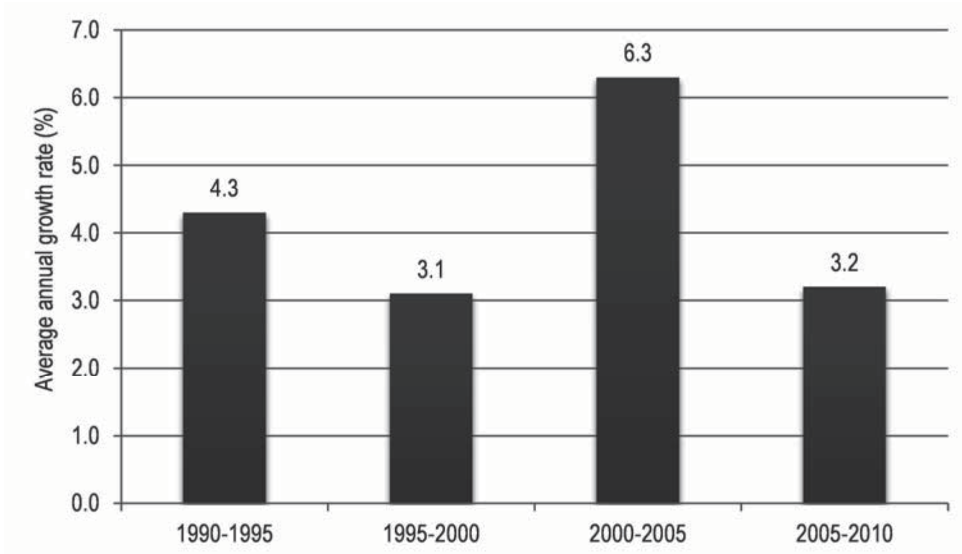
Source: General Statistics Office of Viet Nam.

Table 10.3. Viet Nam's top trading partners, 2000-10

Rank	Viet Nam's top 10 export partners in 2000	USD million	Viet Nam's top 10 export partners in 2010	USD million
1	Japan	2 575	United States	14 251
2	China	1 536	China	7 743
3	Australia	1 272	Japan	7 728
4	Singapore	886	Korea	3 092
5	Chinese Taipei	757	Australia	2 704
6	United States	733	Switzerland	2 652
7	Germany	730	Germany	2 373
8	United Kingdom	479	Singapore	2 121
9	Philippines	478	Malaysia	2 093
10	Malaysia	414	Philippines	1 706
Rank	Viet Nam's top 10 import partners in 2000	USD million	Viet Nam's top 10 import partners in 2010	USD million
1	Singapore	2 694	China	20 204
2	Japan	2 301	Korea	9 758
3	Chinese Taipei	1 880	Japan	9 016
4	Korea	1 754	Chinese Taipei	6 977
5	China	1 401	Thailand	5 602
6	Thailand	811	Singapore	4 101
7	Hong Kong, China	597	United States	3 780
8	Malaysia	389	Malaysia	3 413
9	United States	364	Indonesia	1 909
10	Indonesia	345	India	1 762

Source: UN Commodity Trade (Comtrade) Statistics Database.

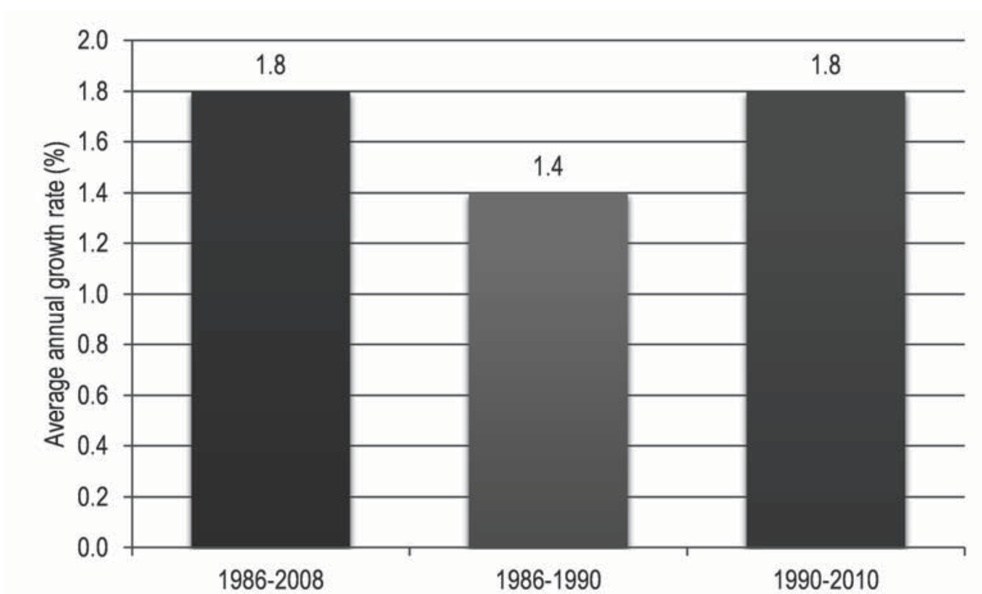
Figure 10.4. Trends in labour productivity growth, Viet Nam, 1990-2010



N.B. Average annual growth rate of GDP at constant basic prices per hour, using 2005 PPPs.

Source: APO (2012).

Figure 10.5. Trends in total factor productivity (TFP) growth, Viet Nam, 1986-2010



Source: APO (2012).

Viet Nam's accession to the World Trade Organisation (WTO) in January 2007 has driven further liberalisation of the economy but also increased global competitive pressures. Crude oil is a leading export, accounting for 22% of export earnings in recent years. Despite the importance of the oil sector, Viet Nam has very limited refining capacity, with only one operational oil refinery.

In recent years, exports have accounted for more than 60% of GDP, with manufactured products accounting for over 50% of total exports. The top manufacturing sectors are food processing, textiles, chemicals and electrical goods, with almost a third of manufacturing and retail activity concentrated in Ho Chi Minh City. Due to foreign investment, Viet Nam is exporting more technology-based products, including electronics, computers and parts, and software. These account for about 10% of manufactured exports, a lesser share than in many other countries in the Southeast Asia region.

There has been positive growth in labour productivity (Figure 10.4) and total factor productivity (TFP) (Figure 10.5) over the past 25 years, but from a very low base. Labour productivity, for example, stood at 3% of the US level in 1990, and it had only risen to 5.7% of the US level by 2010. The contribution of TFP to economic growth shrank from 43% over the period 2000-2005 to -6% over the period 2005-2010, with non-IT capital accumulation accounting for the highest share of growth (71%) over the latter period (APO, 2012).

Productivity levels have increased in the agricultural sector – particularly in rice, maize, soybeans and coffee – and in wood, chemicals, non-metallic minerals, electrical machinery, and medical instruments. However, foreign-owned enterprises have far higher productivity levels than both state-owned and indigenous firms, driven almost entirely by higher levels of investment and technology usage. State-owned enterprises are less productive than other domestic enterprises despite their greater access to government incentive schemes for both investment and technology development.

Viet Nam continues to rank low on scales of global competitiveness. According to the World Economic Forum's Global Competitiveness Index, Viet Nam ranked 65th out of 142 economies in 2011, up from 75th in 2009, compared to Singapore (2nd), Malaysia (21st), and Thailand (39th), though ahead of the Philippines (75th) and Cambodia (97th).

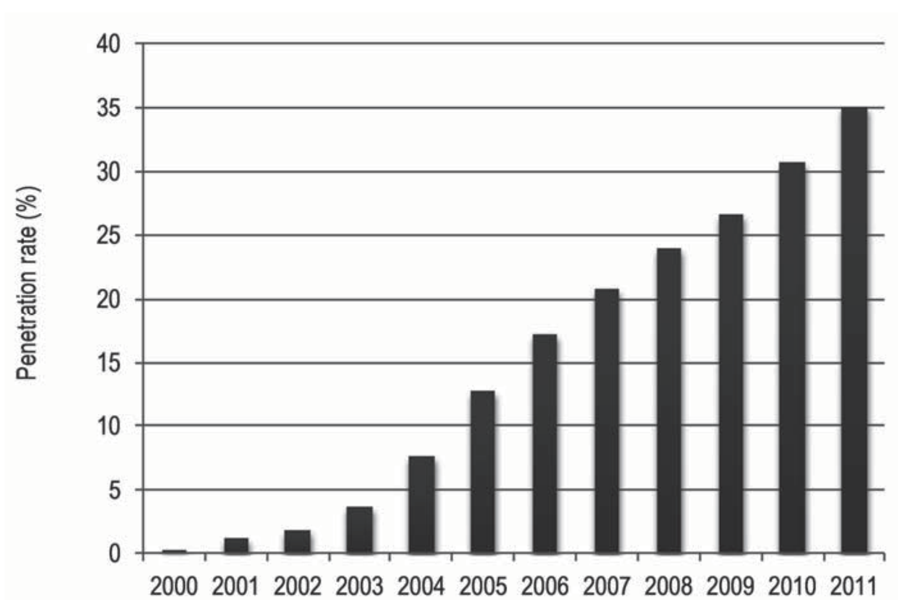
10.1.2. Framework conditions for innovation

Viet Nam has a relatively weak innovation infrastructure and Government actors dominate all aspects of science and technology activities. Innovation policies have concentrated more on R&D and knowledge generation rather than on policies to promote the diffusion, adoption and application of knowledge. Innovation support institutes have been generally ineffective and the use of novel technology by industry is low, with the workforce lacking the requisite skills. Collaboration between innovation system actors is either non-existent or insubstantial, while national investment in research and development (R&D), innovation and higher education remain weak.

The Government is aiming to improve matters in the 2011-2020 Science and Technology Development Strategy signed by the Prime Minister in 2012. The Strategy has three main targets; *i*) to raise the value of high-tech and applied science products to about 45% of GDP by 2020 and to ensure a 15-17% annual growth rate of the science and technology market; *ii*) to increase the ratio of scientific researchers and professional staff in ICT to 9 or 10 people per 10 000 employees, while up to 5 000 highly skilled engineers will be trained to operate in Viet Nam's priority fields by 2015; and *iii*) to develop 60 basic and applied science research centres of international standing by 2020. The government has identified a number of priority sectors within the Strategy: petroleum, metallurgy, machinery, basic chemicals, fertilizers and construction materials.

Viet Nam's technical infrastructure, including roads, seaports, and power generation, is generally ranked as poor and constitutes the greatest obstacle to investment in the country. However, the government has supported the development of the information and communications technology (ICT) sector and has made major investments in network modernisation and capacity upgrading. Beginning in 1995, the Government started to license non-state companies in addition to the Viet Nam Post and Telecommunications Corporation (VNPT). The pricing of telecommunication services has also been liberalised, resulting in a more competitive ICT sector. Internet penetration in terms of users per 100 inhabitants rose to 35.1 in 2011 (Figure 10.6). These levels are much lower than existing levels in countries such as Singapore (75%) and Malaysia (61%), but much higher than in Indonesia (18%) and Cambodia (3%). The number of fixed broadband subscriptions per 100 inhabitants also remained very low in 2010 at 4.3.

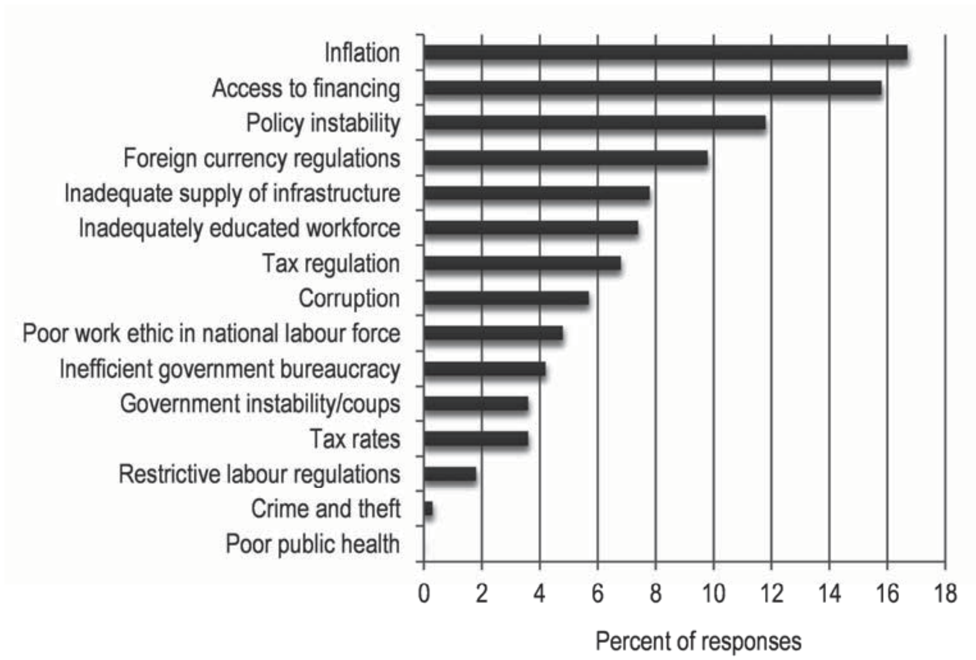
Figure 10.6. Internet users per 100 inhabitants, Viet Nam, 2000-11



Source: ITU (2012).

Viet Nam lacks venture capital companies or an equity market and levels of start-up firms and entrepreneurship are very low. Both large and small firms, which lack the management capabilities to gain general bank credits, face difficulties in accessing and mobilising finance (see Figure 10.7). Bureaucratic hurdles to the setting-up of new businesses are also steep. For Viet Nam to become a mature, internationally competitive economy, the Government needs to bring the business environment more in line with international benchmarks. This requires changing the administrative culture of regulators and public service delivery agencies, with an emphasis on introducing a user-centred approach (OECD, 2011). The Government is currently in the process of implementing changes recommended in Project 30, a policy aimed at reducing the cost of administrative procedures by 30% to, among others, encourage business competitiveness.

Figure 10.7. The most problematic factors for doing business in Viet Nam



Source: World Economic Forum (2012). Percentages represent the weighted results of a ranking of the five most problematic factors from a list of 15 by respondents to the WEF survey.

In 2007, the US-based International Data Group (IDG) launched a venture capital fund to invest in information technology businesses in Viet Nam. IDG Ventures Vietnam plans to invest USD 120 million in Vietnamese IT outsourcing firms, telecommunications and software producers, and publishing of IT-focused magazines. In addition, Viet Nam Innovation Day is an annual programme co-organised by the World Bank and the Vietnamese government to provide seed funding for innovative, early stage ideas at the grassroots level. The theme in 2011 was 'Innovation for Social Equity and Sustainable Growth', with the objective of developing products and services for the benefit of the poor and under-served communities in the areas of energy efficiency and agriculture-based products and services.

Although the current law on intellectual property is adequate, Viet Nam lacks an intellectual property court, technical officials and an enforcement mechanism. State-owned enterprises tend to receive preferential treatment in terms of equity, credit and market access. Viet Nam has separate metrology, standards and patent institutions, but the system is dominated by the public sector and coverage, quality and use of services by private firms is low. Most facilities, including laboratories, equipment and skilled staff, are inadequate, and the use of quality standards (such as those of the International Standards Organisation or ISO) by Vietnamese industry is limited. The World Intellectual Property Association (WIPA) is now assisting Viet Nam to improve the capacity of government agencies and personnel to register and protect intellectual property.

10.2. Innovation performance

Viet Nam's innovation performance is significantly lower than that of high-income countries and most of the middle-income countries in the Southeast Asia region, but relatively high for its stage of development. Viet Nam ranked 104th on the World Bank's Knowledge Economy Index (KEI) in 2012, based on scores averaged across four pillars relating to the knowledge economy, including education and innovation, with a particularly low score (2.75) and rank (113th) in the latter category (Table 10.4).

Overall investment in research and development (R&D) was 0.19% in 2002, the latest available data. About 80% of R&D expenditures came from the state budget. Approximately 70% of Viet Nam's research expenditures are devoted to applied research and technological development and a relatively small share to basic research.

Table 10.4. Knowledge Economy Index and Knowledge Index: Viet Nam, 2012

Indicator	Value
Knowledge Economy Index (KEI) #	3.40
Knowledge Index (KI) *	3.60
Economic Incentive and Institutional Regime	*2.80*
Innovation	*2.75*
Education	*2.99*
ICT	*5.05*
Position in World Rank	104
Change in Rank from 2000	+9

The Knowledge Economy Index (KEI) is calculated based on the average of the normalised scores of a country on all four pillars related to the knowledge economy: economic incentive and institutional regime; education; innovation; and ICT.

* The Knowledge Index (KI) measures a country's ability to generate, adopt and use knowledge. The index is based on key variables in the three knowledge pillars: education; innovation; and ICT.

Source: World Bank (2012a). There is some missing data for Viet Nam.

Investment rates in scientific research per capita and the ratio of S&T researchers in the population are also low, and R&D outputs of international quality are limited. By 2005, Viet Nam had about 40 000 researchers working in different sectors of the economy. However, the existing pool of scientists and engineers is structured so that 72% are employed by national centres for R&D, universities, ministries or government agencies.

Vietnamese information technology firms' knowledge accumulation is hindered due to limited financial capacity and a lack of skilled personnel. In the past ten years, most Vietnamese firms and domestic IT businesses that took on outsourcing work from foreign partners have focused on output of information technology products to meet short-term market demands rather than investing in research to advance technological capabilities.

Table 10.5. Number of patents granted in Viet Nam, 1981-2008

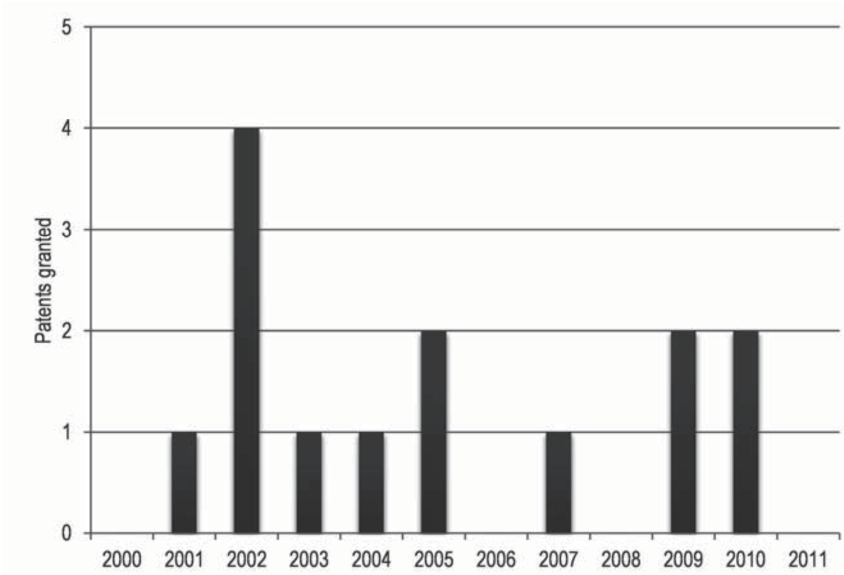
Year	Patent granted for		
	Vietnamese	Foreigners	Total
1981-89	74	7	81
1990	11	3	14
1991	14	13	27
1992	19	16	35
1993	3	13	16
1994	5	14	19
1995	3	53	56
1996	4	58	62
1997	0	111	111
1998	5	343	348
1999	13	322	335
2000	10	620	630
2001	7	776	783
2002	9	734	743
2003	17	757	774
2004	22	676	698
2005	27	641	668
2006	44	625	669
2007	34	691	725
2008	39	627	666
Total	360	7 100	7 460

Source: General Statistics Office of Viet Nam.

Viet Nam ranks very low in terms of patent indicators, with the foreign sector dominant and the domestic sector relatively passive. More than 95% of patent applications and patents granted in Viet Nam are submitted by foreign enterprises (Table 10.5), while the number of USPTO patents granted to Vietnamese beneficiaries is very low (Figure 10.8). The majority of patents are in the fields of civil engineering, special machinery and organic chemistry. Vietnamese firms are more oriented to technology adoption and product design improvements than to patenting new products, processes, or techniques.

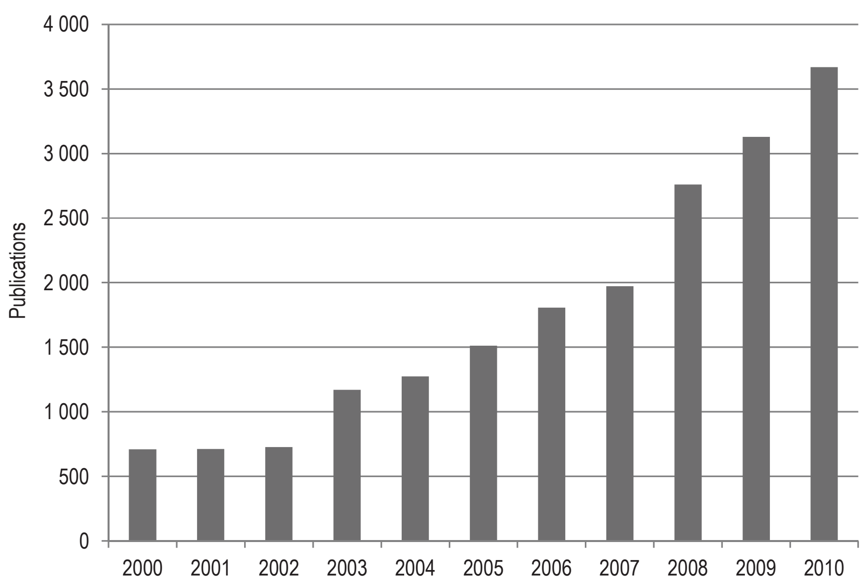
In terms of the number of scientific publications produced, Viet Nam is still at a very low level, though there has been a rapid increase over the last decade (Figure 10.9). There were more than twice as many publications in the period 2006-10 as in 2000-2005 and overall publication rate rose more than five-fold between 2000 and 2010, rising to 3 670. Co-authorship rates are high at 76%, reflecting the influence of foreign countries in the conduct of R&D, with Japan, the United States and France being the leading collaborators.

Figure 10.8. Trends in USPTO patents granted to Viet Nam, 2000-11



Source: US Patent and Trademark Office (USPTO).

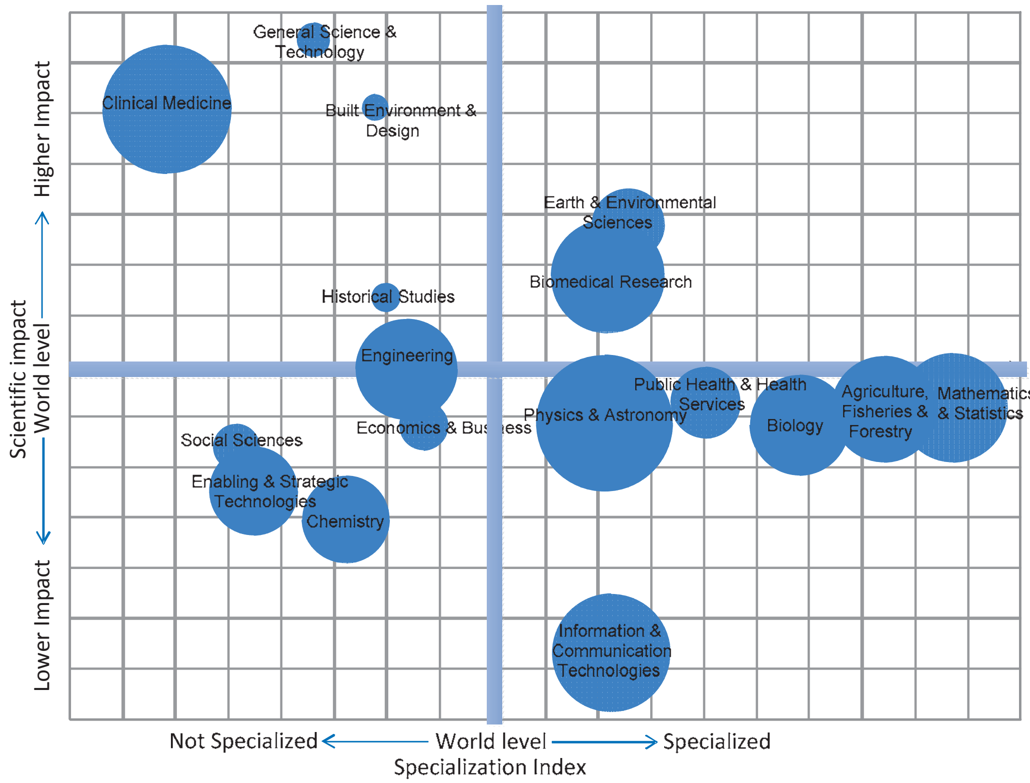
Figure 10.9. Trends in scientific publications in Viet Nam, 2000-10



Source: Science Metrix analysis of Scopus (Elsevier) database.

Clinical medicine, although not a relative specialisation, performs well in terms of relative impact ranking and is well above the World average. Earth and environmental sciences and biomedical sciences also score well in this regard. The greatest specialisation is in mathematics and statistics, agricultural sciences and biology with citation impacts slightly below the global average in all three disciplines (Figure 10.10).

Figure 10.10. Positional analysis of Viet Nam's scientific publications, 2000-10



Source: Analysis of Scopus (Elsevier) database by Science Metrix. This combines the number of publications by scientific field (area of circles), the specialisation index (a measure of relative intensity in a field compared to the World average) and the average of relative citations (citations relative to the World average controlling for age and field).

10.3. Innovation policy orientations and frameworks

Viet Nam has made much progress through economic reforms since the late 1980s, making particularly significant structural changes in the 1990s. With regard to government policies for science, technology and innovation, Viet Nam faces a number of challenges, primarily pertaining to the low level of STI development and in determining an appropriate role for government in providing incentives and an environment conducive to higher levels of innovation.

Viet Nam's innovation policy is developed within the context of specific strategies such as the Science and Technology Development Strategy of 2003-2010 and more recently that of 2011-2020. Starting in 2004, the government introduced several major reforms to the management of science and technology, including new measures for technology transfer. In terms of STI governance, there is no overriding coordination body on innovation policy to ensure a whole of government approach or to foster coherent implementation of the innovation policy mix in Viet Nam. At the central government level, there are two major governance layers for STI policy: overall policy guidance and supervision at the top level of the State and the Government (National Assembly, Prime Minister and Communist Party), and policy design and implementation conducted by the ministries and affiliated agencies. In addition, there are a few independent bodies reporting directly to the head of the Government, such as the Viet Nam Academy of Science and Technology (VAST).

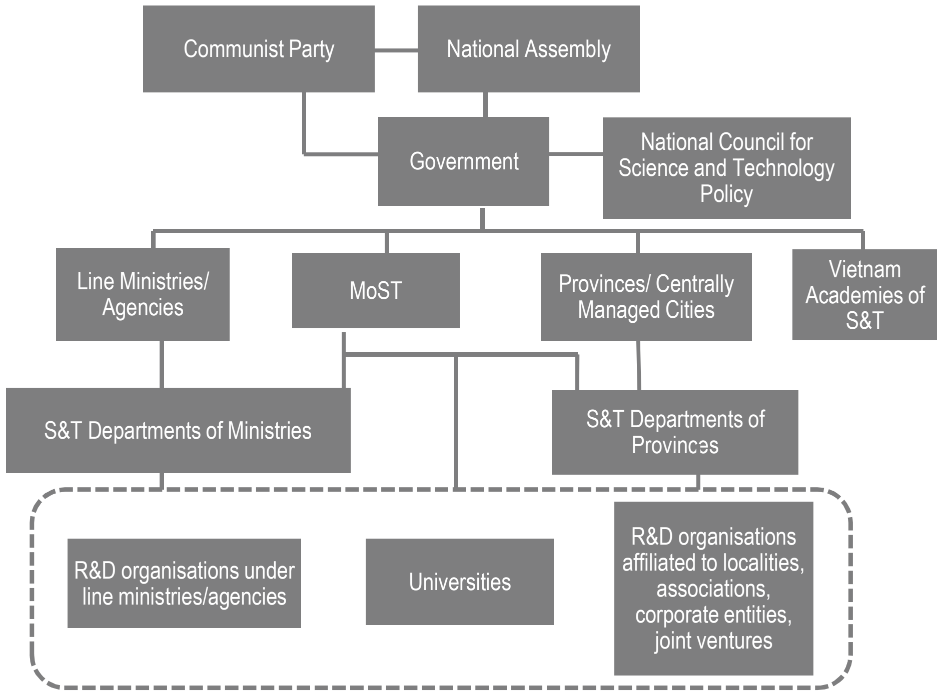
The Committee on Science, Technology and Environment of the National Assembly, the Department of Science and Education within the Office of Government – a ministerial-level agency to assist the central government and the Prime Minister – and the Ministry of Science and Technology (MoST) are the main bodies making major decisions on innovation issues in Viet Nam. While these bodies have attempted to put in place new policies, regulations and organisations to increase innovative capacity, their implementation has been intermittent and results have been limited to date. One reason for this is the insufficiently precise formulation of S&T priorities which do not provide R&D institutes with clear guidance on research opportunities for the national and international contexts.

There are also publicly funded bodies that support policy design and implementation. These can be grouped into *i)* strategic intelligence units that contribute to evidence based policy making and *ii)* agencies with delegated responsibility to manage and/or fund some of the government S&T functions, measures and programmes. The former group is composed of organisations such as the National Institute for Science and Technology Policy and Strategy Studies (NISTPASS), which provides advice and proposals for government authorities on promoting S&T activities; the National Agency for Science and Technology Information (NASATI), which is in charge of information gathering, documentation and statistics; and the Viet Nam S&T Evaluation Centre (VISTEC). The latter group includes the National Foundation for Science and Technology Development (NAFOSTED), which provides funding for basic research; the State Agency for Technology Innovation (SATI), which is responsible for promoting commercialisation and technology transfer to firms; and the National Office of Intellectual Property. In NAFOSTED's first two years of operation (2008-2010) it funded about 500 projects of basic research in natural science and around 100 in social sciences and humanities, for a total approved funding of around 400 billion VND (NAFOSTED).

At the regional level, S&T policy management is undertaken by provincial Departments of S&T (DOST) under the direct guidance and supervision of MoST and Science and Technology offices within people's committees. The regional DOSTs receive their budget allocation from MOST, with the exception of the DOST in Ho Chi Minh City, which gets a local budget allocation from the City Government. The level of decentralisation within the system is thus very limited.

The Ministry of Science and Technology is relatively weak in Viet Nam and the overall government structure is not conducive to the co-ordination of public policy relating to innovation. The Ministry has mandates to conduct the general management of S&T activities; to formulate S&T policies and incentive programmes to be submitted to the national government for approval; and to monitor the implementation of S&T strategy plans after they are approved. Other innovation actors include the Ministry of Education and Training (MOET), which is in charge of universities and colleges, the Ministry of Planning and Investment (MPI), and the Ministry of Finance (MOF). The MPI and MOF are responsible for formulating policies and incentives for promoting innovation in Viet Nam. The National Council for Science and Technology Policy plays an advisory role. There have, however, been recent attempts to modify the existing governance structure to reinforce the institutional capability of the Government. This has seen the creation of a series of agencies, such as the Agency for Technology Entrepreneurship and Commercialisation Development.

Figure 10.11. Institutional profile of Viet Nam's science, technology and innovation system



The extent to which public expenditure on S&T is channelled through ministries has resulted in high management costs. It has been estimated that at minimum one-third, maybe as high as one-half of S&T budget money is consumed in the administrative processes, within ministries and beneficiary organisations. The Government has made efforts to streamline these organisations, though much further work still remains to be done.

The Government focus has been on setting S&T policy directions and managing the work of the many public research institutes, rather than on playing a direct role in technology transfer and the commercialisation of research. The state has invested in research infrastructure by establishing large research laboratories within leading universities and facilities, but it does not support many science and technology activities of direct assistance to firms. It does, however, offer other services, *e.g.* trademark registration, campaigns to increase domestic consumption, and a credit programme offered as part of the recent stimulus package. It also offers, through agencies such as the International Trade and Promotion Centre of Ho Chi Minh City, incentives for exporting or attracting foreign direct investment. Within specified industrial and export zones, there has been significant investment in local infrastructure aimed at reducing costs and improving the competitiveness of firms located in them.

The establishment of the National Fund for Technology Transfer, which was passed by law in 2006 but has yet to become operational, aims to expand the commercialisation of research. This Fund's functions are to provide financial support for promoting the technology transfer process and assisting SMEs in technological innovation and improvement; to accelerate technology transfer to mountainous and remote areas; to support the start-ups of technological enterprises or incubators; and to strengthen human resources for technology transfer and technical improvements. At the same time, SATI is planning to establish two new technical centres to assist small firms: one focusing on designing, pilot manufacturing and testing and the other offering technology transfer services.

In recent years, Viet Nam has attempted to increase financial incentives for investment in science and technology and innovation. The government extends tax incentives to enterprises engaged in R&D and those investing in technologically advanced machinery and equipment. These include VAT exemptions on machinery that must be imported from abroad, tax deductions for expenditure on science and technology, and business income tax exemptions for income from contracts related to science and technology and for share dividends from joint stock companies.

In addition to the general incentives available to all enterprises, specific programmes target key technology-intensive sectors such as information technology, biotechnology, and automation technology. A state fund has been approved to allow firms investing in technology to have easier access to credit, but this has yet to be fully implemented.

Among its policies to support the development of the information technology services industry, the government has instituted a number of specific measures, which include:

- Business income tax exemption for:
  - Income earned from scientific research and technological development;
  - Products manufactured during test production;
  - Products made from technology applied for the first time in Viet Nam.
- Income tax deductions for expenses associated with scientific and technological research and innovation activities.
- IPR protection for computer programs, the compilation of data and layout design for semiconductors and integrated circuits.
- Fifty year copyright protection and twenty year protection for invention patents.

10.4. National innovation system

10.4.1. Business sector

The technology level of the business sector in Viet Nam is generally low and out-dated, with the manufacturing sector considered to be 2 to 3 technology generations behind peer countries in the region. This is true in most sectors except those where investments have been made by multinationals in advanced technologies, *e.g.* in areas such as information technology, oil and gas, and consumer electronics. However, since the introduction of Decree 80 (2010), foreign investments in S&T have in fact become increasingly difficult as they are subject to many levels of approval. The Decree states that authorities must be informed when an agreement takes effect, approval must be obtained when using foreign funding, projects must be approved by the local people's committee and foreign organisations wishing to open representative offices will only be allowed to do so after one year of operation or five years if wishing to open a branch (Viet Nam Briefing, 2010).

R&D is generally not conducted by multinational enterprises in Viet Nam. MNEs use technology determined by their overseas parent companies for optimal efficiency in the context of Viet Nam. They tend to operate independently from domestic companies and do not form local networks of production, supply and distribution that involve them. However, Intel recently received a license from the Ministry of Planning and Investment to build a USD 300 million assembly and testing facility to produce chips and computer parts and has become the first major foreign investor in high technology in Viet Nam.

The larger state-owned enterprises (SOEs) are not proactive in research activities unless they are in receipt of state subsidies to carry out R&D projects based on the national science and technology plan. They generally lack incentives to innovate since they use their monopolistic positions to avoid competition. Very few SOEs have set up their own R&D institutes. While, in principle, government incentives to promote technology and innovation are aimed at all enterprises, in practice SOEs have most access to these schemes and receive 85% of subsidies. Most R&D by state-owned firms has been conducted in the shipbuilding and telecommunications industries.

Development of the information technology sector is a government focus and a high priority for public support: currently around 600 software development firms located in Ho Chi Minh City and Hanoi employ around 15 000 IT professionals, an increase from 170 firms and 5 000 workers in 1999. Despite government support, ICT production by local Vietnamese firms, including those located in the High-tech Park in Ho Chi Minh City, is characterised by low value-added assembling using imported components.

SMEs in Viet Nam, which constitute the majority of firms, do not have the capacity to organise R&D activities internally and lack sufficient information on new knowledge or financial resources to obtain technology. Barriers to technological development include lack of information on appropriate technologies, low awareness of government technology initiatives, a lack of acknowledgement on the part of enterprises of the need for technology, and complicated procedures for accessing supports. Such constraints are particularly acute for non-state firms, which constitute less than 15% of enterprises receiving incentives from the government. The low technology level of domestic enterprises hinders any possible technology-related spillover effects that could occur as a consequence of supplying inputs and services to MNEs. It also leads to their minimal participation in global value chains.

Overall, the proportion of indigenous enterprises using modern technology in the manufacturing sector remains small, despite an increasing number of firms investing in machinery and equipment. For example, firms in the textile and clothing and chemical industries of Viet Nam spent only 3% of their turnover on technological innovation in recent years, of which a major part was spent on importing machines or technology. The Viet Nam Association of SMEs provides some support to domestic enterprises and organises matchmaking meetings between SMEs and MNEs to encourage the transfer of relevant technologies. The SME Promotion Centre of the Viet Nam Chamber of Commerce and Industry (VCCI) also lobbies for delegations of business leaders from large companies and SMEs to accompany government officials whenever travelling abroad.

10.4.2. Higher education institutes (HEIs)

Viet Nam is attempting to improve its infrastructure of institutes, research centres, laboratories, S&T information centres, and libraries associated with Higher Education Institutes (HEIs). However, as in the case of government support for business research, support to university research is not a strong feature of public research funding mechanisms, which are not especially designed to serve universities. According to the Ministry of Education and Training (2010), Viet Nam counts 376 HEIs, of which 81 are non-public, significantly up from the pre-2005 level (Table 10.6). There are plans to increase the current number of private universities to enable 40% of all students to study at private universities by 2020 (the proportion at the end of 2000s was 13%). There are also 250 vocational universities and community colleges, including 30 private schools. Foreign university training bases in Viet Nam include the Genetics Study Centre of Singapore in Hanoi and the Royal Melbourne Institute of Technology (RMIT) of Australia in Hanoi and Ho Chi Minh City.

Table 10.6. Number of higher education institutions (HEIs) in Viet Nam, by ownership, 2001-09

Type	2001	2002	2003	2004	2005	2009
Public	60	64	68	71	79	295
Public %	78.0	79.0	78.2	76.3	76.0	78.5
Non-public	17	17	19	22	25	81
Non-public %	22.0	21.0	21.8	23.7	24.0	21.5
Total	77	81	87	93	104	376

Source: Statistical Report of Ministry of Education and Training, Viet Nam.

In the university system, institutes and colleges have hundreds of laboratories, of which about 60 meet regional and international standards. Experimental equipment for research has been improved, especially at the Viet Nam National University sites in both Hanoi and Ho Chi Minh City. Other Vietnamese universities with research activities include the Hanoi University of Technology, Ho Chi Minh City University of Technology, Hanoi Medical University, the University of Danang, and Can Tho University. More than half of Viet Nam's universities and colleges provide post-graduate programmes. Although there are many highly educated professors at the universities, only 20% of Viet Nam's university teachers are involved in research and fewer still in practical technology development. Furthermore, the majority of academic staff are over 55 years old, with few younger replacements evident. The main research programmes are in the fields of information technology, medicine, biotechnology, materials technology, automation and mechanics.

The Hanoi University of Technology (HUT) is the largest technical university in Viet Nam with more than 40 000 students and 2 000 staff. The University is attempting to supply quality graduates to meet the needs of the Vietnamese economy. Currently, HUT has seven companies that help to market and commercialise university technologies and it has set up incubation centres in a nearby science park. Staff and students are encouraged to initiate start-up companies with the help of the incubation centres.

Can Tho University conducts research to support the development of the Mekong River delta region through enhanced agricultural and aquaculture techniques, seed development and improvements in farming methods, while the Hanoi University of Agriculture is also prominent in farm-related investigations. Most agricultural research by universities has focused on lowland farming systems, particularly the development, adaptation and dissemination of new rice varieties. However, the agricultural research system has a complex structure, with overlapping responsibilities among the universities and the many public institutes reporting to the Ministry of Agriculture and Rural Development (MARD).

10.4.3. Public research institutes (PRIs)

The public sector plays the major role in the innovation system in Viet Nam. Until the early 1990s, R&D activities were undertaken mainly by public research institutes (PRIs). These organisations were under the administration of line ministries and specialised in areas such as natural sciences, social and cultural research, agriculture, and engineering. They tended to be separate from the polytechnic universities and isolated from other innovation actors, including the private sector. They had little incentive to commercialise their research results, since their activities were subsidised by the state regardless of their practical applicability.

This situation changed when Viet Nam started the transition towards a market economy and opened up to all types of firm. The total number of R&D institutes in Viet Nam increased from 519 in 1995 to over 1 200 by 2005, while the share of public R&D institutes dropped significantly from 72% of the total in 1995 to just above 50% by 2005 (Table 10.7). R&D institutes operated by the private sector and non-governmental organisations now account for around half of the total.

A current challenge is the large number of public R&D institutes (over 600), a large share of which are small and lack adequate funding. The majority have insufficient technical and financial resources, are uncoupled from the market and the private sector, and do not conduct high quality research or engage in technology transfer. The commercialisation of research and technology is at a low level as researchers are generally content publishing papers. For example, the premier Viet Nam Academy of Science and Technology has 30 research institutes, 3 000 staff – including 700 PhDs, and a budget of USD 20 million, yet it produces very few patents or commercialised technologies. On the other hand, non-public institutes do not have sufficient opportunities to receive state research support directly: they generally act as sub-contractors of public research institutes when conducting state-funded projects. The specific aim of having 60 internationally acclaimed basic and applied research centres by 2020 according to the latest Strategy suggests the possibility of streamlining of public research institutes to pool the limited R&D resources.

Table 10.7: Changing ownership structure of R&D institutes in Viet Nam, 1995-2005

Sector	**1995**		**2000**		**2005**	
	Number	(%)	Number	(%)	Number	(%)
Public	374	72.06	517	60.61	639	52.40
- PRIs attached to ministries/agencies	289	5.68	342	4.09	456	37.3
- Universities	51	9.82	120	14.06	116	9.11
- State-owned corporations	34	6.56	55	6.46	67	5.49
NGOs[1]	130	25.04	311	35.64	524	43.1
Private	15	2.89	25	2.86	57	4.5
Total	519	100	873	100	1220	100

[1] In Viet Nam, non-government institutes are required to be registered under the supervision of the national professional associations.

Source: Ministry of Science and Technology (MOST), Viet Nam.

However, there are some instances, such as in the biotechnology field, where sufficient funding has led to high quality results. VABIOTECH is a fully state-owned vaccine research institute under the purview of the Ministry of Health that has become world-class in the manufacture of vaccines. The Institute reinvests 10% of revenues back into research and facilities. The professional staff includes local university graduates, all of whom receive two years of additional training from foreign universities, and visiting fellows from developed countries, who serve as a channel for knowledge transfer.

Viet Nam has almost 5 000 staff members working at over 30 state agricultural research institutes, all of which operate under the supervision of the Ministry of Agriculture and Rural Development (MARD). The Institute for Agricultural Science conducts research on the breeding and screening of plant varieties and animal breeds, the technical aspects of crop and livestock production, and the improvement of existing farming systems. But the scattered and small-scale nature of funding leads to poor quality agricultural research compounded by the relative absence of research evaluation. Relevant agricultural research results are often not shared with farmers and rural workers. Although there are a significant number of agro-scientists working at the local level who also participate in agricultural investigations, there is too little interaction between the various actors in this sector.

10.4.4. Linkages between innovation actors

The number of Vietnamese organisations acting as a bridge between knowledge generators (research institutes and universities) and users (firms and farmers) has grown in recent years, but they remain limited in skills and expertise. These are mostly public bodies with the private sector playing a limited role. For example, there are several centres for promoting technology transfer and information under the local Department of Science and Technology (DOST) of Hanoi and Ho Chi Minh City and the Centres for Promoting Agricultural Activities under the local agencies for Agriculture and Rural Development. In addition, technology incubators are linked to polytechnic universities and to a growing number of technology parks, which play a role in facilitating knowledge diffusion.

On the local level, the State Agency for Technical Innovation (SATI) is supported by the departments for science and technology in the provinces of Viet Nam, which are the main connectors for innovation networks. SATI formed a joint programme with the Japanese government that has supported about 1 000 Vietnamese companies in upgrading their manufacturing operations through buying Japanese equipment. Under the new Technology Transfer Fund, there is a planned Centre for S&T Transfer Services to help local enterprises adopt foreign technology and to transfer know-how and technologies from public research institutes and universities. In addition, SATI organises technical training and capacity building activities at the local and provincial levels.

There are several industrial parks in Viet Nam hosting foreign firms that receive favourable tax, land and infrastructure treatment. A special arrangement with local authorities provides funding to firms who hire local workers. More technical universities are being constructed within the parks and synergies are sought through regular meetings between firms, local government, and vocational education and training centres. Attempts are being made to strengthen local content provisions and attract suppliers to locate near the multinationals to increase jobs and revenues. But as in the case of Samsung, foreign firms supply most of the components for manufacturing Samsung mobile phones, while indigenous firms are primarily assemblers for the local market. Most Vietnamese companies do not have the technical capacity or skills to compete with foreign suppliers of parts, including Chinese companies, and knowledge transfers between foreign and local firms is limited in Viet Nam.

Started in 1998, the Hoa Lac High-Technology Park has been built with USD 100 million government funds and USD 500 million financial support from the Japanese government. In 2010 it hosted 10 companies – primarily Japanese. It aims to promote research and development, produce high technology products, incubate technology enterprises and develop human resources. A training centre focuses especially on Japanese as a second language and the upgrading of co-operation with Japanese partners. By 2010 the incubator facility had 12 small spin-off companies in the fields of biotechnology and information technology. However, construction of the Park has suffered from lack of funding and delays and is far from being fully operational. In 2010, a high-technology agricultural park with nine private investors opened outside Ho Chi Minh City with the aim of conducting research and transfer technology to improve agricultural productivity and ensure food safety.

A significant barrier to the commercialisation of research results from the public sector is that universities and research institutes cannot legally sign contracts with the private sector due to their non-profit status. Contracts between the private sector and individual researchers are allowed but are taxable. Even when academic entities are registered formally as companies, regulatory barriers can be significant, both during the registration process and in daily operation. A new law facilitating business creation by scientists was recently passed, but its practical implications are still unclear. The government needs to facilitate collaboration and partnerships between research institutes and the private sector by improving the legal framework that governs agreements and contracts and clarifying existing regulation.

10.5. Human resources

With a population of 85 million, Viet Nam is a country with abundant human resources and a young labour force, since about two-thirds of the population is between the ages of 15 and 60. However it remains low placed on international indices of education and human resource development. Viet Nam’s development is still impeded by an insufficient supply of higher education graduates and a very limited science and technology workforce. One of the main aims of the latest Strategy is to address this problem by increasing scientific researchers and professional staff in ICT and by training up to 5 000 engineers.

Access to education in Viet Nam has expanded rapidly and primary enrolment is now almost universal. Enrolment in colleges and universities has nearly doubled from some 0.9 million in 2001 to over 1.6 million in 2008. At the upper levels of education, 5% of the 25-55 population cohort reached the undergraduate stage in 2006. But despite a 94% literacy rate, the overall tertiary enrolment ratio is moderate at about 12%. Only about 30% of skilled workers hold university, college or higher education degrees, while a share of the remainder has had some level of technical or vocational training. Science, engineering, manufacturing and construction students account for almost 20% of the total tertiary student population.

The Ministry of Education and Training (MOET) is responsible for Viet Nam’s universities and colleges. The State remains the key provider and financier of education in Viet Nam, but the share allocated to higher education is low by international standards. Viet Nam has more than doubled its spending on education since 2000, but the expenditures are skewed towards the lower levels of education. On average, annual State budget allocations to HEIs account for 50% to 60% of their total budget, while tuition fees provide from 30% to 35%. By 2020, Viet Nam aims to increase the coverage of higher education to 35% of the age 18-24 population cohort, with a larger share provided by private sector institutions.

Students not attending university may undergo some type of vocational training for three years. Over 300 000 students attend 250 public and private technical and vocational schools overseen by the Ministry of Labour. There is, however, no dual vocational education system whereby students combine theoretical training with practical training at a company. In general, indigenous companies prefer not to take on trainees or apprentices, while foreign firms prefer to train their workers in-house or import highly skilled workers for handling specialised machinery, often from China.

Reforms are needed to enable the higher education system to meet demands for trained science and technology workers in an expanding economy. Changes are needed to improve curricula, to stimulate the recruitment and hiring of teachers, and to align academic programmes more closely to labour market needs. The rigidity of the university system makes mobility problematic for a younger and more dynamic generation of academics, many of whom have been trained in the West, and other problems result from a traditional approach to teaching and learning. There are also currently debates on what constitutes a useful education, as currently skills needed by employers are often at odds with the focus of Viet Nam's higher education on theoretical learning.

As in the case of other countries in the Southeast Asia region, Viet Nam suffers from an increasing brain drain of educated and talented young professionals. Statistics show that as many as 70% of Vietnamese students who study overseas fail to return home. There are now some 3 million Vietnamese living abroad, equivalent to 3.5% of Viet Nam's population. In 2007, a scheme was initiated to encourage Vietnamese living abroad to return to work in the public sector. A new plan is being drafted to provide incentives to the Vietnamese diaspora to work in the expanding domestic information technology sector, with the aim of transforming a 'brain drain' into an increasing 'brain gain'.

10.6. SWOT analysis

Based on the material presented above, several strengths and weaknesses of Viet Nam's innovation system can be identified, along with future opportunities and threats. These are summarised in Table 10.8.

Table 10.8. Summary SWOT (strengths, weaknesses, opportunities, threats) analysis

Strengths	Weaknesses
• Political stability provides foundation for future foreign investments • Continued economic growth • Diminishing poverty levels • Strong agricultural sector • Strong export trade in rice and coffee • Access and proximity to large indigenous and global markets • Abundant labour force	• Poor overall economic infrastructure • Poor innovation infrastructure • Weak policy focus on research and innovation • Weak higher education system • Low levels of research and development, especially in the private sector • Low productivity levels • Few technology-based exports • Relatively small MNE base • Limited access to finance for innovation and start-ups • Absence of links between foreign and domestic firms • Underdeveloped capacities of R&D statistics and indicators and of strategic intelligence
Opportunities	**Threats**
• Young population and sizeable diaspora • Stronger focus on an improved higher education sector • Increased FDI and an expanding MNE base • Expanding information technology sector • Improving innovation infrastructure and policy emphasis • Good innovation potential given stage of development • Opportunity to exploit its Technology Transfer Fund • Growing tourist destination • Indigenous biodiversity potential	• Global financial situation • Lack of administrative and legal reforms • Failure to tackle banking system reform and levels of corruption • Entrenched public research system • Strong regional competitors • High trade and tariff barriers for imports • Increasing brain drain

Viet Nam's track record in terms of political stability, economic growth and poverty reduction provide a sound platform for future development and for attracting FDI. It has an abundant labour force, a sizeable indigenous market, a strong agricultural sector and good trade links that provide it with access to global markets, all of which can be exploited as an increasing emphasis is placed on the export of manufactured products.

At the same time, there are several weaknesses to contend with. The undeveloped state of physical infrastructure is a deterrent to inward investment and Viet Nam's innovation infrastructure has, until recently, been relatively weak, with few policies in place to effectively stimulate innovation. Its higher education system has not delivered adequate outputs in terms of supply of sufficiently qualified S&T personnel, university research and commercialisation, while the country's expenditures on R&D and innovation, especially by the private sector, have been insufficient. Within industry itself, productivity levels remain low despite some growth and there are few technology-based exports. Productivity and the share of technology-based exports are appreciably higher in the MNE sector, which is, however, relatively small compared to the situation in other Southeast Asian countries. Moreover, there are few links between MNEs and indigenous firms, and access to capital for the latter to develop, or for the launch of start-ups, is limited. The acute shortage of statistics and indicators must also be addressed to provide government and other stakeholders with reliable information and internationally comparable statistics for formulating government policies on STI, making business decisions on R&D and innovation and for the evaluation of policies and programmes.

There are nevertheless opportunities for growth. There is a young population, an expanding MNE base and a growing information technology sector. Improvements to the innovation infrastructure and a keener focus on higher education research and innovation policy also suggest there is good innovation potential, especially if existing trade links are exploited and new support mechanisms such as the Technology Transfer Fund are utilised effectively.

The greatest threats, apart from the prospect of a deepening global crisis, are likely to come from inadequate reforms tackling deficiencies in the legal and banking systems, an unwillingness to streamline government bureaucracy and eradicate corruption, and a failure to overcome the inertia of an entrenched public research system. Competition from regional competitors is also likely to be stiff, and protectionist policies involving high tariff and trade barriers for imports could be counterproductive. An increasing brain drain is also a possibility if local employment opportunities for highly qualified S&T personnel do not increase.

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Annex A

Economic relationships between China and Southeast Asian countries: Science, technology and innovation issues – A Chinese perspective

This paper is prepared by a Southeast Asia (SEA) specialist at the Institute for Asia and Pacific Studies, Chinese Academy of Social Sciences, in the context of the OECD Review of Innovation in Southeast Asia*. It examines the current state and main trends in China's economic relationships with Southeast Asian countries, particularly those concerning science, technology and innovation (STI).*[*] *Relations between China and SEA countries, especially economic, have developed rapidly since the 1997 East Asian financial crisis. The paper assesses the development of these bilateral economic relationships, primarily in the area of STI, over the last ten years.*

Section A.1 reviews current economic, trade and investment relations between China and each of the SEA countries, with a brief overview of their evolution and examination of predictions regarding the development of relations in the coming decade. Section A.2 discusses China's strategy and policy vis-à-vis the SEA region and the region's main economies. China considers SEA countries as crucial regional partners and hopes to deepen bilateral economic, trade and investment relationships with them in the coming decades. Section A.3 discusses existing relationships in the areas of STI, such as bilateral agreements and academic exchanges over the period 1999-2009. Section A.4 analyses the favourable factors, including political and economic aspects, and the constraints that influence the current state of science and technology (S&T) exchanges and co-operation between China and SEA countries. It appears that there have been significant achievements in the area of bilateral economic relationships, but relatively little progress in bilateral technological relationships. Section A.5 discusses future trends and directions in China's relationship with the SEA countries in STI. It is likely that the coming decade will see relatively strong progress in technological relationships. Section A.6 discusses the role of technology assistance (S&T diplomacy) in future S&T relationships with the SEA countries. Due to certain restrictions, China's technology assistance to SEA countries will be less than that of Japan or other more advanced economies in the East Asian region in the near future. However, it will play an increasing role in constructing bilateral economic relationships. Section A.7 sums up the main findings.

* The countries covered in this study are the ASEAN Member countries Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Singapore, Thailand, the Philippines and Viet Nam.

A.1. Bilateral economic relationships between China and SEA countries

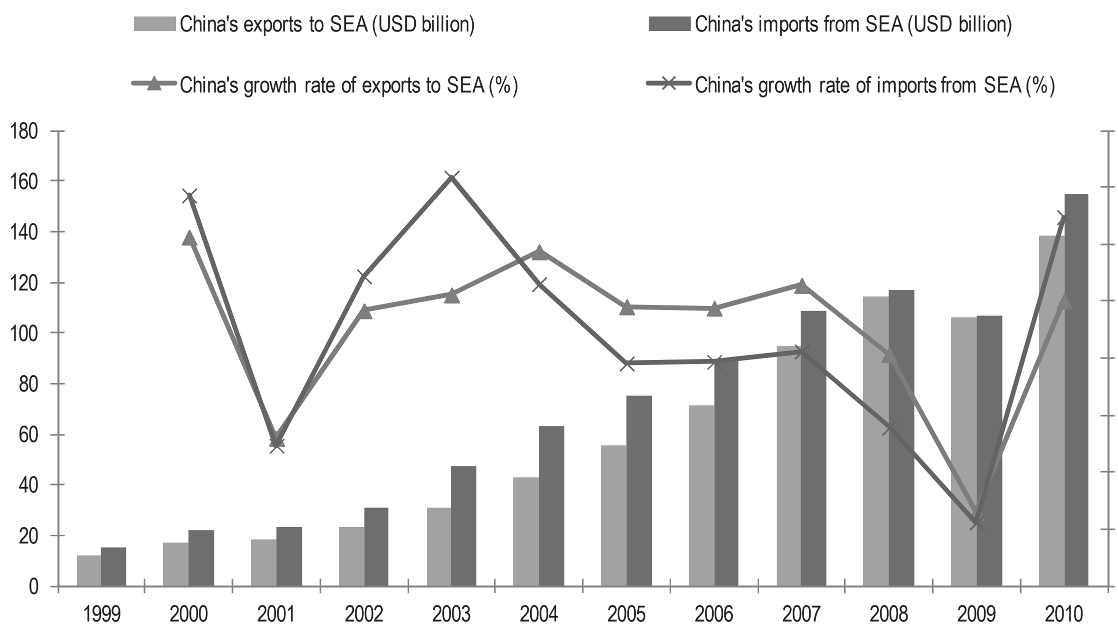
A.1.1. The evolution and current situation of bilateral economic relationship between China and SEA countries (1991-2010)

Economic relations between China and SEA countries were established following an improvement in political relations following the end of the cold war. Since the China-ASEAN Dialogue Relations of 1991, both parties have shown keen interest in co-operation. China was accorded full dialogue partner status at the 29th ASEAN Ministerial Meeting (AMM) in July 1996. Subsequently, China was the first ASEAN dialogue partner to accede to the Treaty of Amity and Cooperation (TAC) in Southeast Asia at the 7th ASEAN-China Summit in October 2003. China's accession to the TAC has contributed to making the TAC the basis of a code of conduct for inter-state relations in the region. At the summit, relations between China and SEA countries were raised to a higher plane with the signing of the Joint Declaration of the Heads of State/Government of the Association of Southeast Asian Nations and the People's Republic of China on a Strategic Partnership for Peace and Prosperity.

At the 8th China-ASEAN Summit in November 2004, a five-year plan of action (2005-10) to implement the Joint Declaration was adopted. This plan of action has served as the master plan to strengthen the strategic partnership between the two sides for regional peace, development and prosperity. In 2006 at the Commemorative Summit Marking the 15th Anniversary of ASEAN-China Dialogue Relations, the leaders issued a joint statement aimed at further strengthening ASEAN-China relations towards an enhanced strategic partnership.

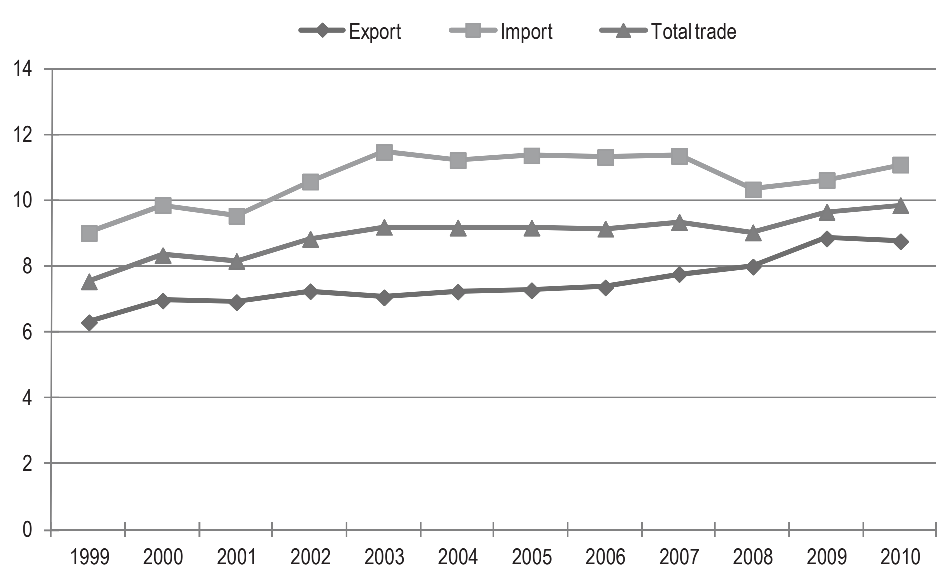
With the improvement in bilateral political relations and the opening up of the Chinese economy increasingly closer trade and economic ties between China and SEA have been forged. This is especially the case after the signing, at the 6th Leaders Summit held in November 2002, of the Framework Agreement on Comprehensive Economic Cooperation involving the ASEAN-China Free Trade Area (ACFTA). 1 January 2010 was targeted for the implementation of ACFTA in Brunei Darussalam, Indonesia, Malaysia, the Philippines, Singapore, Thailand and China, and 2015 for Cambodia, Laos, Myanmar and Viet Nam. In November 2004 the Agreements on Trade in Goods and Dispute Settlement Mechanisms were signed and were implemented in July 2005. The Agreement on Trade in Services was signed during the 10th China-ASEAN Summit in January 2007 and entered into force on 1 July 2007. The China-ASEAN Trade Negotiating Committee (CA-TNC) concluded negotiations on the China-ASEAN Investment Agreement in November 2008 and the agreement was signed during the 41st ASEAN Economic Ministers Meeting in August 2009. This put an end to the China-ASEAN negotiation process on a free trade area (FTA) set in the Framework Agreement on Comprehensive Economic Cooperation between China and SEA countries. The implementation of ACTFA in 2010 created the third largest FTA in the world with a combined population of 1.9 billion (Asian Development Bank, 2009) and a gross domestic product (GDP) close to USD 6 trillion.

Figure A.1. The volume and growth of China's trade with SEA countries (1999-2010)



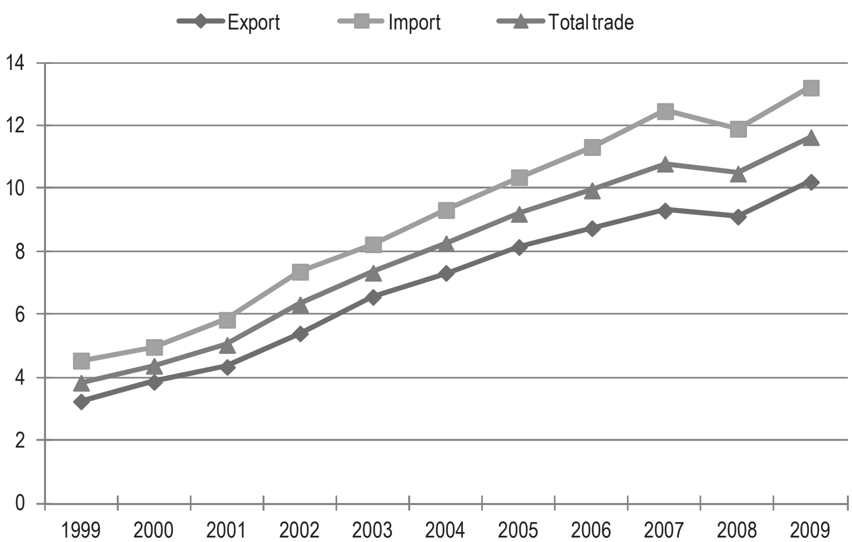
Source: UN Comtrade and MOFCOM, P.R.China.

Figure A.2. China's trade with SEA as a share in China's total trade (%) (1999-2010)



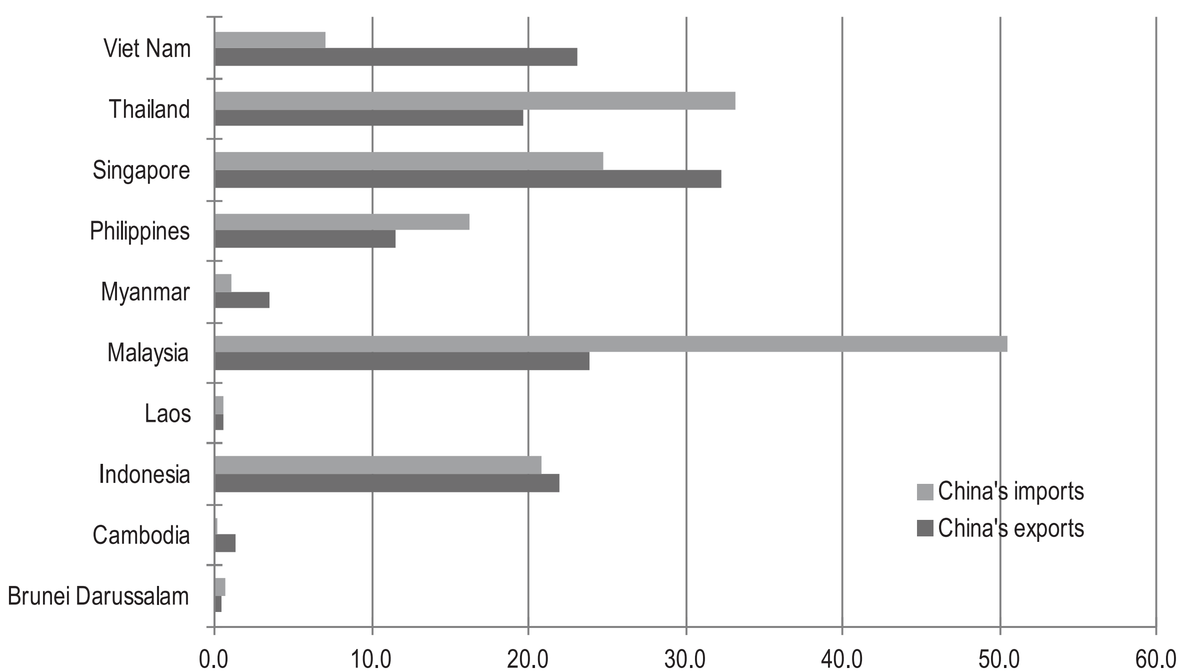
Source: UN Comtrade.

Figure A.3. Share of SEA's trade with China in SEA's total trade (%) (1999-2009)



Source: UN Comtrade.

Figure A.4. China's trade with SEA by country, 2010 (USD billion)



Source: MOFCOM, P.R. China.

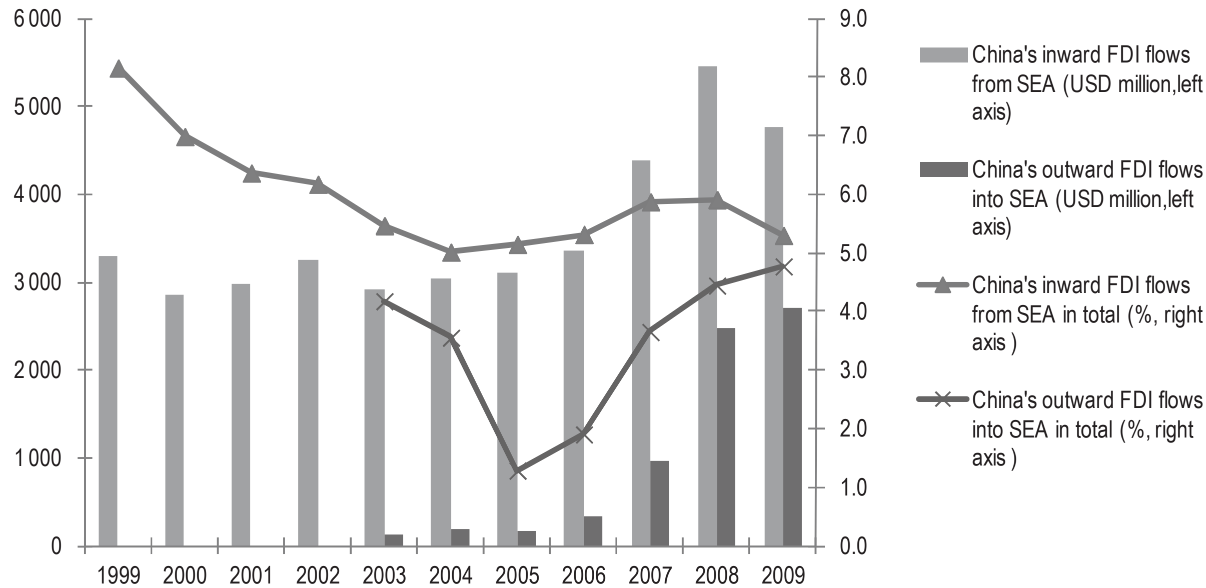
The establishment and development of close bilateral economic relations have promoted the rapid expansion of bilateral trade and foreign direct investment (FDI). Total trade between China and SEA countries increased from USD 27.2 billion in 1999 to USD 213 billion in 2009 for an annual increase of 22.9%, according to China's Ministry of Commerce (MOFCOM). In 2010, total trade between China and SEA countries amounted to USD 292.8 billion (MOFCOM). China's imports from SEA countries reached USD 154.6 billion, a growth rate of 44.8%, while China's exports to ASEAN reached USD 138.2 billion, a growth rate of 30%. ASEAN is China's fourth largest trading partner, accounting for 9.8% of China's total trade, while China is ASEAN's leading trading partner with 11.3% of trade in 2010, marginally larger than that of the European Union (ASEAN).

As seen in Figure A.4 the benefits of ACFTA are unevenly distributed among ASEAN countries. Trade with China tended to feature either a strong surplus as in the case of Thailand, Malaysia and the Philippines, or a trade deficit as in the case of Viet Nam and Singapore. Some observers (*e.g.* Goto 2011) have also noted the impact of Chinese imports on domestic producers and entrepreneurs in Laos, particularly in labour intensive manufacturing.

FDI flows between China and SEA have increased rapidly. China's FDI flows into SEA countries increased from USD 119.3 million in 2003 to USD 2.7 billion in 2009 for an average annual increase of 68.2%. By the end of 2009, China's FDI stocks into SEA countries reached USD 9.6 billion. China has approximately 2 000 firms in SEA countries with 60 000 local employees. As of the end of June 2010, the cumulative total of mutual investments between the two reached approximately USD 69.4 billion; SEA's investment in China totalled about USD 59.8 billion while China's total non-financial investment in SEA was about USD 9.6 billion. China's outward investment is accelerating to catch up with the level of SEA's FDI in China. Due to Singapore's role as a regional hub for capital flows, the volume of Singapore's FDI exaggerates the country's bilateral investment relationships with China or other AEASN members, as many western companies have headquarters in Singapore and use them to channel investments elsewhere in Asia.

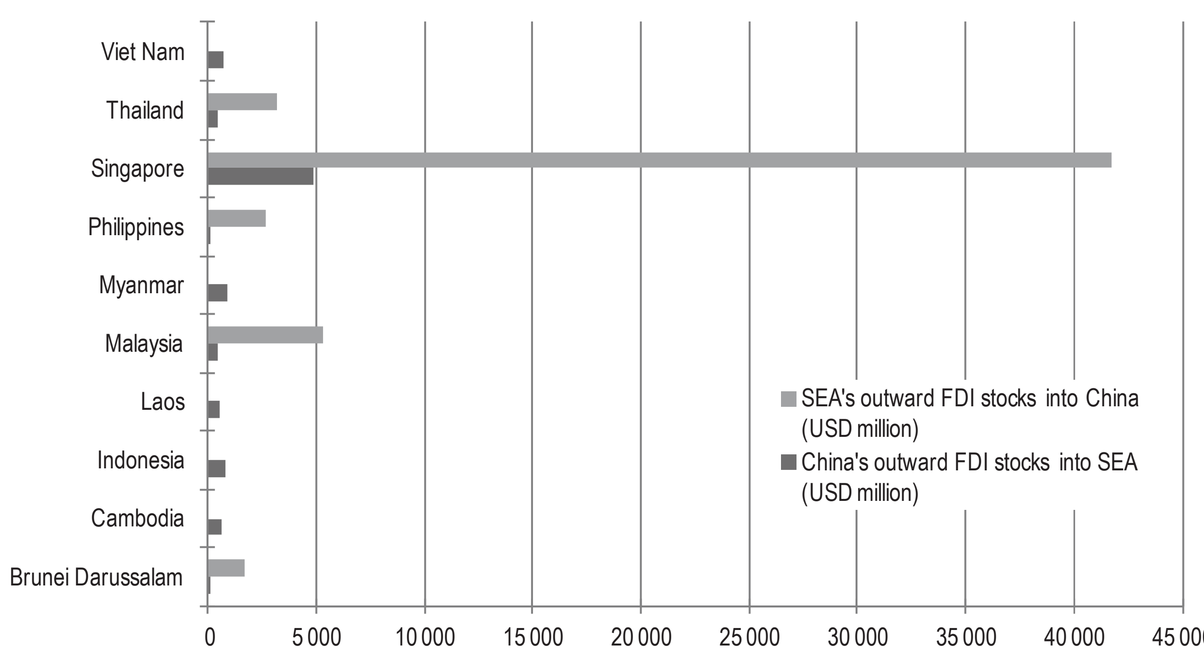
In the field of economic co-operation, China and SEA countries have identified 11 priority areas for bilateral co-operation: energy, transport, culture, public health, tourism, agriculture, information technology, two-way investment, human resource development, Mekong River Basin Development and environment. China and ASEAN have signed many memoranda of understanding (MOUs) and co-operation frameworks in these areas. The turnover of China's economic co-operation, whose measurement is composed of contracted projects, labour co-operation and design consultation, with SEA countries increased from less than USD 2 billion in 1999 to more than USD 11 billion in 2009, for an average annual growth rate of 20.4%.

Figure A.5. China's inward FDI flows from SEA countries and China's outward FDI flows to SEA countries



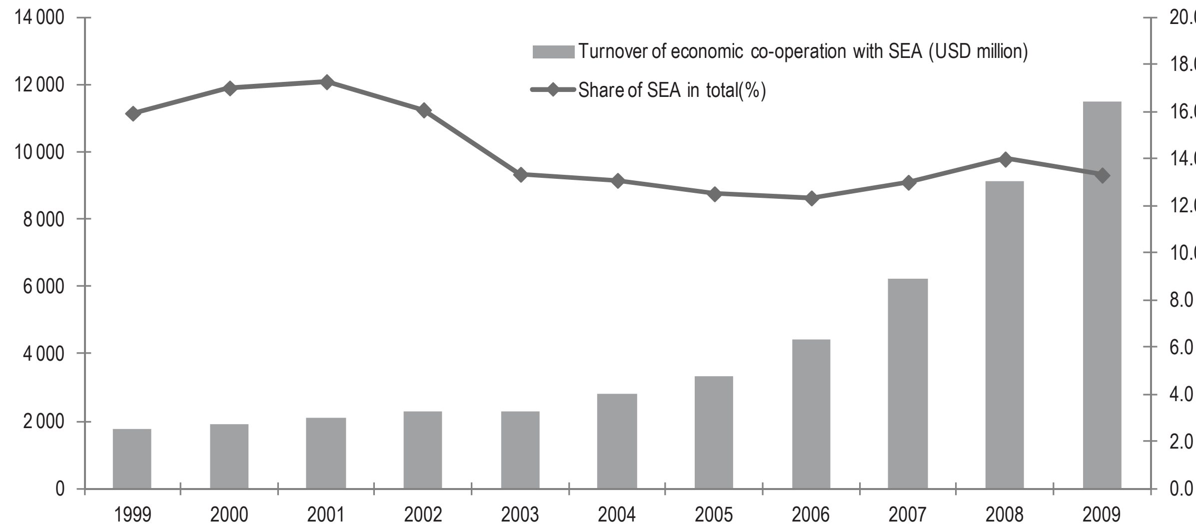
Source: China's Statistical Yearbook (2000-2009) and 2009 Statistical Bulletin of China's Outward Foreign Direct Investment, MOFCOM, P.R. China,

Figure A.6. China's inward FDI stocks from SEA countries and China's outward FDI stocks to SEA countries as of 2009



Source: China's Statistical Yearbook (2000-2009) and 2009 Statistical Bulletin of China's Outward Foreign Direct Investment, MOFCOM, P.R. China.

Figure A.7. Turnover of China's economic co-operation with SEA and share in total (1999-2009)



Source: China's *Statistical Yearbook* (various years 2000-2009).

A.1.2. Outlook for economic relationships (2010-20)

Economic relations between ASEAN and China have laid a foundation for the development of prosperous relations over the next decade. The international economic environment is expected to help further strengthen bilateral economic and trade co-operation. As economic globalisation accelerates, both sides will face challenges. Both China and SEA countries experienced the financial crises of 1997 and 2008, each of which caused a serious shock to their economic growth, and both sides are well aware of the role played by bilateral co-operation in dealing with the crises. Following the East Asian financial crisis of 1997, China began to accelerate the ACFTA negotiation process. During the 2008 global financial crisis, China and SEA countries further strengthened co-operation in financial and other areas with real benefits. In 2009, SEA's exports to China fell significantly less than its exports to the world. Exports of ASEAN-6, Thailand, Singapore, Philippines, Indonesia, Malaysia, and Viet Nam to the United States and the world dropped by 21.3% and 17.7%, respectively, from 2008, while its exports to China fell by only 8.2%.

Secondly, common interests of industrialisation and growth of per capita income may encourage both sides to strengthen co-operation. China's national development target for the next 10 to 15 years is to develop a well-off society, while SEA countries are engaged in building the ASEAN community. However, the huge potential of this bilateral co-operation has yet to be exploited, leaving much room for development in the coming years. Although growing rapidly, trade and FDI are still small as a share of each side's total. There are great prospects for co-operation in other fields such as finance, human resource development, education and technology, with the market potential of some 1.9 billion people yet to be developed.

Third, the conditions for bilateral co-operation have improved and will facilitate further integration. The two sides have gradually set up a series of mechanisms and frameworks to facilitate communication and co-operation, since establishing dialogue in 1991 as illustrated in Figure A.8. In addition to an annual summit of heads of state/ government, meetings and consultations are held at the Ministerial and at the senior official levels. These mechanisms form the overall structure of ASEAN-China co-operation. Funds for bilateral co-operation have also increased over time.

Figure A.8. China-ASEAN regional economic co-operation mechanisms

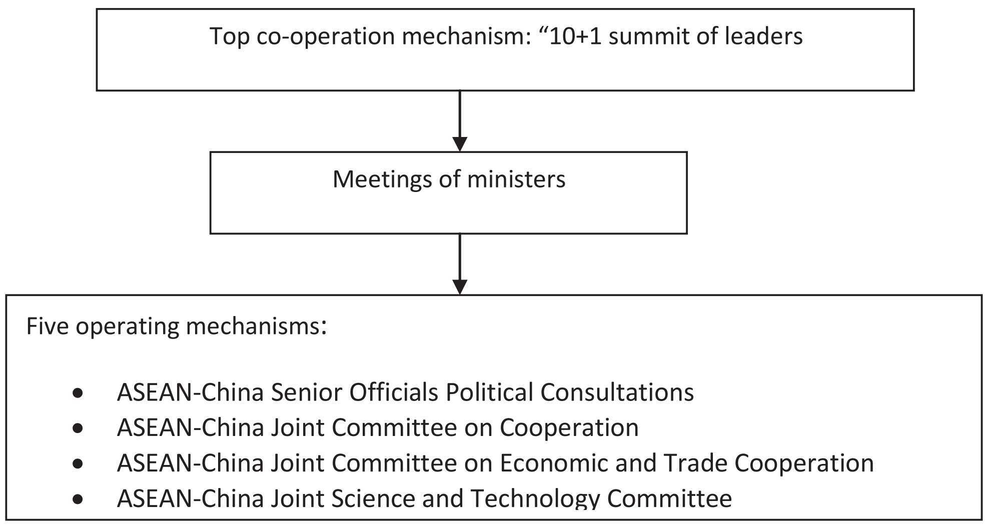
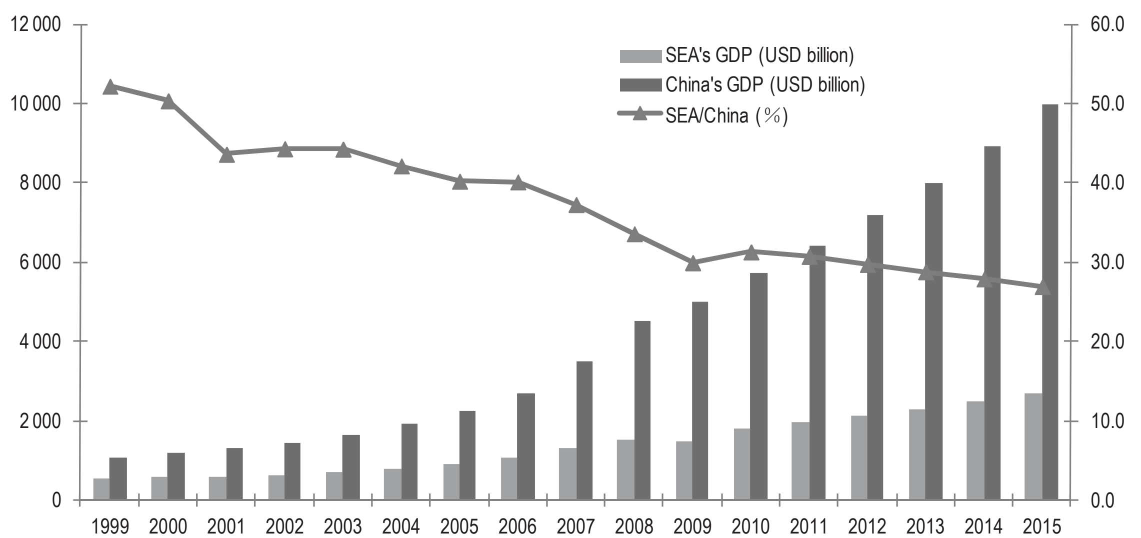


Figure A.9. Comparison of SEA’s GDP to China’s GDP



Source: IMF Database.

Over the next ten years, it is expected that the economic growth of the two sides will continue due to increasing exports from SEA countries to China and China's FDI flows into SEA countries. It is expected however that the distance between their respective GDPs will widen if China continues its unprecedented rates of growth (IMF, 2010). The economic relationship between SEA and China may however experience some challenges in the coming years, primarily due to trade frictions over market access or political issues. A primary area of contention is the South China Sea which has already harmed intra-ASEAN economic cooperation. If these problems continue, the economic integration of ASEAN may be delayed, possibly harming further integration between SEA and China.

As seen, economic relations between China and SEA countries should continue to move towards common prosperity, especially with the enforcement of ACFTA, as long as political relations within the region remain stable.

A.2. China's strategy and policy *vis-à-vis* the SEA region

A.2.1. China's strategy and policies relating to SEA countries, 1999-2009

China and ASEAN share geographical proximity, cultural similarities and economic complementarities. For a long time, China has focused on building its relations with SEA countries and has gradually developed and refined a series of policies. Since the establishment of dialogue relations in 1991, China refers to ASEAN countries as good neighbours, good friends and good partners under the guidelines of China's new security concept. Schüller (2010) argues however that China's interests in fostering closer economic and political ties with SEA go beyond the stated purposes. The ultimate objectives are for trust building, appeasing the concern of ASEAN member countries that China's economic rise would threaten the prospect of their development, and restricting the influence of other powers in the region and their access to the ASEAN market.

"Amicable neighbourhood" policies

In July 1991, Chinese Foreign Minister Qian Qichen was invited to attend the opening ceremony of the 24th ASEAN Foreign Ministers' Meeting and held the first informal talks with foreign ministers of the six ASEAN members at the time. This marked the start of the China-ASEAN dialogue. In July 1994, China was invited to attend the first meeting of the ASEAN Regional Forum (ARF) as ASEAN's consultation partner, and became one of the founders of the forum, which initiated discussions on co-operation in the area of regional security. In April 1995, the China-ASEAN Vice Ministerial Consultation Meeting was held to create a new mechanism to deepen the dialogue between the two sides. In July 1996, at the 29th ASEAN Foreign Ministers' Meeting in Jakarta, Indonesia, China formally became a full dialogue partner of ASEAN. In 2008 the Chinese government decided to accredit China's ambassador to ASEAN. Thus since 1991 China has elevated its relations with SEA countries from general relations to full dialogue partnership. China's relationship with individual ASEAN countries however has been slightly more staggered and slow as seen in Table A.1.

Table A.1. Process of "relations" between China and SEA countries

	Cambodia	Indonesia	Laos	Malaysia	Philippines	Thailand	Viet Nam
Establishment of co-operative good-neighbourly and mutual trust relations for the 21st century					1996		
Establishment of long-term stable relations					2000		
Establishment of a comprehensive co-operative partnership	2006	1999	2000				2003
Establishment of a comprehensive strategic co-operative partnership		2005		2004	2005		2008
Establishment of strategic co-operation and common action plan		2010		2009	2009	2007	

Source: Ministry of Foreign Affairs, P.R. China.

"Secure" neighbourhood policies

In the security field, the two sides actively promoted the idea of strengthening mutual trust through dialogue, resolving disputes through negotiations and realising regional peace through co-operation. The first issue was the South China Sea, a stumbling block to the development of good political relations between China and SEA countries. The signing of the Declaration on the Conduct of Parties in the South China Sea (DOC) in 2002 was the first political document on the issue and was regarded as an important step for settling territorial and jurisdictional disputes peacefully. In an effort to implement the DOC, the first and second ASEAN-China Senior Officials' Meetings (SOM) were convened in December 2004 and May 2006, respectively The declaration maintained peace between the parties concerned, however tensions regarding the South China Sea (SCS) have remained. These came to a head in July 2012 when ASEAN was unable to agree on matters related to the SCS- an issue that could potentially derail political and economic relationships within the region in the future.

To build a strong foundation for a long-term partnership, China signed the TAC. China contributed to making it the basis of the code of conduct for inter-state relations in the region and hastened the accession of India, Japan and the Russian Federation to the treaty. This was supported by the Joint Declaration signed by the two parties in 2003. In the same year ASEAN drew up a blueprint for the creation of the ASEAN Community. China expressed its willingness to co-operate actively with ASEAN and provide financial assistance to ASEAN for this process. In regional affairs, China supports ASEAN's role as the driving force in the regional processes initiated by ASEAN, such as the ASEAN plus Three (APT) process, the ASEAN Regional Forum (ARF) and the East Asia Summit (EAS). China would thus appear to be supportive of the role of ASEAN in the region and in pursuing close relations with the organisation.

Table A.2. Major development in the political and security areas

1975	China officially recognised ASEAN
1991	Foreign Minister Qian Qichen was invited to attend the 24th ASEAN Meeting of Foreign Ministers
1992	China became a Consulting Partner of ASEAN
1994	At the second ASEAN Conference of Foreign Ministers, two agreements were signed: the ASEAN-China Joint Committee of Economic and Trade Cooperation and the ASEAN-China Joint Committee of Cooperation in Science and Technology
1995	The first consultation meeting between high level officials (vice foreign minister) of China and ASEAN was held in Hangzhou
1996	At the 6th meeting of the 29th ASEAN Ministerial Meeting, China's status was raised from consulting partner country to comprehensive dialogue partner country
1997	China signed the Joint Statement on ASEAN-China Cooperation Towards the 21st Century with ASEAN
2002	China signed the Joint Declaration of ASEAN and China on Cooperation in the Field of Non-traditional Security Issues and the Declaration on the Conduct of Parties in the South China Sea
2003	China acceded to the Treaty of Amity and Cooperation (TAC) in Southeast Asia at the 7th ASEAN-China Summit in October 2003, and also signed Joint Declaration on Strategic Partnership for Peace and Prosperity
2004	A MOU on Cooperation in the Field of Non-traditional Security Issues was signed by China in January 2004 in Bangkok
2006	The Commemorative Summit Marking the 15th Anniversary of ASEAN-China Dialogue Relations issued a joint statement to further strengthen ASEAN-China relations towards an enhanced strategic partnership

Source: Ministry of Foreign Affairs, P.R. China.

"Prosperous" neighbourhood policies

Since 1997 China and ASEAN have held 13 10+1 meetings to encourage prosperous relations. In order to promote the smooth implementation of the agreement on trade in goods, both ASEAN and China commenced the Early Harvest Plan for agricultural products in 2003 to allow consumers on both sides to enjoy the benefits of the FTA as soon as possible. Until 2006, some 600 agricultural products enjoyed zero tariff rates. This was further expanded as of the commencement of ACFTA in 2010 to include more goods.

China also contributed funds to ASEAN cooperation by creating a special fund for Asian regional co-operation in 2004 and investing USD 32 million over time. To promote China-ASEAN infrastructure and inter-connectivity, China announced in 2009 its decision to set up a USD 10 billion China-ASEAN Investment Cooperation Fund to finance major ASEAN-China investment co-operation projects in infrastructure, energy and resources, information and communication technology and other fields.

Table A.3. Major bilateral economic agreements between China and SEA countries

	Brunei Darussalam	Cambodia	Indonesia	Laos	Malaysia	Myanmar	Singapore	Philippines	Thailand	Viet Nam
Agreement for Avoidance of Double Taxation and the Prevention of Fiscal Evasion with Respect to Taxes on Income	2004		2001	1999	1985		1999	1999	1986	1995
Agreement on Promoting and Protecting Investment	2000	1996	1994	1993	1988	2001	1999	1992		1992
Agreement on Trade		1996		1988	1988			1975		1991
ASEAN-China Joint Committee on Trade, Investment and Economic Cooperation		2000			1988				1985/ 2003*	1994
ASEAN-China Joint Committee on Bilateral Cooperation			2000				1999			
Memorandum of Understanding on Promoting Trade, Investment and Economic Cooperation	2004					2004	1999	2005		1992
Memorandum of Understanding on Border Trade				1988		1994				1998
Agreements on Bilateral Currency Swaps / Agreement on Bilateral Bank Cooperation			2009	2002	2009				2001	
Memorandum of Understanding on SMEs							2007			
China-Singapore FTA							2008			
Joint Declaration on Bilateral Cooperation		2000	2000	2000	1999	2000	2000	2000	1999	
Agreement on Enlarging and Deepening Bilateral Economic and Trade Cooperation								2007	2009	2006

Notes: *In 1985 China and Thailand established a Joint Committee on Trade and Economic Cooperation at the ministerial level; it was upgraded to deputy prime minister level in 2003.

Source: The Ministry of Foreign Affairs, the People's Republic of China.

Table A.4. China's main proposals made during the "10+1" summits, 1997-2009

	China's proposals
The 1st China-ASEAN Leaders Summit held in Malaysia in 1997	To strengthen co-operation in the fields of resources, technology, market, finance, information and human resource development
The 2nd China-ASEAN Leaders Summit held in Viet Nam in 1998	To contribute USD 200 000 to the ASEAN Fund
The 3rd China-ASEAN Leaders Summit held in Philippines in 1999	To increase the role of ASEAN-China Joint Science and Technology Committee; and strengthen agricultural development
The 4th China-ASEAN Leaders Summit held in Singapore in 2000	To add USD 5 million to the China-ASEAN Cooperation Fund to promote bilateral co-operation in economy, trade, technology and information and expand co-operation in the field of human resource development; to support the e-ASEAN Framework Agreement; to propose the establishment of the China-ASEAN Expert Group on Economic Cooperation.
The 5th China-ASEAN Leaders Summit held in Brunei in 2001	To make agriculture, information and communications, human resource development, mutual investment and Mekong River development as priority areas for co-operation in the near future. To train 100 senior information and communication personnel for ASEAN countries.
The 6th China-ASEAN Leaders Summit held in Cambodia in 2002	To start the process of CAFTA; to implement the "early harvest" plan; to establish regular meetings of Ministries of Information Industry; to sign the long-term memorandum of co-operation on the information industry of China and ASEAN; to train 500 information technology staff for ASEAN in the next five years.
The 7th China-ASEAN Leaders Summit held in Indonesia in 2003	To co-operate with ASEAN in the fields of electronic information, biotechnology, the use of remote sensing, seismology, marine sciences and research of biological resources in tropical areas.
The 8th China-ASEAN Leaders Summit held in Laos in 2004	To propose ten new initiatives for co-operation, such as the establishment of meetings of China-ASEAN energy ministers; to sign an MOU on the Information Highway in the Greater Mekong Subregion with the Mekong River Basin 5 countries; to add USD 5 million to China-ASEAN Cooperation Fund and to set up a total of USD 15 million in special funds for Asian regional co-operation, particularly for strengthening co-operation on human resource development projects of the Vientiane Plan of Action.
The 9th China-ASEAN Leaders Summit held in Malaysia, in 2005	To add transport, energy, culture, tourism and public health as five new priority areas of co-operation.
The Commemorative Summit Marking the 15th Anniversary of ASEAN-China Dialogue Relations in China in 2006	To donate USD 1 million to the ASEAN Development Fund; to offer USD 1 million to support the ASEAN integration initiative; to train 8 000 ASEAN talents and invite 1 000 young people from ASEAN to China in the next five years.
The 10th China-ASEAN Leaders Summit held in Singapore in 2007	To speed up the negotiation on the Investment Agreement; to make a co-operation strategy plan on China-ASEAN transport over the next 10-15 years; to develop a plan to train 8 000 personnel in various areas for ASEAN in the next 5 years.
The 11th China-ASEAN Leaders Summit held in Singapore in 2007	To advocate the establishment of China-ASEAN network and information security co-operation framework for emergency response; to sign a China-ASEAN Memorandum of Understanding on technical regulations, standards and conformity assessment; to establish a China-ASEAN Centre; to reach a consensus agreement on intellectual property rights; to develop a China-ASEAN environmental protection co-operation strategy; To establish the China-ASEAN Cooperation Centre on environmental protection. To implement the initiative to train 8 000 professionals in various fields for ASEAN in the next five years and to train about 2 000 people in 2008 through various training programmes. …/…

Table A.4. China's main proposals made during the "10+1" summits, 1997-2009 *(cont'd)*

The Bao'ao Asia Forum April 2009	To establish the China-ASEAN Investment Fund in the amount of USD 10 billion for infrastructure, energy resources, information and communication projects; to offer the SEA countries USD 15 billion in credit, including preferential loans of USD 1.7 billion in the next 3-5 years; to provide RMB 270 million in special assistance to less developed ASEAN countries.
The 12th China-ASEAN Leaders Summit held in Thailand in 2009	To increase from the USD 1.7 billion announced in April 2009 to USD 6.7 billion of the USD 15 billion in preferential loans; to actively promote the China-ASEAN action plan of comprehensive grain production capacity building; to implement the China-ASEAN rural development plan; and to pass the China-ASEAN co-operation strategy on environmental protection; to enhance co-operation in the fields of biodiversity conservation, ecological protection, cleaner production, environmental protection industry, new energy and renewable energy; to train 100 ASEAN environmental officials in the next three years; to reach 100 000 exchange students in 2020 in each side; to develop a joint action plan on the implementation of the Joint Declaration on Strategic Partnership of the China-ASEAN for peace and prosperity from 2011 to 2015; to establish the China-ASEAN Centre.

Source: Ministry of Foreign Affairs, the People's Republic of China.

A.2.2. China's major strategy and policies relating to SEA countries (2010-20)

Developing good-neighbour relations and strengthening its strategic partnership with SEA countries are part of China's long-standing foreign strategy. It is believed that sustained good political relations can promote fruitful economic and technological co-operation between the parties over the long term. China has implemented all measures currently required under the ACFTA framework and as a result has contributed to strengthened co-operation with individual SEA countries. At present China has signed an FTA with Singapore and may consider signing similar FTAs with developing countries within ASEAN in the future.

In addition, China will co-ordinate its regional policies with SEA countries to promote the regional integration process through the "East Asian community" based on the current framework of "10+1" and "10+3". At the same time, China wishes to resist trade protectionism in the world.

A.3. Science, technology and innovation relationships between China and SEA countries

China and SEA had engaged in co-operation on S&T before becoming strategic partners. Bilateral S&T co-operation was established at both the governmental and non-governmental levels. The former includes the official S&T co-operation between the governments of China and SEA countries, with official meetings, the signing of agreements on S&T and the establishment of working groups to engage in S&T activities. The latter is mainly carried out by universities, research institutes and enterprises and involves activities such as exchanges of researchers and students, development of joint research projects, joint publication of scientific papers, academic meetings and the China-ASEAN Expo.

A.3.1. Introduction of governmental co-operation on S&T between China and SEA countries (1995-2009)

An institutional framework for S&T co-operation

Progress on bilateral S&T co-operation has mainly taken place under the "10+1" framework since 1997. In addition to the annual leaders' summit, the ASEAN-China Joint Science and Technology Committee (JSTC) was established in 1995 and meets every two years alternately in China and ASEAN countries to plan, approve, co-ordinate, monitor and evaluate joint co-operative programmes and activities. Many joint programmes and activities have been set up under this Committee.

Table A.5. Work of the China-ASEAN Joint Committee on Science and Technology Cooperation

	Time	Place	Contents
1st meeting	Mar. 1995	Bandar Seri Begawan, Brunei	Both sides signed the Terms of Reference of the ASEAN-China Joint Science and Technology Committee (JSTC) and the Procedural Guidelines of the ASEAN-China Joint Science and Technology Committee (JSTC)
2nd meeting	Oct. 2001	Bo'ao, Hainan	The two sides put forward a number of proposals on co-operation programmes, including to hold seminars on technological co-operation on functional foods, marine science and technology, the application of remote sensing to precision agriculture, and information resources services and management among ASEAN countries; to hold a training class on earthquake prediction techniques; and to conduct co-operation in the field of rice.
3rd meeting	Sept. 2003	Ho Chi Minh City, Viet Nam	Both sides reviewed progress in S&T co-operation in the priority fields of the past years; proposed new co-operation projects; exchanged ideas about funds and its channels; listed materials technology as an additional priority; and signed minutes of the third meeting of the China-ASEAN Joint Science and Technology Committee.
4th meeting	Information not available		
5th meeting	Information not available		
6th meeting	Sept. 2010	Suzhou, China	Exchange of ideas about modifying China-ASEAN S&T Cooperation Agreement and improving the joint co-operation mechanisms; agreement to further expand support channels for relevant projects with the help of good mechanisms.

Source: China International Science and Technology Cooperation and Ministry of Foreign Affairs, China.

Meetings of ministers under the Joint Committee are held in the fields of agriculture and forestry, information and communication technology, the environment, energy, and education. The working groups in these fields are responsible for S&T activities between China and SEA countries as a whole or individually. In addition, China and SEA countries have founded research centres, for example, China founded the China-ASEAN Cooperation Centre on Environmental Protection in 2010. Its main responsibilities are environmental co-operation in the framework of ASEAN; developing and implementing proposals on China-ASEAN co-operation on environmental projects; co-ordinating affairs related to the implementation of the China-ASEAN Cooperation Strategy of Environmental Protection; advancing China-ASEAN co-operation in the environmental protection industry; and carrying out relevant exchanges and co-operation.

Table A.6. Working groups on S&T between China and individual countries

	Brunei Darussalam	Indonesia	Laos	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam
Establishment of S&T Joint Committee		1997		1992		#	1993	1978	#
Establishment of Agricultural Joint Committee						#			
Establishment of Economic, Trade and Technology Joint Working Committee		1990	1997		1997				

Note: # year not available.

Source: Ministry of Foreign Affairs, P.R. China.

Many agreements and MOUs have also been signed between ASEAN and China on S&T co-operation in fields considered as being important or crucial. They cover both traditional industries such as agriculture or fisheries and modern industries such as ICT and environmental protection. Bilateral agreements and MOUs mainly cover: training programmes for officials in the fields of agriculture, ICT, mining and others; joint research and development (R&D); sources of funds for co-operation; infrastructure programmes; information exchange and dialogue between governments; and seminars.

Table A.7. Agreements related to S&T signed by China and ASEAN

2002	Memorandum of Understanding on Agricultural Cooperation
2003	Memorandum of Understanding on Cooperation in Information and Communication Technology
2004	Memorandum of Understanding on Joint Cooperation in Pushing Forward the Construction on the Information Superhighway in the Greater Mekong Sub-region
2005	The Beijing Declaration on ASEAN-China ICT Cooperative Partnership for Common Development
2005	The Plan for the GMS Biodiversity Conservation Corridors Initiative
2007	A 2007-2012 Plan of Action to Implement the Beijing Declaration on ASEAN-China ICT Cooperative Partnership for Common Development
2007	An extended ASEAN-China MOU on Agricultural Cooperation for 2007-2011
2009	Memorandum of Understanding between ASEAN and China on Strengthening Cooperation in the Field of Standards, Technical Regulations and Conformity Assessment
2009	Memorandum of Understanding between ASEAN and China on Cooperation in the Field of Intellectual Property
2009	Cooperation framework of the China-ASEAN Telecom Regulatory Council on network security and the China-ASEAN 2009-2010 Cooperation Plan for Communications.

Source: Ministry of Foreign Affairs, P.R. China.

Table A.8. Agreements on S&T co-operation between China and individual SEA countries, 1978-2009

	Brunei Darussalam	Cambodia	Indonesia	Laos	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam
Agreement or MOU on S&T Cooperation		2008	1994/ 2009		1992	2000/ 2009	1978	1992	1978/ 1997	2002
Agreement or MOU on Agricultural Cooperation	2009	2000	2001	2000	2003	2000	1999		1997	2004
Agreement or MOU on Forestry Cooperation			2001							
Agreement or MOU on Fishery Cooperation	2000		2001			2001	2004/ 2007			2000
MOU on Mining Cooperation			2001			2000				
MOU on Energy Cooperation	2010									
MOU on ICT	2000				1992	2004	2001			
MOU on Environmental Cooperation								2007	2005	
Agreement on Co-Operation Framework for Space Science and Technology				2008	2003					

Source: Ministry of Foreign Affairs, P.R. China.

Most bilateral agreements and MOUs were signed before those between China and ASEAN. However, the latter have replaced the former to some degree. For example, most bilateral agreements and MOUs involving agriculture were signed in 2000 or earlier, with few being signed since. Moreover, the agreements or MOUs between China and ASEAN have broader coverage than those between China and individual SEA countries. They play, as is expected, a more important role in promoting bilateral co-operation than those between China and individual SEA countries.

In addition to the agreements outlined above, at the Fifth China-ASEAN Leaders Summit held in 2001, five priority areas for co-operation in the 21st century were identified. These were; ICT, environment, agriculture, human resource development and education. The documents adopted since this time are listed above in Table A.8.

ICT co-operation

Since its recognition as a priority area some important documents and co-operation mechanisms have been adopted. These include the China-ASEAN Telecommunications Ministers Meeting, other high-level exchange mechanisms and the China-ASEAN ICT Week. The priority areas for co-operation include ICT infrastructure, universal service, network and information security, and human resource development. Key projects include the construction of the Information Superhighway in the Greater Mekong Sub-region (GMS), the establishment of the China-ASEAN Information Highway, the China-ASEAN Telecom Forum for Universal Service, the China-ASEAN Coordination

Framework for Network and Information Security Emergency Responses. ASEAN believes that these projects will encourage development in regional areas and increase business growth throughout ASEAN by allowing businesses to harness technologies and access new markets (ASEAN Study Centre).

Environmental co-operation

Environmental co-operation is also a priority area with mechanisms such as: the China-ASEAN Environment Ministers Meeting, the environmental ministerial meeting on the GMS, and the China-ASEAN Centre for Environmental Protection. The priority areas for co-operation include the implementation of the Plan for the GMS Biodiversity Conservation Corridors Initiative.

Agricultural co-operation

Both China and SEA countries are agriculture-based economies and attach importance to agricultural development. Their agriculture is complementary and offers potential for co-operation. The agricultural co-operation mechanisms are the China-ASEAN Agricultural Ministers Meeting and other high-level exchange mechanisms, with priority areas being cultivation of hybrid rice and aquaculture. This co-operation is not limited to trade of agricultural products but extends to farming, animal husbandry, aquaculture, processing of agricultural products, animal disease control, rural energy and ecology, and many other areas. Modes of co-operation include human resource development, agricultural science and technology exchanges, small-scale demonstration projects abroad, and promotion of agricultural trade. Highlights of agricultural co-operation, especially since the ACFTA was implemented, include the promotion of super rice, technology dissemination and personnel training. Future agricultural co-operation between China and ASEAN will focus on the seed industry, exchanges of agricultural personnel and high-level industrial co-operation with increased scientific and technological input (Xinhuanet, 2010).

In addition, both sides pay great attention to co-operation on forestry and have signed agreements and joint participation in international co-operation projects such as the model forest and the China-ASEAN precious tree seedling-breeding base created in 2010. China encourages forestry enterprises in Myanmar, Laos, Cambodia and other ASEAN countries to plant trees and undertake drug replacement planting.

Education co-operation

Co-operation in education is also an important area. China and SEA countries need to improve the level of education and fuel economic growth with a well-qualified population. Since CAFTA, relations between China and SEA countries in terms of educational exchanges and co-operation have become closer. China and SEA countries have signed a series of agreements on educational co-operation (Table A.9) and have established a comprehensive co-operation partnership in education. In 2009, nearly 100 high-level education delegations visited each other.

The China-ASEAN Education Cooperation Week, which has now been held three times, and the roundtable conference of education ministers, the first of which was held in August 2010, are platforms for co-operation on education. The China Educational Resource Show is held at the same time as the Education Cooperation Week in Guiyang, China. A working group for education co-operation has been established between China and Malaysia, Singapore and Thailand. The China-ASEAN Education Information Network provides students and faculties with information on study and research exchanges.

It is expected that co-operation on education between China and SEA countries will increase. The roundtable conference of education ministers decided on the following initiatives: *i)* continuation of a high-level dialogue to strengthen education co-operation and joint research; *ii)* the number of exchange students from each side will reach 100 000 by 2020; *iii)* to this end, China will offer 10 000 government scholarships a year for the next ten years to students from SEA countries studying in China; *iv)* both sides will set up a high-end talent exchange scholarship in the fields of education, environment, medicine, climate, science and technology for joint training of high-level personnel; *v)* both sides will make an effort to promote the mutual recognition of academic degrees.

Table A.9. Bilateral agreements on education between China and SEA countries

	Brunei Darussalam	Cambodia	Indonesia	Laos	Malaysia	Philippines	Singapore	Thailand	Viet Nam
Agreement or MOU on Education Co-operation	2001	2004	2010	2002/ 2005	1997/ 2005	2007	2001	2009	2000/ 2005
MOU on Higher Education Co-operation	2004				2009		2009	1999	
Agreement on Mutual Recognition of Qualifications and Academic Degrees in Higher Education						2009		2007	
Number of schools by mutual certification					38		9	75	

Human resource development

Both China and SEA countries have large populations and attach importance to human resource development (HRD). The co-operation mechanisms include the China-ASEAN HRD Ministers Meeting and other high-level exchange mechanisms, with the priority areas focusing on training. China has financed more than ten projects involving training and exchange of personnel since 2000 under the China-ASEAN Cooperation Fund. As of November 2007, the Fund had financed training for more than 6 000 professionals from SEA in the fields of economics, trade, telecommunications, finance, earthquake prediction, agricultural biotechnology, marine technology and AIDS.

In addition, China and most SEA countries have carried out various forms of training in different fields. As of November 2009, the Ministry of Agriculture of China had trained more than 1 000 agricultural management and technical personnel from SEA countries, and carried out more than 40 agricultural technology pilot projects with SEA countries. Furthermore, training is also organised for a small number of government officials. From 1993 to the first half year of 2007, a total of 364 Cambodian government officials and economic and technical personnel received training in the fields of health, sports, diplomacy, finance, business, industry, agriculture, transport, etc. During the first half of 2010, 66 Cambodian officials participated in 27 training programmes in China in the fields of industry, agriculture, transport, health, communications, infrastructure construction, environmental protection, tourism, climate, water and development of small and medium-sized enterprises (SMEs).

China has also benefited by receiving training programmes provided by some SEA countries. In 1996, a HRD plan was signed between Singapore and China to train Chinese mayors in urban planning and management, economic planning and social development. In 2004, both sides decided to set up a China-Singapore Fund to support the exchange and training of young officials from both sides. In 2007, a MOU was signed to carry out personnel training of national park staff in China's central and western zones on the basis of Singapore's experience in park management.

A.3.2. Academic exchanges between China and SEA countries

Exchange of researchers and students

As seen above, co-operation between ASEAN and China with regards to education has grown considerably. The number of Chinese students choosing SEA countries to pursue advanced studies has increased. By 2009, 229 000 Chinese students were studying abroad. As of August 2009, 68 510 were studying in SEA countries, of whom 36 000 were in Singapore, more than 10 000 in Thailand, 9 200 in Malaysia and 13 in Brunei. In 2009, Singapore was the seventh destination country of Chinese students studying abroad.[1] Among numbers of foreign students in Malaysia Chinese students ranked third.

Since the reform and opening to the outside world, the number of foreign students in China has expanded rapidly. In 2009, foreign students studying in China exceeded 230 000, 34 735 of which were from ASEAN as of August 2009. According to projections by the Ministry of Education of China, it is expected that 100 000 students from each side will study in the alternate country by 2020.

Table A.10. Students and researchers from SEA countries studying in China

	Total of foreign students in China	Viet Nam	Thailand	Indonesia	Malaysia	Philippines	Singapore	Laos	Myanmar
2000	52 150	647	667(10)	1 947(4)			854(7)		
2001	61 869	1 170(6)	860(10)	1 697(4)	632				
2002	85 829	2 300(5)	1 737(6)	2 900(4)	840	638	583		
2003	77 715	3 487(3)	1 554(5)	2 563(4)	841	602	551	403	232
2004	110 844	4 382(4)	2 371(6)	3 750(5)	1 241	1 375	929	509	
2005	141 087	5 842(4)	3 594(6)	4 616(5)	1 589	2 176	1 322	569	
2006	162 695	7 310(4)	5 522(6)	5 652(5)	1 743	1 512	1 392		
2007	195 503	9 702(4)	7 306(5)	6 590(8)					
2008	223 499	10 396(4)						320	
2009	238 184	12 247(4)	11 379(5)	7 926(8)			2 200	320	

Note: The number in parentheses indicates the rank among in total foreign students in China.

Source: The Minister of Education of China.

Joint research projects

At present, China has a limited number of joint research projects with SEA countries with the exception of Singapore, signalling an uneven impact of China across ASEAN in this respect. Some of the developing SEA countries seek to strengthen their R&D co-operation with China. Indonesia has identified seven areas for technological development, including food and agriculture, energy, health and medicine, for 2010-14. At the meeting of the China-Indonesia Science and Technology Joint Committee in 2010, ten projects for co-operation were decided upon. China and Viet Nam have also undertaken a number of joint research studies and seminars on the prevention and control of the trafficking of women and children and promotion of safety for immigrants in recent years.

Joint research projects are undertaken mainly on the bilateral level between China and Singapore. This is because Singapore has the most highly developed technology among ASEAN countries, especially in the fields of biomedical, environmental and water technologies, and interactive and digital media. Inter-governmental co-operation between China and Singapore has two main aspects: joint R&D and commercialisation of scientific research achievements in the fields of materials, manufacturing, biotechnology, microelectronics and information technology (IT). The China-Singapore Technology Company was established in 1995 and the two parties began a joint research programme in 1998. In October 2003, the Representative Office of the Torch Centre of China's Ministry of Science and Technology was formally established in Singapore. In 2007, the two parties explored S&T co-operation on the eco-city and promotion of interaction in the field of digital media technology, followed by the implementation of joint research projects in microelectronics, materials and other fields and the carrying out of joint research projects under an MOU on R&D co-operation on interactive digital media technology signed in March 2008.

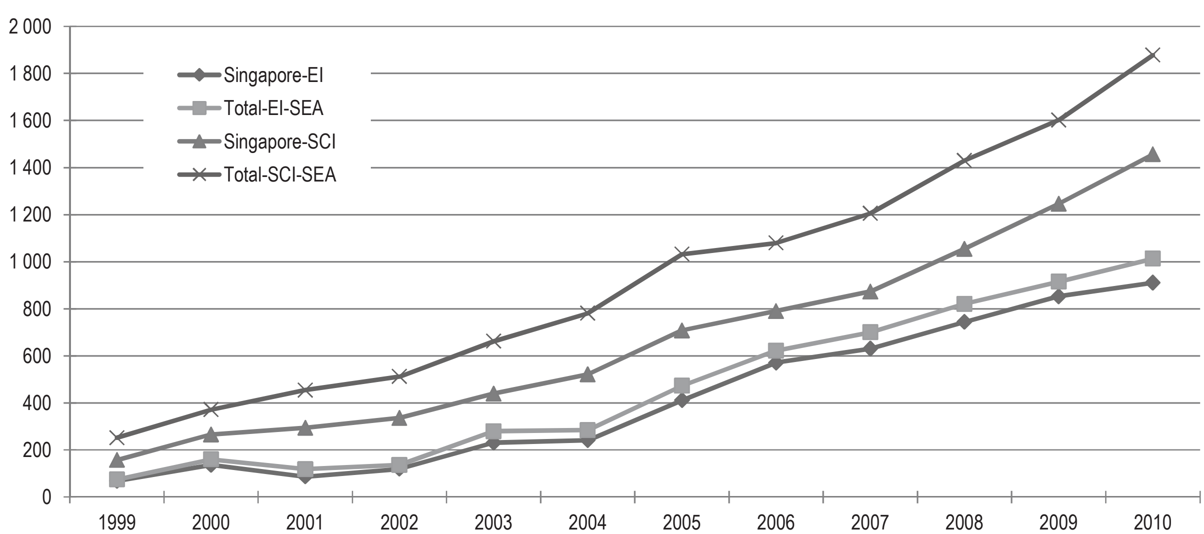
In addition, China has developed R&D co-operation with Thailand and the Philippines. Among the international academic institutions with which China's National Natural Science Foundation signed a co-operation agreement (or MOU), only the National Research Council of Thailand (NRCT, signed in 1992) and the International Rice Research Institute (IRRI, signed in 2000) in the Philippines represented ASEAN as of March 2008. China also encourages Chinese research institutions and high-technology enterprises to participate in Malaysia's Bio Valley programme. However, the relationship between SEA and China with regards to joint research projects is quite weak and shows much room for improvement.

Joint publication of scientific papers

Based on the Engineering Index (EI) and the Science Citation Index (SCI), co-authored publications involving authors from China and SEA countries (but not limited to these) are rising steadily (Figure A.10). Between 1999 and 2010, they amounted to 5 596 in EI and 11 260 in SCI. Among these, the papers with authors from China and Singapore (but not limited to these) rank first, an indication of the scientific and technological strength of Singapore (Tables A.11 and A.12). China is also strengthening co-operation with other SEA countries with publications listed in EI increasing from 5 in 1999 to 102 in 2010 and those in SCI increasing from 95 in 1999 to 422 in 2010. While these numbers have been growing, they account for an insignificant share of the 472 000 Chinese scientific papers published internationally. Moreover, papers by authors from China and SEA countries often have co-authors from other countries or regions (see Statistical Appendix, Table A.A2).

Generally speaking, papers involving countries that are strong in scientific and technological areas cover a wider span of subjects. Those with authors from China and Singapore range over 173 subjects, while those from China and some less advanced SEA countries deal with fewer than 20. In addition, the areas covered differ. Because of Singapore's strength in the engineering, electrical & electronic area, the largest number of papers by authors from China and Singapore is in this category (see Statistical Appendix, Table A.A3).

Figure A.10. Papers published jointly at the bilateral or multilateral level



Source: Ei Compendex Web. Science Citation Index Expanded (SCI-EXPANDED)

Table A.11. Joint publications of scientific papers by China and SEA countries

Based on EI statistics (1999-2010), as of December 2010

	Journal papers	Conference papers	Total
Singapore	5 004	1 649	6 653
Malaysia	205	39	244
Thailand	160	37	197
Philippines	113	2	115
Viet Nam	64	5	69
Indonesia	43	4	47
Brunei	4	2	6
Myanmar	2	0	2
Cambodia	1	0	1
Laos	0	0	0
Total	5 596	1738	7 334

Note: The papers are jointly published by authors not only from China and SEA countries, but also from other countries such as the United States, Japan, Korea, and EU member states.

Source: EI Compendex Web.

Table A.12. Joint publications of scientific papers, China and SEA countries

Based on SCI statistics (1999-2010), as of December 2010

	Journal papers	Authors from countries or regions	Subjects
Singapore	8 141	99	173
Malaysia	1 435	84	123
Thailand	972	106	139
Philippines	414	101	89
Indonesia	206	81	79
Cambodia	40	26	23
Brunei	19	5	14
Myanmar	18	30	15
Laos	12	20	15
Viet Nam	3	3	1
Total	11 260		

Note: The papers are jointly published by authors not only from China and SEA countries, but also from other countries such as the United States, Japan, Korea, and EU member states.

Source: Science Citation Index Expanded (SCI-EXPANDED).

Academic conferences

There are few joint academic conferences in the region, and those that are held are generally under a multilateral framework which includes both SEA and China (see Table A.A4). The few bilateral academic conferences that occur are usually held by China and Singapore.

Table A.13. Joint conferences at the regional level

2005 and 2008	China-ASEAN Symposium on Intellectual Property Rights
2006	China-ASEAN Agricultural Energy Forum
2007	China-ASEAN Forestry Cooperation Forum
2007	China-ASEAN Human Resource Development Cooperation Forum
2009	China-ASEAN Subtropical Agricultural Industrialization Development Forum
2009	New and Renewable Energy Development and Application Forum
2010	China-ASEAN Joint Conference on Intellectual Property Rights
2010	China-ASEAN Seminar on the development of aquaculture industry

Source: Ministry of Science and Technology，China-ASEAN Expo，State Intellectual Property Office of China.

A.3.3. Technology flows through trade and investment between China and SEA countries

Bilateral trade in medium- or high-technology products

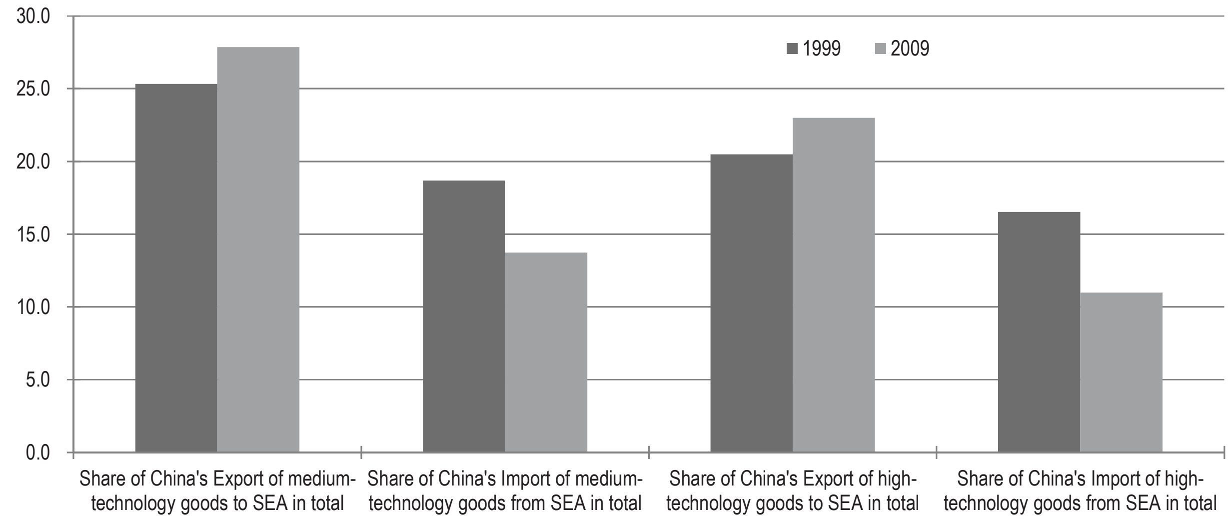
China’s medium- and high-technology exports to SEA countries have increased as a share of total exports while China’s imports from SEA countries have decreased (Figure A.11). This indicates that China’s technological gap with SEA countries is increasing. Moreover, while China has an overall trade deficit with SEA countries, it runs a trade surplus in medium- and high-technology products at USD 27.7 billion in 2009 up from USD 367 million in 1999.

Technology trade

China’s technology imports[2] from SEA countries are in an inverted U shape. Prior to 2006, they were USD 200 million before increasing to more than USD 500 million and then decreasing to less than USD 400 million. China’s imports of technology services from SEA countries accounted only for around 1.5% of its total technology imports, reaching a peak of 2.5% in 2006. Singapore is the major source of China’s technology imports from SEA countries, accounting for 70-80% of the total. Owing to the present level of China’s technology, China has exported few technological services and little technology to SEA countries. Exports of royalties and licence fees totalled USD 400 million in 2009.

Figure A.11. China's trade in medium- and high-technology goods[1] with SEA countries

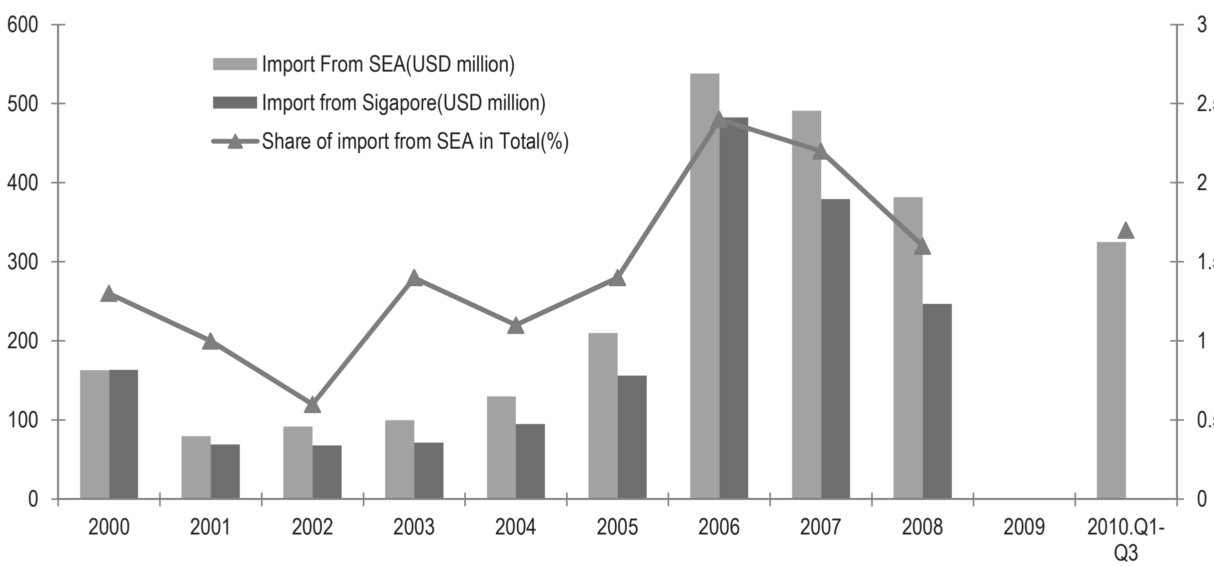
Percentage of total exports



1. Based on UNIDO's classification of medium- and high-technology products.

Source: UN Comtrade.

Figure A.12. China's imports of technology from SEA countries



Source: MOFCOM.

FDI flows and stocks related to technology and education from China to SEA countries

Table A.A1 (see Statistical Appendix) shows that China's flows and stocks of FDI to SEA countries for scientific research, services and geo-survey and for education and IT account for only 1.4%, 0.1% and 0.4%, respectively, of China's total outward FDI stocks to SEA countries. The share of outward FDI stocks in education to SEA countries in total FDI stocks in education is the second highest (33.5%),[3] after Power and other utilities, while the share of outward FDI stocks in scientific research, services and geo-survey and IT industries to SEA countries in China's total FDI stocks in these industries is very low, at 4.6% and 2%, respectively. China clearly invests more in education in SEA countries than in scientific research, services and geo-survey and IT industries.

Table A.14. History of the China-ASEAN Expo

	Contents	Effects
1st Expo, 2004	SMEs, technology and innovation; special exhibition in the fields of electronic information, optical electromechanical integration, biomedicine, new materials, energy, resources and the environment.	Information not available.
2nd Expo, 2005	Advanced and applicable technology; special exhibition.	China signed 19 projects with SEA countries in the fields of agriculture, biomedicine, new materials, environmental protection, electronic information, mechanical and electrical industries with turnover of RMB 235 million, traded goods valued at RMB 16.7 million.
3rd Expo, 2006	Advanced and applicable technologies for rural areas; 20th Anniversary Exhibition of China's Spark Programs.	China signed 58 co-operation projects with SEA countries with a total investment of USD 3.1 billion, for which China introduced 18 investment projects from SEA countries with a total investment of USD 515 million while China engaged 40 investment projects in ASEAN with a total investment of USD 2.56 billion.
4th Expo, 2007	Applicable technologies in rural areas; Achievement Exhibition of Agricultural Science and Technology Commercialisation.	China signed 59 "going out" projects with a total investment of USD 1.58 billion. China signed 37 co-operation projects with SEA countries for the investment of USD 1.19 billion.
5th Expo, 2008	Information and communication co-operation.	The 10 ASEAN countries signed 58 co-operation projects with a total investment of USD 3.55 billion, while China signed 44 "going out" projects valued at USD 2.76 billion.
6th Expo, 2009	Advanced and practical high technology in rural areas; agricultural machines and technology for SEA countries.	ASEAN signed 59 projects totalling USD 3.18 billion, while China signed 48 "going out" projects for a total investment of USD 1.89 billion.
7th Expo, 2010	Trade in services; special show in the fields of financial services, logistics services and education services.	China signed 58 "going out" projects with SEA countries for a total investment of USD 2.66 billion.

Source: www.caexpo.org.

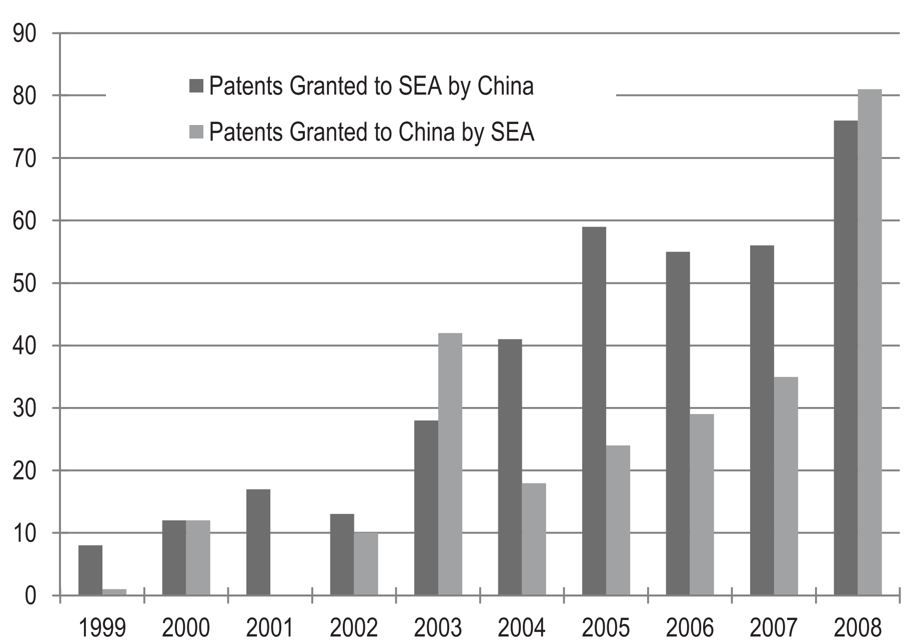
China-ASEAN Expo

The China-ASEAN Expo (CAEXPO) serves as an important channel for promoting trade, investment and technology transfer between China and ASEAN. At the meeting of China-ASEAN leaders held in 2003 it was decided that China would be the permanent venue for the annual Expo, with a view to strengthening the exchange of products and information to help the CAFTA process. Since 2004, the China-ASEAN Expo has become a platform for increasing bilateral economic and trade relations. So far, it has led to trade turnover of USD 9.89 billion and investment projects valued at USD 41.76 billion. The China-ASEAN Business and Investment Summit (CABIS) held back-to-back with the CAEXPO, also serves as an effective way of bringing government and the private sector together to exchange views on matters affecting the economy and business of ASEAN member states and China.

A.3.4. Intellectual property issues

There is very little co-operation on intellectual property (IP) between China and SEA countries. In 2008 China granted 412 000 domestic patents, an increase of 17.1% from the previous year. 94 000 of these were invention patents, an increase of 37.9%. This is in contrast to 47 716 patents granted to foreign countries or regions, of which only 76 went to SEA countries. SEA countries, for their part, granted 10 176 patents to foreign countries or regions, among which only 81 were to China. Most of these patents involved Singapore and China (Singapore granted 51 of the 81 patents to China, and China granted 58 of the 76 patents to Singapore). The number of patents granted to China by SEA countries grew steadily between 2004 and 2008, however much work remains to be done to encourage intellectual property within the region.

Figure A.13. Patents granted between China and SEA countries (1999-2008)



Source: WIPO and State Intellectual Property Office of PRC and China's Statistical Yearbook (2000-2009).

A.4. Factors favourable to S&T co-operation

A.4.1. Factors favourable to S&T co-operation between China and SEA countries

Political context

Economic and technological co-operation between China and SEA countries has accelerated rapidly since the signing of the CAFTA Agreement on Trade in Goods in 2004. The developments outlined throughout this paper cannot be separated from the improvement in political relations between China and SEA countries, which has laid a solid foundation for S&T co-operation and produced expectations of stable S&T co-operation. The actions outlined may also serve as an indication of increasing mutual trust, an important prerequisite for future economic and technological co-operation.

Economic context

Chinese and SEA developing economies are fast evolving. In their pursuit of economic development and higher per capita income, S&T plays an increasingly important role. Both sides are presently making an effort to restructure their industrial base from labour-intensive to technology-intensive industries and paying attention to green technology and the introduction of clean energy. For example, because the owners failed to carry out health impact assessments (HIA), work at 65 new plants at Map Ta Phut, Thailand's biggest industrial estate, was suspended by the courts in December 2009. In addition to traditional industries such as agriculture, which does not necessarily imply low technology, high-technology industries such as the environment and clean energy are becoming a focus of co-operation.

Technological context

Increasing R&D inputs on both sides enlarges the opportunities for S&T exchanges and co-operation. To meet the demand for technology, China and some SEA countries are trying to increase their R&D. As Table A.15 indicates, China and Singapore have high R&D growth rates, and the share of gross expenditure on research and development (GERD) in GDP in Singapore and China keeps rising. Malaysia also would like to increase this ratio. Malaysia’s public investment in R&D during the Ninth Malaysia Plan was about 0.7% of GDP and total expenditure on R&D was expected to reach 1% of GDP under the Tenth Malaysia Plan. Thailand's present R&D budget is THB 25 billion, only 0.25% of its THB 10 trillion GDP. The Science Ministry of Thailand expects annual spending on R&D to reach THB 100 billion, equal to 1% of Thailand’s GDP, by the end of the 11th National Economic and Social Development Plan in 2016. The real or projected increase in R&D in these countries will raise the level of their technology and specialisation and enhance their ability to supply technology for economic growth.

Table A.15. Gross expenditure on R&D: growth rates and share of GDP in China and SEA countries, 2000-2009

Percentage

	Growth rate of GERD		GERD as a share of GDP			
	Singapore	China	Singapore	Malaysia	Thailand	China
2000	13.3	31.9	1.9	0.5	0.3	0.9
2001	7.4	16.4	2.1		0.3	1.0
2002	5.3	23.5	2.2	0.7	0.2	1.1
2003	0.6	19.6	2.1		0.3	1.1
2004	18.6	27.7	2.2	0.6	0.3	1.2
2005	12.8	24.6	2.3		0.2	1.3
2006	9.3	22.6	2.3	0.6	0.3	1.4
2007	26.5	23.5	2.5		0.2	1.4
2008	12.4	24.4	2.6	0.6		1.5
2009	15.2	25.7	2.3	0.6		1.7

Source: National statistics offices.

A.4.2. Constraints on S&T co-operation between China and SEA countries

The factors that affect the level of S&T co-operation between China and developing SEA countries are related to their ability to supply technology, as this is closely related to their stage of economic development and their policies.

Stage of economic development

At present, China and SEA countries are in a process of technology accumulation. China is moving towards becoming an emerging technology power while some developing SEA countries with small shares of R&D in GDP lag behind in terms of S&T capabilities. They are not yet creative centres like the United States or the European Union. They have insufficient ability to meet their or their partners' demand for technology required for economic growth and therefore need to source technology from countries such as the United States, the EU and Japan. In short, China and SEA countries, with the exception of Singapore, are more demanders than suppliers of technology.

S&T co-operation policies

Other constraints on S&T co-operation are the limited policy support geared towards S&T cooperation between China and SEA and the predominant focus on advanced countries for S&T cooperation on both sides. Although both sides view international S&T co-operation as very important in order to compensate for their deficiencies in S&T, especially S&T research capabilities, infrastructure and funds, each directs their co-operation policies towards countries with advanced technology, leaving little room for co-operation between them. China developed its international S&T co-operation programme in 2001 in order to enhance its technological strength through international co-operation.

Singapore is China's only partner amongst SEA countries. SEA countries individually have no official policies for international S&T co-operation (Schüller, 2008), although ASEAN has an institutional framework for international S&T co-operation based on the prerequisite that the partner be a world leader.

In addition, there are too few funds for S&T co-operation. For a long time, China and SEA countries lacked the funds to start S&T co-operation. In recent years, the situation has improved somewhat. With its increasing economic strength, China finances some S&T exchanges and co-operation with SEA countries. However, this is not significant when considering the amount provided by other countries. For example, Japan contributed USD 195 million to ASEAN for youth exchange programmes in East Asia in 2007; by contrast, funds used for China-ASEAN co-operation totalled less than USD 50 million.

In summary the main features of bilateral S&T co-operation are as follows:

The scale of S&T co-operation is currently small. There are much fewer joint publications of scientific papers (based on a case study), joint research projects, bilateral academic conferences and patents granted to each other than to third parties. For example, the joint projects in technology for agriculture are small and scattered and it is hard to see any obvious economic and social benefits to local people.

Second, the S&T co-operation is one-way. Generally speaking, between Singapore and China, Singapore is the exporter of technology and China is the receiver. Between China and SEA developing countries, China is the exporter of technology and the developing SEA countries are the receiver. The result is few possibilities of joint research and joint achievements.

Third, S&T co-operation cannot only be bilateral. Important S&T conferences attended by China and SEA countries and joint research projects are held at the multilateral level and seldom at the bilateral level. This suggests that S&T co-operation between China and SEA countries will probably benefit from a multilateral framework and should look towards its development.

A.5. Future trends and directions in China's relationship with SEA countries in S&T and innovation

As of 2007, China had developed S&T exchanges and co-operation with 152 countries and regions and signed intergovernmental S&T agreements with 99. China's Ministry of Science and Technology (MOST) has accredited 131 S&T officials in 45 countries including Singapore, Thailand and Indonesia, and 62 Chinese institutions abroad. Thus despite weak S&T co-operation in the region some factors are improving.

China, as an emerging technological power, is accumulating a technological advantage over developing SEA countries. The overall level of technology in SEA countries is still low owing to the level of R&D inputs and to shortages of S&T personnel, a problem that is hard to remedy quickly. In contrast, China's strength in S&T has increased steadily, especially in the present century. It has relatively integrated disciplines from basic theory to applied science, ranging from biotechnology to electronic information. China accounts currently for 11.5% of the world total of S&T papers and in 2008 ranked second after the United States in terms of numbers of international S&T papers.

There is great potential for China-ASEAN S&T co-operation, largely based on their complementarities. Demand for China's technology from developing SEA countries will increase. The future S&T co-operation may have the following prospects:

First, the scale and quality of bilateral S&T co-operation is likely to be enhanced. Today's increasing exchanges of researchers and students will probably lead to greater S&T co-operation. The funds provided by China for S&T co-operation have increased, especially in recent years, and will lead to more joint research projects. In addition, the S&T co-operation mechanism is maturing and will provide both sides with better support.

Second, S&T co-operation will expand from traditional to modern industries. China's progress in high technology or new technologies in these years will probably offer new areas for S&T co-operation. Also, joint research between SEA countries and China may fill the gaps or even replace some of joint research projects between SEA countries and third parties.

Third, bilateral S&T co-operation will take place simultaneously with multilateral S&T co-operation. The leading S&T powers will continue to have a positive impact on bilateral S&T co-operation between China and SEA countries, meanwhile, the latter can make full use of multilateral and regional frameworks to strengthen bilateral S&T co-operation and exchange.

A.6. Role of technology assistance (S&T diplomacy) in China's future S&T relationship with SEA countries

A.6.1. Development of technology assistance (1999-2009)

China's technology assistance policies (S&T diplomacy)

S&T diplomacy is seldom used in China's official documents and is difficult to find in statements. However, technology assistance is regarded by China as an important way to strengthen S&T co-operation with developing countries. By the end of 2009, China had offered economic and technical assistance to more than 120 countries and donated to more than 30 international and regional organisations (News China, 2010). By the end of August 2009, China had carried out various forms of technical co-operation in recipient countries and sent 550 000 technical experts in agricultural development, research and consulting, geological prospecting, etc. (China Economic Net, 2010). China's technology assistance to developing countries focuses on agriculture, medicine, energy, environmental protection, information and communication, and manufacturing.

China's S&T assistance policies aim to develop science and technology in developing countries, enhance their scientific and technological base, and promote their economic and social development through personnel training and demonstration projects. This assistance is available to developing SEA countries. China actively supports the development of S&T co-operation in high-technology fields in SEA countries in order to strengthen their high-technology base. For example, China helped to implement a project on rice breeding and marketing in Myanmar, to carry out a co-operation project to eliminate malaria quickly in Cambodia and Indonesia and to promote a project for an agricultural technology demonstration platform in the Philippines. In order to strengthen S&T co-operation with SEA countries, China will set up a series of offices for China-ASEAN co-operation in the fields of business, investment, tourism and youth training programmes, as well as co-operation projects in poverty alleviation, medical and health, port co-operation, inspection and quarantine co-operation (Xinhuanet, 2010).

China's foreign aid to SEA countries

In recent years, China has expanded its foreign aid to developing countries, including SEA countries. China is a key source of foreign aid to Cambodia. According to the 2010 Aid Effectiveness Report (AER) prepared by the Cambodian Rehabilitation and Development Board (CRDB) of the Council for the Development of Cambodia (CDC), over the period 2000-09, development assistance from China to Cambodia totalled USD 465 million or 7% of the overall endorsement from all partners. The amount increased annually from USD 2.6 million in 2000 to USD 114.7 million in 2009, at which time its development assistance ranked second after Japan. Aid from China to Cambodia was concentrated on transport (70.2%), community & social welfare services (15.9%), governance and administration (8.9%), information and communication (2.2%), post and telecommunications (2.1%), and others (0.73%). China also increased its foreign aid loan to the Philippines to about USD 1.1 billion in 2010, more than double the USD 483 billion in 2009 (NEDA, 2010). China's aid to the Philippines has focused on agricultural areas. In 2003, the Sino-Philippines Agricultural Technology Centre built by the Chinese was completed. This has promoted advanced and practical technology for improving food (mainly rice) yield and resulted in China's hybrid rice growing over large areas of the Philippines.

China is the fourth largest source of assistance for Laos. According to statistics from the Laotian Department for International Cooperation, the Ministry of Planning and Investment (2009), Laos received ODA of over USD 78 million from China from 2004 to 2008, of which USD 35.8 million was grants and USD 42.2 million in soft loans, accounting for approximately 7.4% of aid given to Laos. Chinese aid to Laos (2004-08) concentrated on transport (47.2%), rural development (15.7%), health (12.4%), communication (8.4%), education (7.8%), and cement factories (7.8%). Comparing the structure of China's aid to that of other countries, China concentrates more on transport and communications while other countries tend to have a more diversified profile. Aid from other countries goes to public administration (23%), transport and communication (20%), agriculture and rural development (14%), education (13%), health (9%), energy and mining (8%), trade (7%), and others (6%).

China's assistance to Viet Nam largely concentrates on development sectors and areas such as industry, mining, railway construction, energy, textiles, chemicals and physical infrastructure. This aid is largely in the form of preferential loans. China's assistance to Viet Nam is rather modest both in amount and in the percentage share of Viet Nam's total aid. Based on statistics from the official records of the Ministry of Planning and Investment (2008), the total of soft loans and grants from China between 1993 and 2008 was just over USD 359 million (almost 1.1% of total ODA inflows to Viet Nam), of which more than USD 330 million was in preferential loans (accounting for 1.2% of total soft loans provided to Viet Nam) and only around USD 29 million in the form of grants (0.53% of total grants to Viet Nam).

In 2007, China and Indonesia signed a consulting project on the technological transformation of four strategic firms in order to enhance Indonesia's technology and innovation in shipbuilding, steel, aircraft and others. A Chinese firm participated in the technology assistance. As of 2009, China's largest telecommunication equipment company, ZTE, completed the training of more than 5 000 local telecommunication professional personnel in Indonesia.

Information on China's aid to Thailand is not available, presumably because the amount, if any, is negligible. In 2008, total ODA from all sources was USD 39.09 million, of which only 0.31% (or USD 120 400) from Asian countries, including China.

Some international studies (*e. g.* Goto 2011) argue that much of China's foreign aid is tied to preferential treatments for Chinese state owned enterprises and to promoting Chinese exports. As seen above, the aid from China to SEA has had a strong focus on transport. While benefits of the improvements in transport are clear for the recipient countries, they have also facilitated significant increases in Chinese imports to countries bordering with China, which have been said to have the effect of crowding out local production in the case of less developed countries (LDC).

Human resource development

Apart from funding foreign-aid projects, China's technology assistance policies address the development of human resources in developing countries. For a long time China has offered scholarships and training programmes to developing countries. As of the end of 2009, China had offered government scholarships to more than 70 000 foreign students from developing countries studying in China. China has also trained 120 000 professionals in economics, management, agriculture, health, justice, education, environmental protection. At present, more than 10 000 persons from developing countries are trained in China every year.

In recent years, the Chinese government has significantly increased the scholarships granted to students and scholars from SEA countries studying in China. As noted previously, in 2008 China set up the China-ASEAN (AUN) Scholarship Program (a special full scholarship) to encourage students, teachers and scholars from SEA countries to study and participate in exchanges with China. As of 2007, 8 095 students and scholars from SEA countries had Chinese government scholarships. Students and scholars from Laos receive more scholarships from China than from other SEA countries. During the academic year 2009/10, China expected to provide 1 200 government scholarships to SEA countries under the AUN and other scholarship programmes.

6.2. The role of S&T diplomacy in promoting S&T relationships

S&T diplomacy will play an increasingly important role in promoting S&T relationships between China and SEA countries.

First, S&T itself helps to enrich the resources available for S&T diplomacy and improve foreign relations. Since the improvement in relations between China and SEA countries in 1991, S&T diplomacy, including government agreements and MOUs on S&T co-operation, development of S&T co-operation projects and training of personnel, have occurred, however there is need for further expansion in the future.

Second, S&T helps both sides to settle issues not only in the traditional areas but also in non-traditional ones. For example, the SARS (severe acute respiratory syndrome) outbreak in 2003 caused alarm across China and SEA countries. Both sides used their S&T strengths to control its spread. At present, both sides make active use of S&T diplomacy to express views and settle issues of concern.

Third, S&T diplomacy can produce real benefits for both sides. Training projects and government scholarships for students and scholars from other countries bring obvious and direct benefits to local people and help ease or increase relations between the two sides.

In the future, China will continue to make use of S&T assistance to broaden and deepen its relations with SEA countries. The increasing role of S&T in China's economic growth will expand the space for S&T diplomacy, and China may exploit its strengths in S&T to increase its assistance to developing SEA countries. S&T diplomacy is no doubt an effective means of helping China and developing SEA countries meet the challenges in the fields of environment, energy and renewable industries and to promote sustainable economic development, common prosperity and ensure security. For example, good development in the GMS benefits not only local people by improving their living standards but also the local environment and border security for China and GMS members.

There are likely to be changes in China's S&T diplomacy. The participants are expected to become more diverse by broadening partners beyond Singapore and possibly increasing funding for S&T assistance, particularly to the least developed SEA countries such as Cambodia, Laos and Myanmar. In addition to direct intergovernmental co-operation, more Chinese enterprises and multilateral institutions will participate in S&T assistance to developing SEA countries. S&T diplomacy should also expand from traditional to high-technology industries

A.7. Summary of main findings

- The improvement in political relations between China and SEA countries between 1991 and 2003 paved a good foundation for exchange and co-operation in the economic and technological areas. In the future China will continue to play an active role in bilateral economic and S&T co-operation with SEA countries, based on its policy to promote regional economic growth and prosperity.
- In 2004 both sides started to accelerate the process of economic and technological co-operation, including agreements, increased trade and FDI. The expansion of economic co-operation and trade has been mainly realised in the bilateral framework while the expansion of S&T co-operation has been mainly realised in a multilateral framework because both sides' current technological level restricted bilateral S&T co-operation in advanced and high-technology fields. Therefore, they had to rely on the technological strength of a third party, at the multilateral level, to meet the needs of their economic growth.
- Policy attention and recognition of the importance of S&T cooperation, increased funding, and an enlarging technological advantage between China and developing SEA countries will help create improved prospects for future bilateral S&T co-operation or for S&T assistance from China to developing SEA countries.

Notes

1 In 2009, the first ten countries for Chinese students abroad were the United States, Australia, United Kingdom, Korea, Japan, Canada, Singapore, New Zealand, France and the Russian Federation.

2 According to the Chinese statistical definition, trade in technology covers licensing or transfer of industrial property rights; licensing or transfer of proprietary technology; licensing of computer software; technical services; production line, complete sets of equipment and key equipment. Technical services mean a kind of service provided to settle issues related to technologies.

3 In fact, China's total outward FDI stocks in education are very low, compared to other industries. At the end of 2009, they reached USD 21.23 million, of which USD 7.1 million to SEA countries, mainly for Chinese training programmes, etc.

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Statistical appendix

Table A.A1. China's outward FDI flows and stocks into SEA countries by industry, 2009

	China's outward FDI flows to SEA (USD million)	China's outward FDI flows to SEA in total FDI flows to SEA (%)	China's outward FDI stocks to SEA (USD million)	China's outward FDI stocks to SEA in total FDI stocks to SEA (%)	China's outward FDI stocks to SEA in total stocks by industry (%)	Distribution of China's outward FDI stocks to SEA
Power and other utilities	349.3	12.9	1 858.5	19.4	82.4	Si, My, In, Ca
Wholesale and retailing	910	33.6	1 634.1	17.1	4.6	Si, VN, Ma, Th
Manufactory	275.1	10.2	1 486.5	15.5	10.9	VN, Ma, Th, My, LP
Leasing and business services	152.1	5.6	1 051.2	10.9	1.4	Si, VN, LP
Mining	465.5	17.3	915.3	9.5	2.3	-
Construction	182	6.8	675.5	7.1	19.8	Ca, My, Si
Transport, warehousing & postal service	61.3	2.3	669.2	7.0	4.0	Si
Finance	142	5.3	666.4	7.0	1.4	Si, Ma, In
Agriculture, forestry, husbandry, fishery	110.6	4.1	340.5	3.6	16.8	LP, VN, Th, My, Ca, In, Ph
Scientific research, services & geo-survey	5.3	0.2	131.4	1.4	4.6	NA
Real estate	35.5	1.3	59.7	0.6	1.1	NA
IT	2.4	0.1	40.2	0.4	2.0	NA
Residential service & other services	1.6	0.1	15.5	0.2	1.6	NA
Residential & catering trade	0.4	0.0	15.6	0.2	6.4	NA
Education	2.4	0.1	7.1	0.1	33.5	NA
Others	2.7	0.1	4.7	0.0	0.4	NA
Total	2 698.1	100.0	9 571.4	100.0	3.9	NA

Notes: BD (Brunei Darussalam), Ca (Cambodia), In (Indonesia), LP (Laos), Ma (Malaysia), My (Myanmar), Ph (Philippines), Si (Singapore), Th (Thailand) and VN (Viet Nam). NA: not available.

Source: 2009 Statistical Bulletin of China's Outward Foreign Direct Investment.

Table A.A2. Joint publication of papers by authors from the first ten countries or regions

Percentage

	Co-authorship: China, Brunei and other counties or regions		Co-authorship: China, Cambodia and other counties or regions		Co-authorship: China, Indonesia and other counties or regions		Co-authorship: China, Laos and other counties or regions		Co-authorship: China, Malaysia and other counties or regions	
No. 1	Brunei	100	Cambodia	100	Indonesia	100.0	China	91.7	Malaysia	99.9
No. 2	China	100.0	China	100.0	China	98.5	United States	33.3	China	99.7
No. 3	Australia	15.8	Thailand	32.5	United States	32.5	Japan	25.0	Thailand	11.8
No. 4	Germany	10.5	United States	27.5	Thailand	31.1	Thailand	25.0	Singapore	6.7
No. 5	United States	10.5	Viet Nam	27.5	Japan	28.6	India	16.7	United States	6.2
No. 6			Australia	22.5	India	27.2	Lao	16.7	Australia	5.9
No. 7			France	20.0	Philippines	27.2	Philippines	16.7	Japan	5.6
No. 8			India	20.0	Korea	24.8	Chinese Taipei	16.7	Chinese Taipei	5.1
No. 9			Philippines	20.0	Malaysia	22.3	Viet Nam	16.7	Korea	4.5
No. 10			Malaysia	17.5	Viet Nam	21.4			Philippines	4.4

Table A.A2 *(continued)*

	Co-authorship: China, Myanmar and other counties or regions		Co-authorship: China, Philippines and other counties or regions		Co-authorship: China, Singapore and other counties or regions		Co-authorship: China, Thailand and other counties or regions		Co-authorship: China, Viet Nam and other counties or regions	
No. 1	Myanmar	100.0	Philippines	99.5	China	99.8	Thailand	100.0	China	100.0
No. 2	China	100.0	China	99.0	Singapore	98.1	China	99.6	Singapore	100.0
No. 3	Thailand	38.9	United States	32.1	United States	12.0	United States	24.1	Viet Nam	100.0
No. 4	Viet Nam	33.3	Thailand	21.3	Australia	4.4	Malaysia	17.4		
No. 5	Japan	27.8	Japan	21.0	England	3.3	Japan	14.8		
No. 6	Cambodia	22.2	India	20.3	Chinese Taipei	2.4	Australia	12.1		
No. 7	Nepal	22.2	Korea	19.1	Japan	2.3	Korea	11.9		
No. 8	United States	22.2	Singapore	17.6	Canada	2.1	Singapore	11.4		
No. 9	Malaysia	16.7	Malaysia	15.2	Germany	1.9	Chinese Taipei	10.0		
No. 10	Philippines	16.7	Chinese Taipei	15.0	Korea	1.8	India	9.5		

Source: Science Citation Index Expanded (SCI-EXPANDED)

Table A.A3. Top ten subjects of co-authored scientific and technological publications by authors from China, SEA countries, 1999-2010

Percentage of total co-authored publications

	Co-authorship: China, Brunei and third party		Co-authorship: China, Cambodia and third party		Co-authorship: China, Indonesia and third party		Co-authorship: China, Laos and third party		Co-authorship: China, Malaysia and third party	
No. 1	Ecology	26.3	Infectious diseases	32.5	Environmental sciences	6.8	Meteorology & atmospheric sciences	25.0	Crystallography	60.2
No. 2	Mathematics, interdisciplinary applications	21.1	Immunology	20.0	Infectious diseases	6.8	Public, environmental & occupational health	16.7	Chemistry, inorganic & nuclear	12.2
No. 3	Engineering, multidisciplinary	15.8	Virology	17.5	Public, environmental & occupational health	5.8	Tropical medicine	16.7	Chemistry, multi-disciplinary	3.3
No. 4	Mechanics	15.8	Tropical medicine	10.0	Multidisciplinary sciences	5.3			Chemistry, physical	2.9
No. 5	Plant sciences	15.8	Biochemistry & molecular biology	7.5	Plant sciences	5.3			Chemistry, organic	2.2
No. 6	Automation & control systems	10.5	Parasitology	7.5	Gastroenterology & hepatology	4.9			Materials Science, multidisciplinary	2.0
No. 7	Engineering, electrical & electronic	10.5	Biology	5.0	Immunology	4.9			Infectious diseases	1.4
No. 8	Evolutionary biology	10.5	Dentistry, oral surgery & medicine	5.0	Agronomy	4.4			Environmental sciences	1.2
No. 9	Mathematics, applied	10.5	Microbiology	5.0	Microbiology	4.4			Chemistry, applied	1.1
No. 10	Mycology	10.5	Pathology	5.0	Ecology	3.9			Endocrinology & metabolism	1.0

Table A.A3. ***(continued)***

	Co-authorship: China, Myanmar and third party		Co-authorship: China, Philippines and third party		Co-authorship: China, Singapore and third party		Co-authorship: China, Thailand and third party		Co-authorship: China, Viet Nam and third party	
No. 1	Immunology	16.7	Plant sciences	21.7	Engineering, electrical & electronic	14.1	Mycology	9.8	Mathematics , applied	100.0
No. 2	Infectious Diseases	16.7	Agronomy	20.8	Physics, applied	11.2	Crystallography	8.2	Mathematics	66.7
No. 3	Tropical medicine	16.7	Genetics & heredity	8.9	Materials science, multidisciplinary	9.8	Infectious diseases	6.0		
No. 4	Biochemistry & molecular biology	11.1	Biochemistry & molecular biology	7.7	Optics	8.4	Immunology	5.0		
No. 5	Entomology	11.1	Environmental sciences	7.7	Chemistry, physical	6.6	Public, environmental & occupational health	4.2		
No. 6	Genetics & heredity	11.1	Horticulture	7.0	Physics, condensed matter	4.6	Plant sciences	4.0		
No. 7	Public, environmental & occupational health	11.1	Infectious diseases	6.3	Nanoscience & nanotechnology	4.1	Microbiology	3.7		
No. 8			Gastroenterology & hepatology	4.6	Chemistry, multidisciplinary	3.9	Oncology	3.6		
No. 9			Public, environmental & occupational health	4.6	Mathematics, applied	3.5	Environmental sciences	3.3		
No. 10			Soil sciences	4.1	Computer science, artificial intelligence	3.3	Astronomy & astrophysics	3.2		

Source: Science Citation Index Expanded (SCI-EXPANDED).

Table A.A4. International conferences attended by China and SEA countries

		Conferences	Participating countries	Feature
Chinese Academy of Sciences	1998	China-Singapore Seminar on Life Science and Technology	China-Singapore	Bilateral
	2004	APEIS (Annual Conference on Asia-Pacific Environmental Innovation Strategy Plan)	China, Japan, Singapore, Australia, Mongolia, Russia, Viet Nam and India	Multilateral, annual
	2005	Bilateral Academic Seminar by the Institute of Genetics and Developmental Biology and Temasek Life Sciences Laboratory Singapore	China-Singapore	Bilateral, annual since 2005
	2005	The first meeting of partners on Asian flu study	China, Thailand, Viet Nam, Cambodia, Indonesia, and multilateral institutions	Multilateral
	2005	International Conference on Global Natural Disasters and Disaster Reduction	China, the United States, Sweden, Cuba, Indonesia, Bangladesh, Thailand and multilateral institutions	Multilateral
	2005	The 4th Network Conference of Biosphere Reserves in South East Asia	China, Laos and other countries	Multilateral
	2007	International Symposium on Medicinal Plants and Aromatic Plants	Thailand, China and 19 countries	Multilateral
	2007	The 2nd Seminar on co-operation between the Chinese Academy of Science and the Minister of Science and Technology of Thailand	China and Thailand	Bilateral
	2007/10	Summary on Cambodia's National Botanic Gardens reconstruction projects	China and Cambodia	Bilateral
	2008	PRAGMA (Pacific Rim Applications and Grid Middleware Assembly)	Malaysia, China and other countries	Multilateral
	2009	China-Singapore bilateral seminar on energy plant	China-Singapore	Bilateral
State Forestry Administration of China	2003	International Symposium on Asia-Pacific community forestry in the role of poverty reduction	China and 15 Asia-Pacific countries, including 7 SEA countries, and international institutions	Multilateral
	2004	China-ASEAN Seminar on Conservation of Tropical Biology and Biotechnology Application	China and SEA countries	Bilateral
	2005	China-ASEAN Seminar on sustainable development of bamboo industry	SEA countries and China	Bilateral
Chinese Academy of Engineering	2006	International Symposium on influenza pandemic prevention and control in developing countries	China, Viet Nam and other countries	Multilateral
	2007	The Eighth Qingdao International Symposium on Ophthalmology	China, Singapore and other countries	Multilateral
	2007	International seminars on prevention of new and re-infectious diseases and control measures	China, Malaysia, Thailand and other countries	Multilateral
	2008	Tenth Conference on Orthopaedics of the Chinese Medical Association and the third International COA	China, Myanmar, Singapore and other countries	Multilateral
	2008	The 3rd Great Wall International Andrology Forum (GIAF 2008)	China, Singapore and other countries	Multilateral meeting
	2009	11th International Conference on Isolation from and Control of Energy Dissipation on Earthquake	China, Singapore and other countries or regions	Multilateral
	2009	China Qingdao: International Forum on Blue Economic Development	China, Thailand, Singapore and other countries	Multilateral
	2009	Symposium on Computational Structural Engineering	China, Malaysia, Singapore, Viet Nam and other countries	Multilateral

Source: Chinese Academy of Science, State Forestry Administration of China and Chinese Academy of Engineering.

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