Chapter 4.

Innovation actors in Malaysia

This chapter describes the main actors in the Malaysian innovation system: business enterprises, higher education institutions and public research institutes, highlighting their respective roles in the development of the innovation system in recent years. It reviews scientific, technological and related functions carried out by the main actors within the system and their contributions to innovation.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

This chapter examines successively the role and performance of the main public and private research and innovation actors in the development of the Malaysian innovation system in recent years: business enterprises, higher education institutions and public research institutes.

Business sector

Due to the small size of its domestic markets and its limited investment capacity, following an initial period characterised by export substitution, independent Malaysia has relied heavily on international trade and foreign direct investment (FDI) to stimulate and feed its rapid development. This strategy has proven successful and resulted in a set of diversified and fast-growing manufacturing and, more recently, service industries. The electrical and electronic (E&E) industry in particular has acted as a pioneer and catalyst of structural change towards high-technology manufacturing and allowed Malaysia's industry to connect to and integrate in global value chains (GVCs), focusing on the assembly and testing of different types and generations of components. Malaysia has now diversified well beyond the semiconductors and hard-drive companies established in the 1970s. Despite some remarkable successes in specific clusters, industries and firms, the perceived slowdown of the upgrading process in the 2000s triggered a debate about Malaysia's ability to fully move its manufacturing and services industries to the next "knowledge-intensive" stage. This transition is hampered by bottlenecks related above all to the lack of adequate skills. This is an obstacle for the growth of innovative domestic enterprises, especially small and medium-sized enterprises (SMEs), and makes multinational enterprises (MNEs) reluctant to expand higher value-adding activities in Malaysia.

Structure of the business sector

Overall industry profile

Even more than in other countries of "factory Asia", manufacturing has been a pillar of Malaysia's development success, in particular since the 1980s. Although its weight in the economy peaked in 2000 and has gradually decreased since then, this sector has kept growing in recent years (4.8% per year on average during the Tenth Malaysia Plan 2011-15), contributing 23% of gross domestic product (GDP) in 2015. It also accounted for 18% of employment and 81.8% of total exports in 2015 (compared to 17% and 76.6%, respectively, in 2010) (EPU, 2015a). The E&E industry remains the largest contributor to the manufacturing value added in Malaysia at 25.7% (2014),[1] followed by two other largely export-oriented industries, *viz.* refined petroleum (12.7%) and chemicals and chemicals products (10.9%). E&E represented 42.7% of the manufacturing sector's gross exports and 33.4% of the country's total exports in 2014 (MPC, 2015).

The largest contributor to Malaysia's GDP (at 54%), however, is the service sector, which expanded at a rate of 6.3% per year over the period from 2011 to 2015 (EPU, 2015a; MPC, 2015). Wholesale, retail trade, and restaurants and accommodation account for 61.6% of the contribution of services to GDP; finance, insurance, real estate and business services for 20.6% (SME Corporation, 2015). Like in other Asian economies, manufacturing was a major driving force behind Malaysia's economic and labour productivity growth. Since about 2000, a profound shift has occurred: following secular development trends and enhanced by new ICTs, the service sector's contribution to both output and labour productivity increased at the same or higher rate than the contribution of manufacturing. The manufacturing sector's contribution to economic growth in Asian economies was at 29% between 2000 and 2013, compared to 32% during the preceding decade (APO, 2015).

The importance of the primary and resource-based sectors[2] in the country's exports declined from about 95% at the time of Malaysia's independence to some 43% in 1990, and 17% in 2000 (World Bank, 2014). However, these sectors still play an important role in the Malaysian economy since most of them, in particular palm oil and rubber, and to a lesser extent forestry, have gone through a process of moving "downstream". The manufactured products derived from these resources[3] account for a growing share of exports (from 5.4% in 2002 to 23.3% in 2012) and were the most powerful driver of growth of the manufacturing sector over the period 2002-12 (Bank Negara Malaysia, 2013). By 2013, the share of exports of the resource-based and primary sectors rose to 33%.[4]

Small and large private companies

The vast majority of Malaysian manufacturing and service enterprises are privately-owned SMEs. They represent 97.3% of business establishments according to the census conducted in 2011; most of them operate in the service sector (90% of SMEs) according to the new definition introduced in 2014[5] (Table 4.1). Whereas large firms account for only 2.7% of establishments, they contributed 64.1% to GDP in 2014.

Table 4.1. **Share of small and medium-sized enterprises in the total number of firms and GDP, Malaysia, 2011 and 2014**

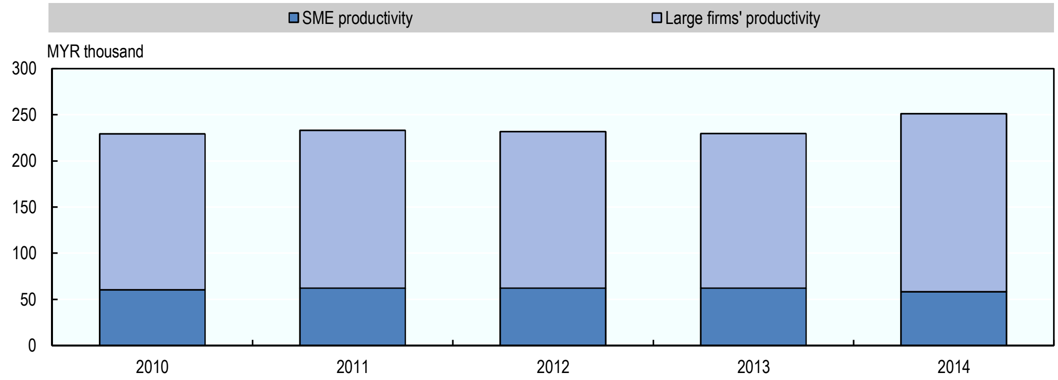
Sector	Share of SMEs (%)	Share in total SMEs (%)	Contribution to GDP (%), 2011	Contribution to GDP (%), 2014
Agriculture	76	1	3.4	4.5
Mining	71.5	0.1	0.1	0.1
Construction	87.1	3	0.8	2
Manufacturing	95.4	5.9	7.9	7.8
Services	98.2	90	20	21.1
Total	97.3	100	32.5	35.9

Source: Department of Statistics, Malaysia.

Large firms account for an even more disproportionate share of exports since they are often export-oriented subsidiaries of MNEs operating in global value chains. The semiconductor industry, for instance, is composed of 126 foreign establishments, which together account for 80% of all semiconductor exports; the 240 smaller domestic firms account for the remaining 20% (EPU, 2014).

A key issue for SMEs is their low level of productivity. As in most developing and emerging economies, small firms' productivity lags behind that of large firms, but tends to narrow as the level of development increases. The productivity of large Malaysian firms was 3.2 times and 2.7 times higher than that of small firms in 2005 and 2013, respectively. The change over the period 2010-14 was rather small, however[6] (Figure 4.1). The gap is particularly large in services where productivity per worker in large firms is more than four times higher than in small firms, partly due to the large number of micro-enterprises (EPU, 2015a). Compared to other countries, the labour productivity of Malaysian SMEs appears particularly low – 3.6 times lower than that of Singapore's SMEs, 7 times lower than in SMEs in the United States (SME Corporation, 2015).

Figure 4.1. **Productivity of small and medium-sized enterprises and large firms, Malaysia**



Source: OECD (2016), *Economic Outlook for Southeast Asia, China and India 2016: Enhancing Regional Ties*, http://dx.doi.org/10.1787/saeo-2016-en.

The factors hampering the performance of SMEs are plenty, and interrelated. These include the large share of unskilled workers in labour-intensive industries across all sectors of the economy, low capability and willingness to engage in human capital development, weak financial capacity and difficulty accessing external financial sources, and lock-in in low value-added segments (SME Corporation, 2012; OECD, 2016, 2014). Moreover, according to a survey of SMEs carried out in 2012,[7] only 11% of those that engage in innovation activities do so to raise their productivity (ACCCIM, 2012).

Since only a few non-financial domestic firms succeeded in growing and establishing their own brand, large firms are – in their great majority – either MNEs or government-linked companies (GLCs), with some notable exceptions. About 400 MNEs[8] were located in Malaysia in 2012, comprising many of the leaders in the E&E industry and in other industries (pharmaceuticals, biotechnology, aerospace, automotive, etc.). Giant services companies such as Temasek Holding, SAP or Frost and Sullivan have subsidiaries in Malaysia.

Only two Malaysian private (non-financial) companies[9] were listed in the United Nations Conference on Trade and Development's (UNCTAD) top 100 non-financial MNEs from developing and transition economies, ranked by foreign assets in 2013 (UNCTAD, 2013). These two companies are among the large domestic firms privately-owned by families.[10]

Government-linked companies in Asia

GLCs, or state-owned enterprises (SOEs) as defined by the OECD,[11] have significant weight in many Asian economies, where they have been assigned important roles in national economic development. The Malaysian government used GLCs to leverage its intervention in a wide range of priority industries (food, chemicals, iron, steel, petroleum transport, wood products, etc.), especially during the 1980s (Bhattacharya, 2002). For instance, PETRONAS, the national oil and gas company, financially supported several government mega-projects outside its core business, such as the development of Putrajaya and the construction of Kuala Lumpur Twin Towers, as well as industry and service endeavours such as the Bank Bumiputra, and the foundation of Proton, the national carmaker.

Despite a major privatisation programme launched in the early 1990s, GLCs still occupy a key position in the Malaysian economy, including in telecommunications, power generation and supply, ports, airports, highways, post, telecommunications, railways and sewerage (OECD, 2015b). Their share of the national value added is about 15% (5% of employment), comparable to Singapore, while they roughly contribute 25% in India and Thailand. Several of these Malaysian companies are listed on the national stock exchange, where together they represent about 50% of the total stock market capitalisation (60% in the People's Republic of China, hereafter "China") (OECD, 2015c).

GLCs operate in a variety of sectors, but are particularly dominant in utilities (including telecommunications, transportation, and oil and gas) (PGC, 2015a). They often occupy monopoly positions in these sectors (OECD, 2013a). In line with trends in other countries with strong SOEs, some Malaysian GLCs have become MNEs, investing and conquering market shares abroad. Of the four Malaysian enterprises that are listed in the 2012 UNCTAD top-100 multinationals from developing and transition economies, two are GLCs.[12]

Despite their weight and pervasiveness, there is little evidence that Malaysian SOEs have contributed much to fostering innovation activities beyond special cases such as Proton,[13] some links with higher education institutions, and some initiatives in the financial (new Islamic financing products and services) and sustainable development areas (biomass projects) (PGC, 2015b). This observation is in line with international evidence: GLCs in Malaysia, as well as in other countries such as Singapore, perform but little R&D for their size (OECD, 2013a). An assessment of the largest Malaysian GLCs' innovation capabilities was undertaken in 2011 in order to promote the innovation mind-set and culture across Malaysian companies. The results of this survey showed that while coming close to best practice level on certain dimensions, Malaysian GLCs were lagging behind the global benchmark on key innovation dimensions such as the "importance of innovation" and "innovation as an integral part of business strategy" (PGC, 2015b). Although they are not always available, the key performance indicators, which are at the core of the government programme for improving the efficiency of GLCs, tend to mostly relate to financial performance. The non-financial indicators have little to do with innovation (PGC, 2015b).

Finally, there are indications that Malaysian GLCs not only do not engage strongly in innovation activities, but that they also act as a disincentive to investment by other companies in the same sectors, in particular in those where they account for a dominant share of revenues (Menon and Hee, 2013).

Innovation and R&D performance of business firms

R&D activities of business firms

Starting from a low level, business expenditure on research and development (BERD) increased rapidly during the 1990s; it slowed in the mid-2000s and turned negative in 2011 before rising again a year later (Figure 4.2). The business sector stands out, accounting for 64.5% of Malaysia's gross expenditure on research and development (GERD) in 2012, down from a peak at 85% in 2006 (MASTIC, 2014a). In absolute terms, R&D has stagnated since 2010.[14]

The breakdown of BERD by field of research broadly reflects the structure of the business sector: the largest R&D effort was in engineering, technology and ICT (48%), followed by natural science, agriculture and forestry (31%). Business R&D expenditure by manufacturing industries is even more concentrated. The E&E industry is by far the largest research performer, accounting for about 79% of manufacturing R&D expenditure in 2011 (71% by electronics alone). With 8% of manufacturing R&D, the automotive sector is a distant second (Table 4.2).

Table 4.2. **Business R&D expenditures by manufacturing sector, Malaysia**

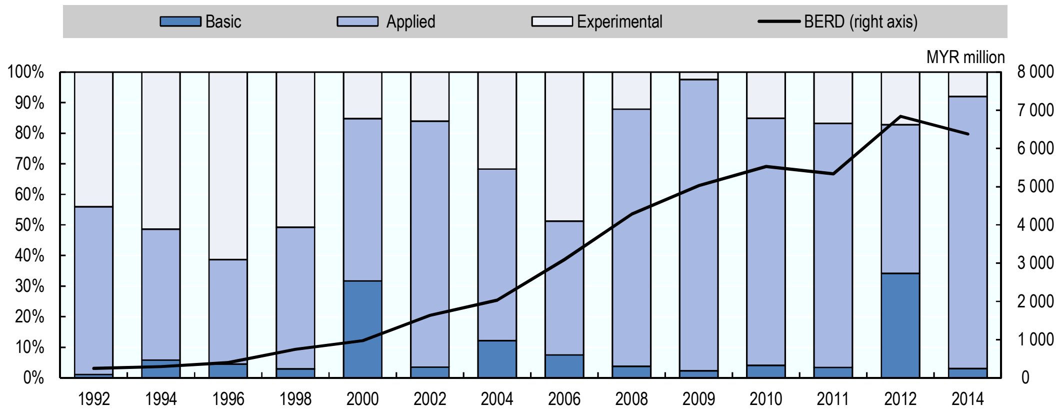
MYR million

	2005	2006	2007	2008	2009	2011
Manufacture of computer, electronic and optical products	1 000.80	787.90	1 749.80	1 401.70	1 243.80	1 417.02
Manufacture of machinery and equipment and electrical equipment and fabricated metal products	101.60	309.70	322.20	147.90	215.00	162.62
Manufacture of food products and beverage	29.90	36.60	70.30	72.10	66.90	71.48
Manufacture of rubber and plastic products	56.80	71.70	104.60	75.40	58.80	75.40
Manufacture of chemicals and chemical products	810.00	48.50	48.00	38.90	48.60	38.93
Manufacture of motor vehicles, trailers and semi-trailers and other transport equipment	265.70	175.40	50.70	160.70	94.90	160.71
Others (including manufacture of wearing apparel and other non-mineral products)	98.30	92.00	85.00	107.80	119.30	77.00
Total	2 363.10	1 521.80	2 430.60	2 004.50	1 847.30	2 003.16

Source: Department of Statistics, Malaysia.

The lion's share of expenditure is for applied research (80% in 2011), followed by experimental research (17%) and basic research (3%) (Figure 4.2). Basic research increased by 92% between 2011 and 2012 (now accounting for 34% of total R&D expenditures) due, according to the Ministry of Science, Technology and Innovation (MOSTI), to various new government initiatives launched to support this kind of research (MASTIC, 2014a).[15] However, as soon as 2014, the distribution of business expenditure went back to its earlier distribution, with an even greater share of applied research due to a decrease in experimental development (MASTIC, 2016).

Figure 4.2. **BERD, total amount and share of total by type of research, Malaysia, 1992-2014**

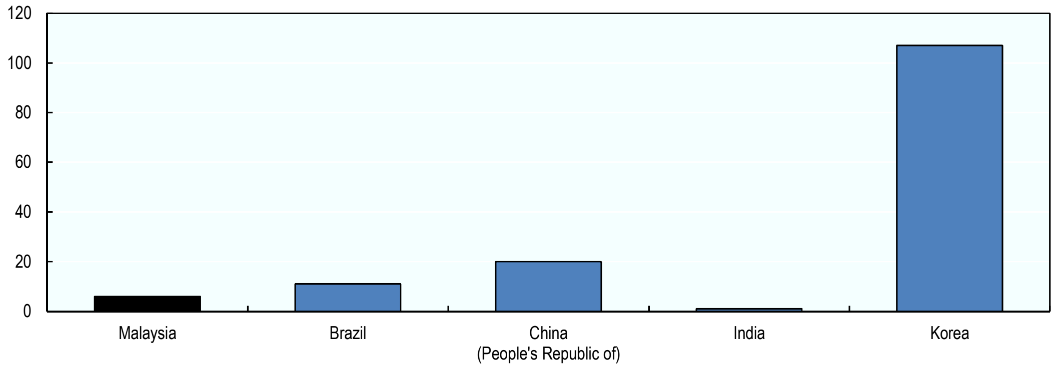


Note: BERD = business expenditure on research and development.

Sources: MASTIC (2001, 2005, 2009, 2013, 2016), *National Surveys of Research and Development*.

In international comparison, the business expenditures of the main Malaysian business R&D investors appear low, even when accounting for the difference in level of development (Figure 4.3).

Figure 4.3. **Number of top 500 corporate R&D investors, per GDP, 2013 or latest year available**



Source: OECD (2014), *OECD Science, Technology and Industry Outlook 2014*, http://dx.doi.org/10.1787/sti_outlook-2014-en.

Business firms' engagement in innovation

According to the 6th National Survey on Innovation conducted in 2012 (MASTIC, 2014b), 70% of responding companies stated that they had engaged in innovation activities during 2009-11. These "innovative firms" were mainly in the service sector (62% of all innovative firms), far exceeding those in manufacturing (38%). Service companies were also proportionally more inclined to carry out innovation activities, as 78% of them declared they were innovative, compared to 60% of manufacturing firms. However, the service firms' innovation activities were of smaller scale in terms of innovation expenditures: only 2% declared expenditures above MYR 250 000, which is consistent with the fact that the predominant activities consisted of small-scale innovation by travel and tour agencies. In contrast, 76% of manufacturing firms were above this threshold, and 42% spent more than MYR 1 million. The most strongly represented sector among innovative manufacturing firms was the computer, electronic and optical products industry, followed by food products and machinery and equipment.

While this survey provides valuable information on the features of innovative firms, it almost certainly overestimates the overall propensity of business firms to innovate. Other available data, although scarce, often dated and not very precise, suggest, for example, that the proportion of firms involved in R&D in Malaysia around 2005 was closer to 5% (OECD, 2013a).

Although somewhat dated, the surveys on investment climate conducted by the World Bank in 2002 and 2007 provide concordant evidence on the limited extent and depth of innovation activities in Malaysian manufacturing firms (World Bank, 2010). Furthermore, efforts of manufacturing firms declined between 2002 and 2007 across all types of innovation, except for those engaging external partners (subcontracting of R&D and joint ventures with a foreign partner). A comparison with the results of similar surveys conducted in a large group of other countries shows that the level of Malaysian firms' engagement in innovation activities was among the lowest and appeared to be significantly below the level achieved by its Asian counterparts (e.g. Indonesia, the Philippines, Thailand, Viet Nam, etc.) (World Bank, 2010). Distinguishing between three types of "technological capabilities", the results of the surveys also indicate that the investment capabilities (selection and preparation of technological projects) and production capabilities (conduct of process and product innovation) barely improved between 2002 and 2007, while "linkages capabilities" (exchange of technologies and knowledge) declined. One of the most remarkable results is that less than 30% of firms have carried out activities relevant to the three types of technological capabilities in recent years. SMEs, which account for the bulk of domestically-owned companies, score significantly lower than large companies (World Bank, 2009). Most Malaysian firms are considered "adapters" (50% in 2002, 40% in 2007) while few are "creators" (10% in 2002, 15% in 2007). More than 40% are only considered "adopters" or had not reported any of these activities in the two years prior to the surveys (World Bank, 2009).[16]

These results are confirmed by detailed studies of the characteristics of R&D activities performed by firms, for instance in the E&E industry, which have demonstrated that, for the most part the most sophisticated forms of innovation remain confined to a small group of firms. The most widespread form of innovation is the upgrading of existing product lines or machinery and equipment, as opposed to the development of a new product line or the introduction of a new technology. A study of 53 MNEs and local E&E firms show that, although they have increased their capability over time, two-thirds of sampled firms in the E&E industry had reached (at the beginning of the year 2000) a basic or intermediate level of innovative capability, mainly in relation to improvement of equipment, tooling, stamping, moulding, as well as process and production organisation capability (Ariffin and Figueiredo, 2003).

Using a different technological framework and more recent data than the World Bank survey, a study conducted on 103 E&E firms concluded that electronic firms experienced the most significant increase in technological capabilities of all firms over the period 2000-07 and R&D intensity over the period 2000-07, reaching ratios of 5.6% of sales in 2007 (up from 3.7% in 2000) and 8.3% of sales (up from 1.1% in 2000), respectively. However, despite progress, two-thirds of these firms performed activities pertaining to the level of "engineering" (process and product adaptation). A third of these firms only reached the highest stages of "early R&D" (process or product development) and only one firm that of "mature R&D" (new process or product) (Rasiah, 2010).

Business firms' human resources for R&D

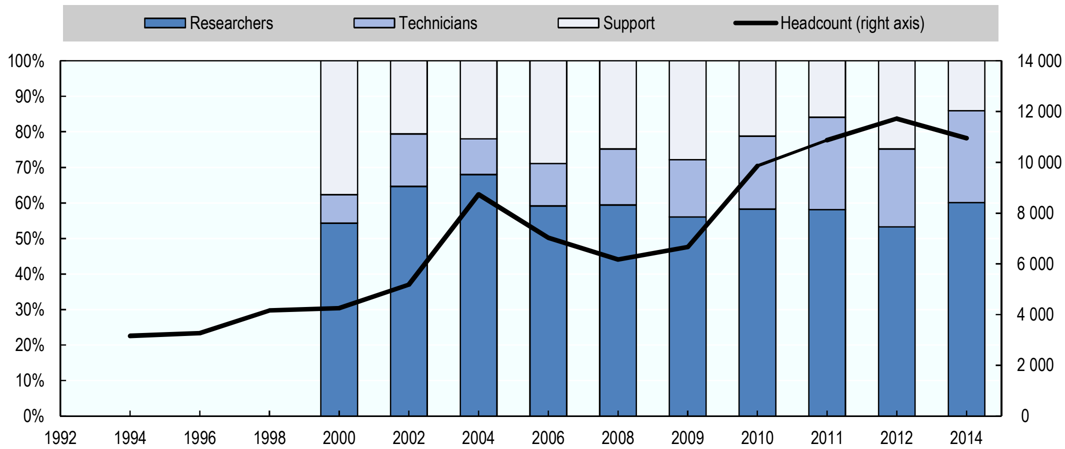
The number of R&D personnel in business firms increased drastically between 1992 and 2004, stagnated until around the end of the 2000s and then increased again, at a slower pace, until 2012. The majority of R&D personnel are researchers (53% in 2012), rather than technicians (22%) or support staff (25%) (Figure 4.4); 69% are male. The latest data available for 2014 show a new decrease of R&D personnel due to a dramatic reduction of support staff (MASTIC, 2016).

Innovation performance of business firms

The available patent statistics for Malaysia do not provide a breakdown with regard to public institutions and private companies. However, it is possible to draw some conclusions from the list of top applicants for PCT (Patent Cooperation Treaty) applications (Table 4.3) and European patent applications (Table 4.4):

- Public institutions are by far the main category of applicants, whether universities, such as Universiti Sains Malaysia, or research institutes/public agencies (Malaysian Palm Oil Board, National R&D Centre in ICT of Malaysia [MIMOS]).
- Some Malaysian firms do engage in patenting activities, but the number of patents remains low; examples are IQ Group (supplier of security and convenience products) and Widetech Manufacturing (manufacturer of correction fluid products), both are Malaysian technology-based firms created in the 1980s.
- Some Malaysian firms that were granted patents are GLCs (PETRONAS and its Institute of Technology, Universiti Teknologi PETRONAS).

Figure 4.4. **Business R&D personnel, total number and share of total by type of post, Malaysia**



Note: Breakdown by type of post not available for the period 1992-98.

Sources: MASTIC (2001, 2005, 2009, 2013, 2016), *National Surveys of Research and Development*.

Table 4.3. **Top ten Malaysian PCT applicants, publication year 2012**

Applicant	Type	PCT filings
MIMOS Berhad	Government-owned company/agency	146
Universiti Sains Malaysia (USM)	Public university	39
Universiti Putra Malaysia (UPM)	Public university	15
PETRONAS	Government-owned company	8
Malaysian Palm Oil Board (MPOB)	Government agency	7
IQ Group	Private company	4
Universiti Malaya (UM)	Public university	4
Widetech Manufacturing	Private company	4
Universiti Teknologi PETRONAS	Government-owned company	3
Malaysian Rubber Board (MRB)	Government agency	3

Source: OECD (2015a), *Boosting Malaysia's National Intellectual Property System for Innovation*, http://dx.doi.org/10.1787/9789264239227-6-en, based on WIPO (2015b), *WIPO IP Statistics Data Center* (database), http://ipstats.wipo.int/ipstatv2.

Table 4.4. **Top 30 Malaysian European Patent Office patent applicants, filing years 2000-11**

Rank	Applicant	Filings	Rank	Applicant	Filings
1	Malaysian Palm Oil Board (MPOB)	38	16	Simplex Major	4
2	Universiti Putra Malaysia (UPM)	37	17	Universiti Malaya (UM)	4
3	MIMOS Berhad	29	18	Universiti Teknologi Malaysia (UTM)	4
4	PETRONAS	18	19	WRP Asia Pacific	4
5	**Harn Marketing**	16	20	Borneo Tsang Furnishing	3
6	**Sime Darby**	15	21	Easycup International	3
7	**IQ Group**	14	22	**Inqpharm Group**	3
8	**Shimano Components**	13	23	Koosan	3
9	**Oyl R&D Centre**	11	24	**Pure Circle**	3
10	**Biolitec Pharma Marketing**	10	25	**Quantum Electro Opto Systems (Qeon)**	3
11	Universiti Sains Malaysia (USM)	8	26	Sirim Berhad	3
12	Government of Malaysia	6	27	**Texchem**	3
13	**Neuramatix**	6	28	**TMS Technologies**	3
14	**Easy Pack International**	6	29	**Widetech Manufacturing**	3
15	**Gha Brands Limited**	4	30	**Advanced Pyrotech**	2

Note: Purely private companies, excluding public research organisations, universities and companies that are government-owned or government-linked, are highlighted in bold.

Source: OECD (2015a), *Boosting Malaysia's National Intellectual Property System for Innovation*, http://dx.doi.org/10.1787/9789264239227-6-en, based on EPO (2015) *EPO Worldwide Patent Statistical Database* (database), www.epo.org/searching/subscription/raw/product-14-24.html.

Upgrading Malaysian manufacturing and service industries

Broad consensus has emerged that firms, including domestic firms and SMEs, need to shift towards the production of more elaborate, higher value-added products and services. There is some debate, however, to what extent Malaysia has already advanced towards this goal and what might be the main obstacles on this path. This section reviews the main arguments and evidence used in this debate, following a simple analytical framework (Figure 4.5). This framework builds on the idea that Malaysia should not only pursue a shift towards more knowledge-intensive manufacturing and service industries, but also expand the range of tasks performed within these industries and, more precisely, within each relevant global value chain. Finally, if the country is to reinforce and reap the full benefits of this challenging shift, it is critical that domestic firms become partners, if not leaders, in these activities. The increase of skills and capabilities of the public and private actors necessary at each stage of this upgrading process feeds back into the country's position in former stages.

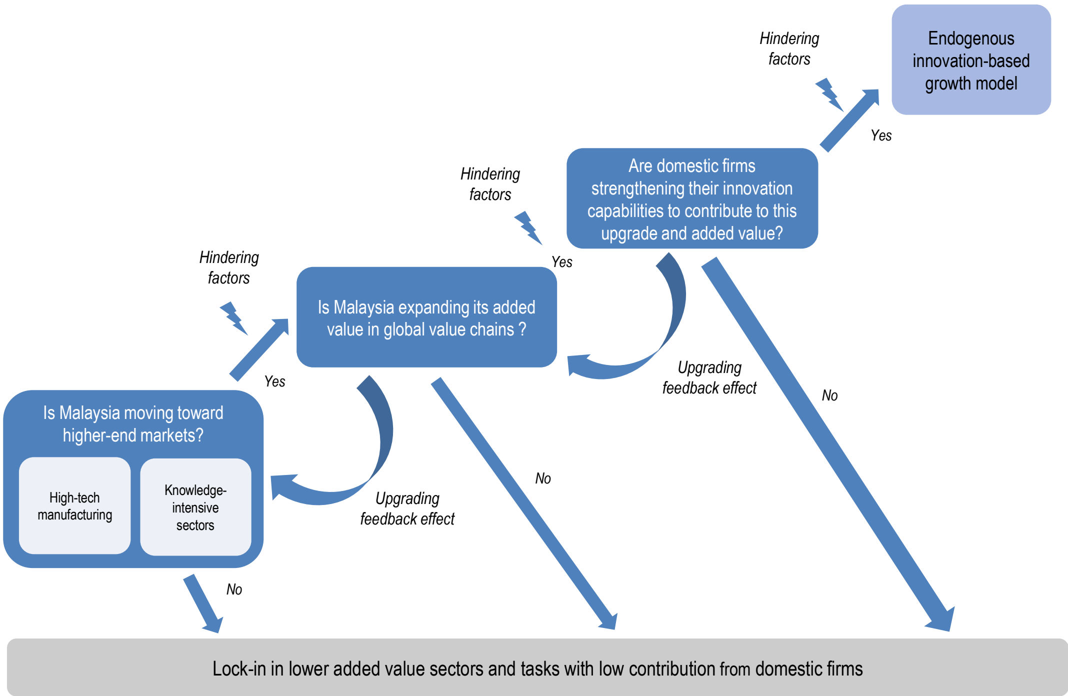
Is Malaysia moving towards higher technology manufacturing?

The success of Malaysian development during the period 1970-98 was largely based on a diversification of its production and exports, driven by manufacturing. The government has played an important role in facilitating and guiding this structural shift with varying success, from the import-substitution industrialisation strategy in the 1960s, which was replaced by Malaysia's defining export-oriented model, the intermittent orientation towards heavy industries and, since the 1980s, initiatives to attract high-technology multinationals.

Although the development of manufacturing was not linear – some MNEs even left Malaysia during times of economic slowdown or because of changes in the labour market or the financial incentives – the virtuous cycle of cluster agglomeration in areas such as

Penang is firmly established. The favourable financial conditions as well as the prospects of synergies and increasing returns of producer networks with the established firms led new companies to move to Malaysia. As a result, the share of manufacturing in total value added increased from less than 10%[17] at the time of independence when it was merely processing agricultural and mining output, to 31% in 2000.

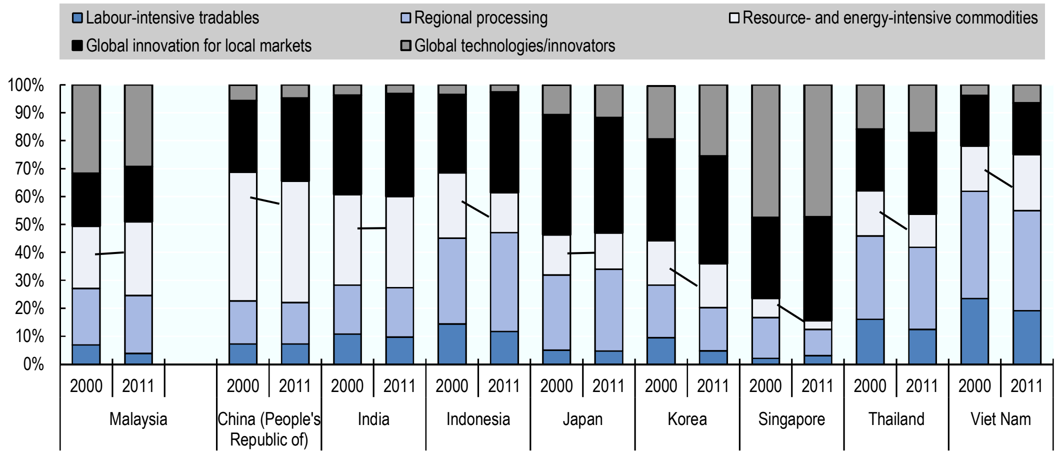
Figure 4.5. **Schematic question tree for analysing the upgrade of the manufacturing and service sectors in Malaysia**



During these years, Malaysia experienced rapid growth of its manufacturing sector, a progressive transformation of the sector toward higher value-added activities, and an increase in manufacturing capabilities (Yusuf and Nabeshima, 2009). The degree of sophistication of production, especially exports, increased continuously throughout the period 1980-2000. Aggregate "high-technology" manufacturing value added grew rapidly until 2000, when it reached MYR 34.1 billion (representing 31% of the total manufacturing output, or 9.5% of GDP). It has since decreased, to MYR 23.6 billion in 2010 (11% of total manufacturing output, 3.1% of GDP). What is more, the "high-technology" sub-sectors that experienced the most dramatic relative decline are those which were at the core of the high-growth regime.

The decomposition of the manufacturing sector into a suitable group of sub-sectors reflects the important upgrade achieved during the four decades that followed Malaysia's independence and the slowdown since around 2000. In 2000, about half of the manufacturing value added was produced by higher-end sub-sectors ("global innovation for local markets" and "global technologies/innovator"),[18] which require more skills and intangible assets than labour- or energy-intensive sub-sectors. However, this structural evolution seems to have stalled since then; the share of regional processing and resource-based sub-sectors even slightly increased between 2000 and 2011 (Figure 4.6).

Figure 4.6. **Sector share of total manufacturing value added in selected Asian countries, 2000 and 2011 (or closest year available)**



Sources: OECD (2013c), *Southeast Asian Economic Outlook 2013: With Perspectives on China and India*, http://dx.doi.org/10.1787/saeo-2013-en; ADB (2013), "Beyond factory Asia: Fuelling growth in a changing world", http://adb.org/sites/default/files/pub/2013/beyond-factory-asia.pdf.

The same trend can be observed for exports, which have been by far the main "destination" of manufacturing value added. The share of exports of goods classified as "high-technology" increased from 38% in 1990 to 58% in 2000. Subsequently, they fell sharply to 31% in 2013, whereas the share of resource-based, primary and medium-technology goods in total exports has increased significantly since 2000 (World Bank, 2014). The level of diversification of exports, which marked the development of the Malaysian economy during its high-growth years, stagnated at the 1990 level in 2000 and 2010 (EPU, 2015a). The composition of exports in 2012 was rather similar to the one prevailing in the 1990s (EPU, 2014). The stagnation and subsequent decline of high-technology manufacturing value added and exports since 2000, combined with sluggish productivity growth in manufacturing industries, is typical of a country undergoing de-industrialisation largely caused by slow upgrading (Rasiah, 2011).

Is Malaysia moving toward knowledge-intensive services?

One of the most important recent changes in the structure of the Malaysian and other Asian economies has been the rise of the services sector. Services have grown rapidly and are now the largest contributor to Malaysia's GDP. While manufacturing is widely held to remain a cornerstone of the Malaysian economy, the role of services in the economy is expected to expand further (ADB, 2013).

The service sector can further contribute – partly in conjunction with the evolution of manufacturing – to Malaysia's goal of becoming a high-income economy by upgrading through the development of knowledge-intensive services.[19] These services are distinguished by higher productivity and stronger synergies with other sectors, and they are more amenable to international trade (ADB, 2013). They can exert a positive impact on the productivity of a wide range of industries that are at the core of Malaysia's economic performance, from resource-based industries and manufacturing to other types of services, including tourism (Box 4.1).

Box 4.1. The interaction between knowledge-intensive services and high-tech manufacturing

Knowledge-intensive services can play a key role in the innovation of developing and emerging economies. By providing specialised knowledge and information to other business organisations, they act as initiators or facilitators of innovation activities, and foster knowledge transfers among or within organisations, industries or networks (OECD, 2006). Business services are of particular importance in supporting the manufacturing sector by providing essential inputs in the production process, such as R&D services, finance, legal services, human resource recruitment, marketing and information technology. The contribution of services is even stronger in advanced high-technology manufacturing, where production processes are more complex, hence requiring R&D, engineering and other business services (Nordås and Kim, 2013). By extension, services with higher productivity and higher technology content are critical in facilitating countries' participation and upgrading in value chains (OECD, 2013c).

The outsourcing of these activities to specialised service companies allows manufacturing firms to concentrate on improving and upgrading their production processes and products. It also enhances the competition between the specialised service providers, which are also under pressure to improve their offer and innovate, which will lead to further increases in productivity in manufacturing and the economy as a whole (OECD, 2006). Although difficult to measure precisely, the synergies between the service and manufacturing sectors are proven to have significant effects not only on these two sectors, but also on the economy as a whole, notably through an increase in productivity, employment and value added (Pilat and Wölfl, 2005).[1] An important result for policy making is that the contribution of better services to moving up the value chain is particularly strong in industries where a country already has technological capacity and comparative advantage (Nordås and Kim, 2013).

However, the effect of knowledge-intensive services on innovation and productivity in the manufacturing sector and elsewhere in the economy cannot be taken for granted. It depends on several conditions at micro- and macroeconomic levels. The client firms' strategy with regards to their service suppliers as well as their internal knowledge management practices and absorption capacity will determine the scale of the benefits they can draw from this relationship (OECD, 2006). On the sectoral level, the ability of the country to provide conducive framework conditions, in particular to eliminate the regulations that hinder investment, competition and innovation in services play an important role (Noland, Park and Estrada, 2012). Regulatory barriers,[2] which tend to be even more prominent in services than manufacturing, are especially detrimental in modern services such as finance, business services and ICT. Given the importance of multinational enterprises for expansion and upgrading, restrictions on foreign direct investment (FDI) are particularly critical.

1. Although not focused on knowledge-intensive services, a measure of linkages between services and other sectors in the Malaysian economy using input-output tables show the intensity of forward linkages of services with the food and beverage as well as with resource-based and E&E industries. The E&E industry is the first client manufacturing sector when it comes to professional, scientific and technical (PST) services (MPC, 2015).

2. For instance red tape, weak contract enforcement and FDI restrictions in services.

The heterogeneity of definitions and method of measurement makes it difficult to get a clear picture of the level of development of knowledge-intensive services. According to OECD calculations based on Asian Development Bank data (Table 4.5), Malaysia is one of the few Asian countries to have a share of "modern services"[20] that is comparable to that of advanced economies, which usually stand at about 30% (OECD, 2013c). Singapore, a leading offshore financial service centre records an even higher share (41%). While slightly decreasing between 1990 and 2010, Malaysia's share of "modern services" remained significantly above that of other Asian countries.

Table 4.5. **Share of sub-sectors in total services value added, 1990 and 2010**

In %

	Traditional services			Wholesale and retail trade			Modern services		
	1990	2010		1990	2010		1990	2010	
Malaysia	67.9	68.3	↗	29.2	30.9	↗	32.1	31.7	↘
China (People's Republic of)	70.2	78.3	↗	26.7	24.4	↘	29.8	21.7	↘
India	80.9	79.5	↘	27.8	30.2	↗	19.1	20.5	↗
Indonesia	84.7	79.3	↘	39.4	36.3	↘	15.3	20.7	↗
Japan	77.3	76.3	↘	21.4	16.9	↘	22.7	23.7	↗
Korea	78.3	72.5	↘	27.6	18.6	↘	21.7	27.5	↗
Philippines	77.4	74.8	↘	28.9	31.6	↗	22.6	25.2	↗
Thailand	77.8	82.1	↗	45.6	41.4	↘	22.2	17.9	↘
Singapore	60.8	58.7	↘	24.5	26.1	↗	39.2	41.3	↗

Source: OECD (2013c), *Southeast Asian Economic Outlook 2013: With Perspectives on China and India*, http://dx.doi.org/10.1787/saeo-2013-en.

ICT services can be used as one possible indicator of the shift towards higher value-added services. The contribution of ICT services to GDP increased from 5.2% in 2010 to 5.5% in 2015, while ICT manufacturing decreased, from 4.6% to 3.9% (EPU, 2015a).

Malaysia has already nurtured some segments in which it takes a leading position. The country is currently the world's largest Islamic banking and financial centre (Box 4.2). Another example is halal food.

A World Bank analysis of export data provides a more morose picture. Modern services, although growing, account for a lower share in total exports than in Singapore and Hong Kong (China) (two offshore services centres) as well as in the Philippines (World Bank, 2014). Some lower income Asian countries have rapidly developed activities based on these services. Indonesia, for instance, more than doubled its value added between 2003 and 2012 (National Science Board, 2014).

As in other countries, knowledge-intensive services still represent a relatively low share of Malaysian service value added. The services sector remains dominated by the lower value-added industries such as wholesale and retail trade, accommodation and restaurants (32% of services value added in 2015) (EPU, 2015a). Exports of services show the same focus on traditional, lower value-added segments. Transport and tourism represented the largest share of foreign exchange in 2013.

Is Malaysia increasing its value added in high-technology manufacturing and knowledge-intensive services?

While there is empirical evidence that there has been considerable expansion of the local supplier base, driven in particular by the outsourcing strategies of US-based MNEs in the late 1980s and early 1990s, and a rise of high-technology manufacturing up to around 2000, the shift towards higher value-added tasks and activities in these high-tech sectors is still very much on the agenda in Malaysia. MNEs often start their operations in a recipient country with assembly and testing lines. Therefore, the process of upgrading in value chains is usually understood as upstream or downstream expansion, starting from elementary (assembly) tasks. However, upgrading can also take other forms. Figure 4.7 shows the different options for firms to increase their value added within GVCs.

Box 4.2. The development of Islamic finance and insurance in Malaysia

Although Islamic financing first emerged in Egypt, Malaysia also benefited from an early start and is now the world's leading location for Islamic finance and insurance. The first Islamic finance institution was founded in 1963 for Muslims to save for their future expenses during their pilgrimage to Mecca (Hajj). From a very rudimentary form of co-operative banking at the start, it has since specialised and been professionalised. It accounted for 25.6% of the total banking system's assets in 2014 (22.4% in 2011). The Islamic capital market also grew significantly, rising at a rate of 11.2% per year during the period of the Tenth Malaysia Plan (2011-15).

Malaysia holds a leading position with 10% of Islamic banking assets in 2012 (43% for Iran, 12% for Saudi Arabia) and 16 fully-fledged Islamic banks including 5 foreign ones. More comprehensive indicators, which include qualitative dimensions, such as the Global Islamic Economy Indicator (GIEI), place Malaysia in an even better position. Malaysia is leading on this index that evaluates the quality of the national overall Islamic economy ecosystem, including social considerations relative to their size. In 2014/15, it was leading the 70 other countries on 4 of the 6 sub-sector indicators (halal food, Islamic finance, travel, fashion, media and recreation, and pharmaceuticals and cosmetics).

In the aftermath of the 2008 financial crisis, to which Islamic finance products are said to have been more resilient than conventional products, and the decrease of manufacturing employment, the government has made Islamic finance and insurance a national priority. There are also synergies with halal food, another policy priority and leading sector, since halal food is required to be financed by Islamic banking.

An important advantage for Malaysia was its mature governance, with a strong regulatory framework. The country passed an authoritative Islamic Financial Services Act in 2013 to oversee Islamic banking operations, whereas competing countries such as the United Arab Emirates and the United Kingdom still rely on their common banking law, completed by some Islamic finance add-ons. Both as an acknowledgment of its leading position and a further advantage, Malaysia hosts international organisations such as the Islamic Financial Services Board (IFSB) and the International Islamic Liquidity Management Centre (IILMC).

In terms of educational infrastructure, Malaysia is also well-placed, although it lags slightly behind the United Kingdom. Malaysia has 50 course providers and 18 universities offering degree programmes in Islamic finance, compared to 60 course providers and 22 universities in the United Kingdom. The International Islamic Financial Centre (INCEIF) established in 2005 was the world's first international university specialising in Islamic finance.

Malaysian universities, however, are ahead of UK ones when it comes to research in Islamic banking and insurance: Malaysia leads internationally in terms of the number of outputs, with more than 100 peer-reviewed research papers released during 2012-14, against 56 in the United Kingdom. However, innovation in this sector tends to remain marginal and imitative. Most new products in fact originate from commercial banks and are subsequently made compatible with the Islamic rules (*Shari'ah*). There are therefore important opportunities for innovation and product differentiation in this sector. In the "Financial sector blueprint" launched by the Malaysian central bank in 2011, product innovation is considered a key condition to achieving the target of Islamic financing, accounting for 40% of total financing by 2020. It was 29% in 2010. Innovation can be determinant in this sector where competition is rapidly growing, as shown by the example of *Shari'ah*-compliant bonds (*sukuk*). Malaysia pioneered the market of *sukuk* in 1990 and is now the world leader, accounting for more than two-thirds of total gross value of this growing market in 2014. In addition to new financial products to attract clients well beyond the Muslim population, many other areas for innovations are currently being explored, such as mobile Islamic banking, micro-financing, digital currencies, *Shari'ah*-compliant crowdfunding platforms, SME financing initiatives, etc.

Sources: Hussain, Shahmoradi and Turk (2015), "An overview of Islamic finance", www.imf.org/external/pubs/ft/wp/2015/wp15120.pdf; EPU (2015a), *Eleventh Malaysia Plan*, http://rmk11.epu.gov.my/index.php/en; Thomson Reuters (2015), "State of the global Islamic economy: 2014-2015 report", www.iedcdubai.ae/assets/uploads/files/ar_20142015_1448266389.pdf; Bank Negara Malaysia (2011), "Financial sector blueprint 2011-2020: Strengthening our future", www.bnm.gov.my/files/publication/fsbp/en/BNM_FSBP_FULL_en.pdf.

Box 4.3. **A typology of global value chain upgrading**

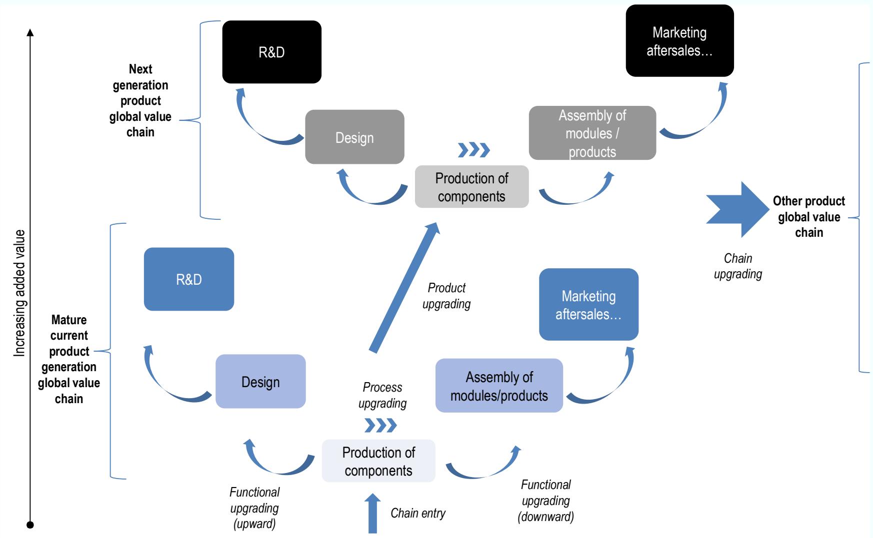
In general terms, upgrading refers to the process of increasing value added in production or shifting to higher value activities in global production operations. Six different types of upgrading can be distinguished (Figure 4.7):

- Entry into the value chain, when a new actor begins to participate in the value chain.
- Product upgrading, which describes the shift to the production of a higher value added, i.e. more sophisticated product in the same activity. A manufacturer in the E&E industry would skip to a new generation of integrated circuit.
- Process upgrading describes improvements in efficiency in the production systems, such as the incorporation of more sophisticated technology via the purchase of new equipment, or a better organisation of production.
- Functional upgrading describes the movement of taking up higher value, i.e. more sophisticated, stages in the chain. The highest value added being generally in intangible activities, functional upgrading involves a shift from assembly upward to design and R&D, or downward to marketing and services, such as advertising and aftersales. This shift calls for the development of knowledge-intensive services.
- Chain upgrading and end-market upgrading, which describes the entry into a new value chain by leveraging the knowledge and skills acquired in the current chain, or the entry in new higher value end-market segments.

Countries often pursue functional upgrading as the most direct way of increasing the value of their participation in these chains. An example is the palm oil industry in Malaysia, which started with cultivation, simple oil refining, and now comprises stages of the entire value chain.

However, especially in emerging economies, product and process upgrading tend to be more easily attainable, since they may require relatively minor adjustments in production and skills development with lower overall investment. Chain upgrading is also very difficult to achieve since it requires significant investment.

Figure 4.7. **Different types of upgrading in global value chains**



Sources: OECD (2013b), *Interconnected Economies: Benefiting from Global Value Chains*, http://dx.doi.org/10.1787/9789264189560-en; Fernandez-Stark, Bamber and Gereffi (2012), "Upgrading in global value chains: Addressing the skills challenge in developing countries", www.cggc.duke.edu/pdfs/2012-09-26_Duke_CGGC_OECD_background_paper_Skills_Upgrading_inGVCs.pdf.

MNE activities with the highest value added, including major R&D centres, mainly remain in "headquarter" countries (and, with increasing globalisation of R&D, in a restricted set of other international hubs of R&D and innovation). Currently available corporate information does not permit an accurate assessment of the level of R&D performed by MNEs on their Malaysian sites, even if the FDI project is publicised as including an R&D or design centre.

An analysis of the domestic value added shows that since 2000, as in most other Southeast Asian countries, although the integration of the Malaysian manufacturing sector in GVCs has continued to increase, it has moved upstream in these chains, i.e. further away from final demand. Malaysia has, in fact, one of the most upstream manufacturing sectors of all emerging economies.[21] While the position of imports is stable, the length of the stages of the value chain operated in Malaysia has shortened, which means that the country seems confined to very specific segments, namely those with the lowest value added. This is particularly the case in the E&E sector where domestic value added of exports is smaller than in many developing and emerging economies, including Thailand, the Philippines and, of course, China (World Bank, 2014).

Malaysia was very successful in attracting leading export-oriented MNEs in high growth sectors from 1970 to 2000. Even in recent years, MNEs still represent the bulk of investment (flows) in the E&E industry, for instance through greenfield or expansion/diversification projects.[22] Starting with mere components assembly and packaging tasks, some slightly more elaborate types of tasks have been progressively performed in these factories or in the surrounding clusters. Also, production has taken up new generations of technologies, with several semiconductor companies manufacturing their high-end components in Malaysia. However, low value-added, less sophisticated activities in these "high-technology" industries have remained dominant. Very few MNEs or domestic firms have decided to perform significant R&D in Malaysia. If at all, the R&D departments of these firms have remained mainly confined to process improvement and adaptation or testing in most cases.[23] A review of the most significant recent investment projects in the E&E industry approved by the Malaysian Investment Development Authority indicates that the majority of projects still relate to the assembly and testing of components.[24] In the meantime, previous sources of Malaysian competitiveness of the E&E industry have eroded, while the position of competing countries with lower labour cost (i.e. Viet Nam) in E&E GVCs has strengthened (World Bank, 2014).

In clear contrast with the situation prevailing in the E&E industry, Malaysia's global leadership in palm oil rests on its position at the technological frontier in this area and its control over the entire value chain, from raw materials to final products. Starting from cultivation and oil processing, the main players in the sector have succeeded in developing new products as well as expanding and upgrading their role in the various segments of the value chain (Rasiah, 2006b). R&D started to become significant as early as the 1960s but remained concentrated on palm oil at the start. Nowadays, innovation projects in this area, some of which are supported by the Economic Transformation Programme as part of the Palm Oil and Rubber NKEA (national key economic area), span the whole value chain, from improving the fruit yield and smallholders' productivity to increasing the efficiency of oil processing, valorising the resource (biogas, second-generation biofuels) and expanding the range of applications (palm-based derivatives in food and health-based products) (PEMANDU, 2014).

Further initiatives to attract MNEs with higher value-added activities and to support the development of the innovation capabilities of domestic firms were implemented in the 1990s and 2000s. Tax allowances have been granted to firms located in high-technology parks, while training programmes and incentives and new R&D grant schemes have been put in place by the government.

Another interesting avenue pursued by the government to support the upgrading of the E&E industry is to support the establishment of the physical and knowledge infrastructure for test measurement as shown by the content of the E&E projects in the Economic Transformation Programme. The rationale put forward is to make Malaysia a test and measurement hub in order to lower barriers to entry and support new investment (PEMANDU, 2014).

As a result of government efforts and industry cluster dynamics, new industry segments are emerging, most often building upon the resources of the E&E industry, such as the solar (Box 4.4) and LED sectors. These two industries remain, to a great extent, focused on low value-added segments such as the production of solar panels, while R&D is retained in the headquarter countries (MPC, 2015). Other new areas derive from Malaysia's resource-based industries. This is the case for the biomass industry that partly draws upon Malaysia's leading position in palm oil. Although significant progress has been made in some of these emerging areas, these have yet to be considered as new sources of growth. A detailed analysis using the framework of economic complexity shows that Malaysia has succeeded in moving to new "product spaces", in general towards more sophisticated products (e.g. precision instruments based on E&E capabilities, certain chemicals, certain metal products), which means it has achieved product upgrading. On the other hand, the production of some low value-added products (garments, simple ceramic and wood products) was progressively abandoned. The progress made since around 2000 has been mostly incremental and falls short of the process of upgrading and diversification that underpinned growth during the previous decades (EPU, 2014).

Are Malaysian domestic firms improving their innovation capability?

The importance of FDI to stimulate and enable innovation through market opportunities and various types of spillovers in domestic firms has been widely documented in the economic development and innovation literature through detailed case studies of various economies and sectors. With the gradual outsourcing of increasingly complex components and services, the multiplication of forward and, especially, backward linkages of MNEs generates demand that induces domestic firms located upstream and downstream to enhance their capabilities and engage in innovation.[25] Given the degree of internationalisation of these large firms, their presence in the country can also offer domestic firms a shortcut for a more rapid integration into global value chains, starting with low value-added activities before entering their upgrading process.

The spillovers from MNEs are all the more important as they are often among the leading firms in their sector. They therefore master cutting-edge skills and operate at the highest technological level. Their presence can therefore, in principle, facilitate the transfer of various types of technological knowledge as well as managerial and business skills and competences. Such effects can be expected to be potentially strong in Southeast Asian countries, such as Malaysia, Singapore and Thailand, where MNEs account for the bulk of manufacturing production and exports. However, this process is by no means automatic.

Box 4.4. **An emergent new source of growth: The Malaysian solar industry**

The Third Industrial Master Plan (IMP3) identified solar energy as a new industrial opportunity in 2006. While there was not any production of solar panels at that time, Malaysia is now one of the world's largest producers of solar equipment (wafers, cells and modules), behind China and the European Union. The Malaysian solar module production increased by 41% in 2013, reaching 3.3 GW in 2014. This production capacity is derived from foreign manufacturers – mostly American, European, Korean and Japanese companies – that installed their facilities in Malaysia.[1] In 2013 and 2014, the Malaysian Investment Development Authority granted permission to five new foreign companies to set up their production factories in Malaysia. Meeting the target of 12.9 GW by 2020 will therefore require significant investments, both from new gigawatt scale manufacturing plants and expansion of existing ones.

According to the solar panel manufacturers, Malaysia's two main comparative advantages are the generous tax incentives (for instance, the leading global firm FirstSolar received a 15-year income tax holiday) and the existence of a cost competitive, skilled labour force, partly developed in relation with the semiconductor industry which builds upon similar production processes. However, despite these strengths, which allow Malaysia to compete with other Asian countries such as China, India and Chinese Taipei, the nascent Malaysian solar industry is still fragile as competitive positions are rapidly shifting. The market growth has been supported significantly by the restrictions to Chinese exports of solar panels to the United States and the European Union, which led companies not to locate their factories in China. In addition, domestic demand for solar panels, and more generally a climate favourable to renewable energy, contributes to Malaysia being considered an attractive manufacturing base.

Apart from production capacity, it remains to be seen, as for semiconductors, whether Malaysian activities in solar panels will extend beyond component manufacturing towards vertically integrating a greater proportion of the value chain in the country. Another uncertainty concerns the location chosen by the manufacturers to produce the latest and future generations of solar technologies. So far, in most cases, foreign manufacturers have kept not only R&D, but also their pre-production and downstream operations at their headquarters, where a significant proportion of value added accrues. Some research activities are carried out by laboratories, such as at the Solar Energy Research Institute, the National University of Malaysia and the Standards and Industrial Research Institute of Malaysia. Since its creation in 2005, the Solar Energy Research Institute has performed numerous, mostly small-scale, research projects financed through the competitive grant schemes of the Ministry of Science, Technology and Innovation (MOSTI) and the Ministry of Research, as well as some funding under the Economic Transformation Programme. Only limited research is carried out with private companies, mostly for application and demonstration of technologies. The Standards and Industrial Research Institute of Malaysia is also involved mainly in downstream development and testing.

Government-led initiatives will be essential to support the growth of the Malaysian industry, both on the supply and demand side: support to staff training, the establishment of a domestic accreditation and certification body, incentives for solar panel installation, and connection to the grid.

1. Among those manufacturers are FirstSolar, Flextronics, MSR, SolarTif, PV HiTech, Panasonic Energy, EXT, Hanwa Q Cells.

Sources: Bradsher (2014), "Solar rises in Malaysia during Ttrade wars over panels", www.nytimes.com/2014/12/12/business/energy-environment/solar-rises-in-malaysia-during-trade-wars-over-panels.html?_r=1; News 24 (2015), "Malaysia feels heat as its solar industry soars", www.news24.com/Green/News/Malaysia-feels-heat-as-its-solar-industry-soars-20150818; EPU (2011), "Moving up the value chain: A study of Malaysia's solar and medical device industries, final report", www.epu.gov.my/c/document_library/get_file?uuid=e205228c-67e9-4477-b06f-bbc3e8abc2d8&groupId=283545; PEMANDU (2014), *Economic Transformation Programme 2014 Annual Report*, http://etp.pemandu.gov.my/annualreport2014; Chua and Oh (2012), "Solar energy outlook in Malaysia", http://dx.doi.org/10.1016/j.rser.2011.08.022.

Three main conditions come into play at the level of MNEs and that of the recipient country, respectively:

- MNEs must enter a process of upgrading and externalisation of their activities in the recipient country. As discussed previously, this process has slowed down in the last 15 years in Malaysia.
- The possibilities of upgrading the domestic industry are largely determined by the strategies of the lead MNEs in the value chain. Case studies show that some firms tap into the resources of host countries without transferring any knowledge, whereas others offer genuine upgrading prospects (OECD, 2013b).
- Domestic companies need to have the required absorption capacity to enter a partnership with MNEs and valorise the resources being transferred in the course of the relationship. As shown by many surveys of business firms in Malaysia, both foreign and domestic, a lack of skills is one of the main barriers to innovation (MASTIC, 2014b). MNEs in many instances request a certain level of certification of their supplier base to ensure quality throughout the value chain. The level of capability enhancement needed to achieve upgrading depends on the type of shift across and within value chains (Box 4.3). Process and product upgrading typically leverage the existing labour force through incremental capability enhancements (on-the-job training, short-term courses and specific certifications, etc.). Functional upgrading, on the other hand, generally requires a substantially different set of capabilities, including a high proportion of the workforce with a tertiary education, and is therefore more challenging.

It has been argued by various experts that these conditions have not been fully realised in Malaysia, resulting in an industry structure that bears features of "duality" with insufficient interlinkages between the export-oriented MNEs and the domestic SMEs in import competing sectors (Bhattacharya, 2002). More recent and detailed data analyses focused on the E&E industry provide more nuanced results: Malaysian firms themselves have a high propensity to export, but their share of value added in total exports is comparatively small due to the fact that MNEs have less linkages with domestic suppliers than those located in many other countries (World Bank, 2014).

Case studies suggest that the transfer of technological capabilities through FDI has been limited in Malaysia. The tasks externalised to domestic firms have been mainly in the area of logistics, aiming at cost reduction and delivery timeliness rather than improvement of the product quality (OECD, 2013a). Only a relatively small number of domestic firms, such as Dell and Intel, have succeeded in using linkages with MNEs as a stepping-stone to upgrade their own innovation capabilities (Yusuf and Nabeshima, 2009). In addition, few local firms have succeeded in establishing their own OEM/local brands. In most other cases, the clusters of domestic firms that benefit from forward and, to a lesser extent backward, linkages have remained confined to logistical tasks aiming at cost reduction via proximity relationships within the value chain (World Bank, 2010). However, although knowledge clusters are far less common, some upgrading of domestic capabilities has occurred indirectly, i.e. not in the framework of an institutionalised transaction but through economies of agglomeration and cluster synergies. In the Penang E&E industry notably, local firms have been able to improve their production process by hiring former employees of MNEs that are well trained and experienced (Rasiah, 2006a). Cluster synergies, albeit not founded on knowledge spillovers, were also critical in the success of the palm oil industry (Rasiah, 2006b) and the furniture industry (Ng, Chandran and Thiruchelvam, 2015).

Although imperfect and incomplete, information on R&D inputs and outputs offer some proxy of the extent of technological improvement of the domestic industry. Unfortunately, MASTIC, the Malaysian STI statistics agency, has not published data on R&D expenditures by type of ownership/control of firms for many years. In 2006, the share of foreign-owned and foreign-controlled companies were 65% and 4%, respectively, i.e. close to 70% in total (MASTIC, 2008). Based on raw data from the Malaysian Annual Manufacturing Survey 2008, Chandran, Veera and Santhidran (2014) also show that despite strong variation across industries, local firms invest on average only a small portion of the foreign-owned companies' expenditures on R&D. For instance, in the manufacture of radio, television and communication equipment and apparatus, local firms invest 5 times less than the foreign companies located in Malaysia, while the gap is about 88 times in the manufacture of office, accounting and computing machinery. The gap is much lower in some sectors such as the manufacture of other transport equipment and the manufacture of electrical machinery and apparatus (not elsewhere classified).

Data on the United States Patent and Trademark Office's (USPTO) patents granted to business firms with Malaysian inventors (Table 4.6), which provide an indication of international-level R&D performed in Malaysia, show that in the great majority of cases, the research has been performed within MNEs rather than in domestic firms. Although, as discussed earlier, MNEs are still reluctant to relocate their R&D next to their manufacturing facilities, companies such as Intel and Motorola, which invested very early in applied research in Malaysia, seem to be notable exceptions: both of these two companies applied for about 60 utility patents between 1990 and 2007 (Chandran and Wong, 2011). Only two of the top ten applicants are Malaysian entities, including the Malaysian Palm Oil Board which defines itself as a government agency under the Ministry of Plantation Industries and Commodities.

Only 14% of patents of the Malaysian Intellectual Property Office were granted to Malaysian organisations (including Malaysian universities and research institutes) in 2015.[26] This share is likely to be even smaller when only business applicants are considered since they represent only about 40% of local patent applications (MASTIC, 2014a).[27] Likewise, there was no Malaysian company among the top 100 PCT patent applicants in 2014 (WIPO, 2015b)[28] and only 2 private companies, IQ Group (lighting products) and Widetech Manufacturing (correction fluid), and 2 public companies[29] were among the top ten Malaysian PCT applicants in 2012 (MASTIC, 2014a). There is no automotive company among the top applicants. The government-owned carmaker Proton as well as Perodua Sdn Bhd rely substantially on intellectual property owned by Japanese companies, in particular Mitsubishi Motors (WIPO, 2008). These results are consistent with the analysis of patenting activities in Malaysia by Chandran and Wong (2011). They show that local firms are struggling to improve their technological sophistication and mainly perform incremental process innovation, if any. The authors conclude that the low level of innovation, in particular of domestic firms, is a major barrier to economic upgrading.

Factors hindering the upgrading of the Malaysian industry

According to the perceptions of business firms, as reported in the Sixth Innovation Survey, the main factors limiting innovation, both in services and manufacturing, are cost factors (Table 4.7), closely followed by market and knowledge factors. Across all categories, the factors are considered more constraining by manufacturing firms than by firms operating in services. These results, at least in terms of ranking of the different types of factors, are generally consistent with those obtained in previous surveys (see for instance the Fifth Innovation Survey in MASTIC [2011]).

Table 4.6. **Top 15 business USPTO patent applicants, Malaysian inventors, 2010-14**

First-named assignee	Country of origin	Main sector	Activities in relation with patents	Number of patents granted	
				2014	2010-14
Avago technologies ECBU IP PTE. Ltd. and Avago Technologies General IP PTE. Ltd.	Singapore (Penang)	Electronics	R&D, manufacture and marketing of various electronic products	0	165
Altera Corporation	United States (Penang)	Electronics	R&D, research and development of VLSI design, layout, test and software development	35	98
Intel Corporation	United States (Penang)	Electronics	Assembly and testing of processors	19	91
Freescale Semiconductor, Inc.	United States (Dutch since 2015) (Petaling Jaya)	Electronics	Design, manufacturing, assembly and testing of semiconductors	18	48
Infineon Technologies AG	Germany (Malacca)	Electronics	Assembly and testing	9	45
Western Digital Technologies, Inc.	United States (Petaling Jaya)	Electronics	Manufacturing of computer storage devices	18	40
Malaysian Palm Oil Board	Malaysia (Kuala Lumpur)	Palm oil	Conduct and promote R&D activities relating to the palm oil industry	12	36
Purecircle Sdn Bhd	Malaysia (Negeri Sembilan)	Biotechnology	R&D and refinery of sweetener for food and beverage	1	34
Spansion LLC	United States (Penang)	Electronics	Design centre (design, layout, computer-aided design and verification services)	4	20
Motorola Solutions, Inc.	United States (Penang)	Electronics	Manufacturing, design, development and distribution	5	18

Note: Patent origin is determined by the residence of the first-named inventor listed on the patent grant.

Sources: USPTO (2015), "Patenting by geographic region (state and country): Breakout by organization: Malaysia", *General Patent Statistics Reports* (database), www.uspto.gov/web/offices/ac/ido/oeip/taf/stcasg/myx_stcorg.htm.

Table 4.7. **Factors hampering innovation activities, average results by factor type**

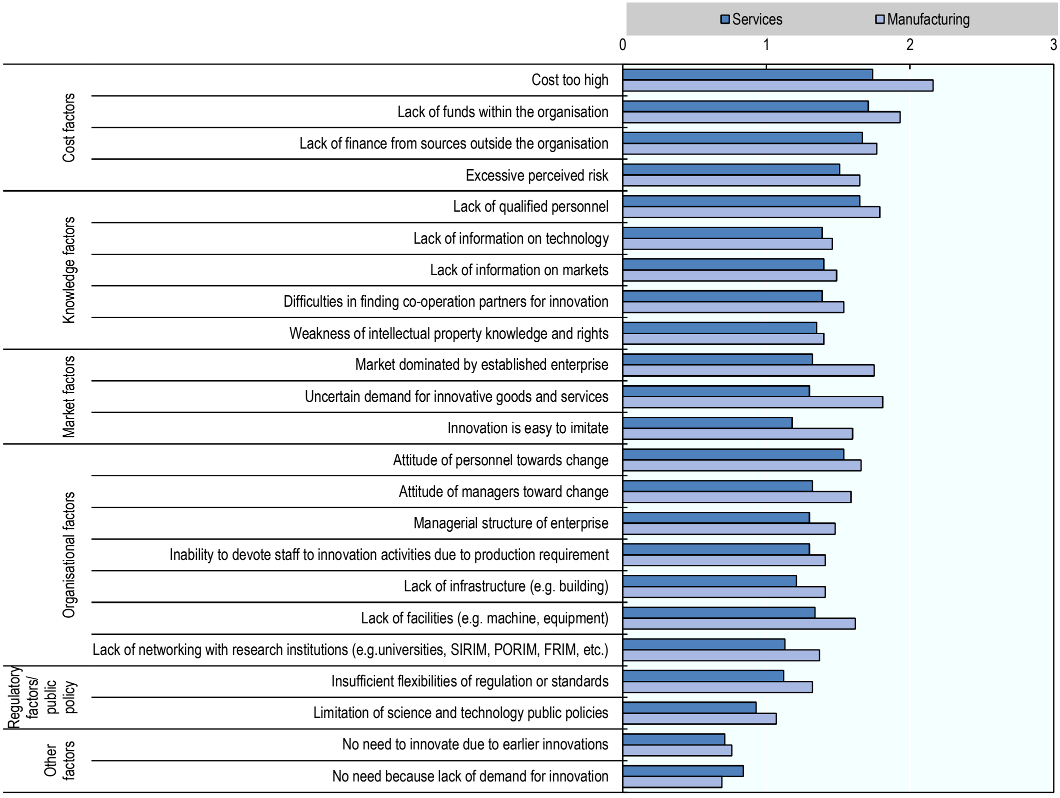
	Services	Manufacturing
Cost factors	1.66	1.88
Knowledge factors	1.44	1.54
Market factors	1.27	1.72
Organisational factors	1.31	1.51
Regulatory factors/public policy	1.03	1.2
Other factors	0.78	0.73

Note: Mean indicator: 0 = not relevant; 3 = highly important.

Source: MASTIC (2014b), *National Survey of Innovation 2012*.

A look at the detailed results reveals that the lack of qualified personnel follows closely after the high cost and lack of funds associated with innovation activities, in particular for manufacturing firms (Figure 4.8). Furthermore, judging by former surveys when distributions of responses were provided over the whole rating scale (as opposed to mean results), a higher proportion of respondents considered the lack of qualified personnel as the highest barrier to innovation.

Figure 4.8. **Factors hampering innovation activities, all factors**



Note: Mean indicator: 0 = not relevant; 3 = highly important.

Source: MASTIC (2014b), *National Survey of Innovation 2012*.

Skills shortage and mismatch has received much attention due to its negative impact on the industry's ability to upgrade its innovation capability. As mentioned previously, this is the root of the problem of attracting FDI in higher end activities and improving the absorption capacity of domestic firms.

Two surveys conducted in 2002 and 2007 (respectively, MyKe 1 and MyKe II, commissioned by the EPU) attempted to assess the knowledge content of business firms in 21 sectors. One of the main results of these surveys is that, overall, although the knowledge content of Malaysian business firms has increased, it is modest.

Another important finding with regard to the upgrading of the domestic industry is that the gap between the MNEs and local firms, although confirmed, is narrowing. The same results emerge for the gap between large and small firms. In the manufacturing sector, except for the E&E, machinery, chemical, rubber and automotive industries, knowledge generation was found to be typically low. This can be explained by the fact that most firms in this sector acquire knowledge solely by adapting and adopting foreign technology (Shapira et al., 2008). The surveys also identified the most important factors constraining knowledge development in three so-called "knowledge contexts" (knowledge acquisition, generation, utilisation and management), technology and human capabilities. The most important factor constraining knowledge acquisition is the lack of funds to finance the plans to improve knowledge capabilities. With regard to workers' skills and knowledge specifically, the lack of English proficiency appears to be the most cited main hindrance to knowledge acquisition, followed by the cost of training and the higher turnover after training (Shapira et al., 2008).[30]

Higher education institutions

The higher education sector of Malaysia has evolved dynamically since its independence. The number of higher education institutions (HEIs) has multiplied and important reforms in terms of funding (e.g. moving to performance-based funding mechanisms) and governance have been or are currently being implemented with the goal of strengthening quality and delivery and fostering excellence in higher education. These reforms are already showing signs of change and important results have been achieved, notably in terms of higher education enrolment rates (at all levels) as well as in terms of enhanced R&D personnel and the research performance of public universities, among other major achievements. Challenges remain in terms of governance (e.g. autonomy) and relevance to industry (connecting with demand), as well as growing funding constraints. The latter relates to the new obligations for HEIs to diversify their sources of funding and find ways to enhance their impact on the economy and society.

Historical evolution

The history of higher education in Malaysia can be broadly divided into four main phases (Lee, 2005; Grapragasem, Krishnan and Norhaini Mansor, 2014):

- Until the 1970s, higher education was restricted to a single university, with access limited to a selected proportion of (usually well-off) elite students.
- The second phase, between 1970 and 1990, saw the start of the democratisation of higher education driven by the state, with the creation of the general higher education structure which is still largely valid to date: several new public universities were created, together with polytechnics institutions (offering certificate and diploma level programmes) and a number of community colleges (providing a wide range of technical and vocational education training courses). Private institutions were also created during this period, offering a wide range of courses at the certificate and diploma levels. These new institutions dramatically increased student access to higher education, in response to the rapid population and economic growth of the country.
- The third phase, from 1990 to mid-2000, was marked by the consolidation of the structure set up during the second phase, with new legislations providing a better defined framework for the whole system.[31] More public institutions were set up (the number of public universities reached 20) and several private colleges were awarded university status. The main objective during this period was to foster the rapid transition of the country towards an upper middle-income economy.
- The last phase, since mid-2000, has been characterised by a number of dramatic changes in the character and functions of higher education in Malaysia. These changes are largely linked to the evolution of the economic nature of the Malaysian economy, to globalisation and to increased competition worldwide. First, the Private Higher Educational Act 1996 was amended in 2003 which subsequently lead to the restructuring of private higher learning institutions in order to make them more competitive globally. The Ministry of Higher Education was created shortly thereafter (in 2004) and in 2007 two plans were launched: the

National Higher Education Strategic Plan (NHESP) Beyond 2020 and the National Higher Education Action Plan (NHEAP), whose objectives were to facilitate the transition of Malaysia to a knowledge economy. These plans were followed by a series of updates and national strategic reforms.

Structure

Malaysia possesses over 20 public HEIs, as well as private universities, foreign university branch campuses and colleges that have substantially expanded in the recent past (OECD, 2013a). The number of public universities rose from 11 in 2002 to 20 in 2008, and private universities expanded from a handful in the 1980s to 51 in 2010. Today there are 24 national private universities, 23 university-colleges and 4 branch campuses of foreign universities. Table 4.8 displays the current composition of the sector.

Table 4.8. **Higher education landscape of Malaysia**

	Number of HEIs	Enrolment	Graduates
Public institutions			
Universities	20	508 526	104 291
Polytechnics	30	89 292	33 310
Community colleges	70	6 319	6 624
Private institutions			
Universities	24	202 714	29 139
University-colleges	23	40 651	1 269
Branch campuses of foreign universities	4	8 107	1 353
Colleges	500	177 501	22 456

Source: Ministry of Higher Education (2011), *Statistics of Higher Education 2011*.

The expansion of private HEIs was spurred by the adoption of the Private Higher Educational Institutions Act and the National Accreditation Board Act in 1996, which allowed private operators to provide higher education programmes under discretionary tuition fees and management. Specifically, the amended act provided the provision for the establishment and upgrading of private universities, university colleges and branch campuses of foreign universities in Malaysia. In this configuration, public universities registered the largest student enrolment with about half a million students and 104 291 graduates in 2010. Public universities reported 54% of enrolment compared to 46.4% in private universities in 2013. In the first three years of the NHESP, enrolment in public universities increased by 21%, making these the main providers of higher education in Malaysia.

The Higher Education Department within the Ministry of Education co-ordinates and monitors the activities of public and private universities and colleges. Public universities are categorised by the Ministry of Education in three groups: 5 research universities (with a focus on research, competitive entry, quality lecturers and a ratio of undergraduates to postgraduates of 50:50), 11 technical/specialised universities (with a focus on technical, education, management and defence research issues, competitive entry, quality lecturers and a ratio of undergraduates to postgraduates of 50:50) and 4 comprehensive/teaching universities (with a focus on teaching, competitive entry, quality lecturers and a ratio of undergraduates to postgraduates of 70:30) (OECD, 2015a). Table 4.9 provides an overview of public universities in Malaysia. The largest public university of the country is the University Teknologi Mara, with 34% of all tertiary students in 2013. Ten public universities were either newly created or granted university status in the 1990s.

Table 4.9. **Size and type of public universities in Malaysia**

Type of university	Acronym	Year of creation	Name	Student enrolment	% of total enrolment	Top 10 PCT Malaysian applicant 2012
Research	UM	1949	Universiti Malaya	27 091	5	Yes
Research	USM	1969	Universiti Sains Malaysia	29 065	5	Yes
Research	UKM	1970	Universiti Kebangsaan Malaysia	30 041	5	No
Research	UPM	1931	Universiti Putra Malaysia	32 092	6	Yes
Research	UTM	1904	Universiti Teknologi Malaysia	33 361	6	Yes
Focused	UUM	1984	Universiti Utara Malaysia	30 837	6	No
Comprehensive	UIAM	1983	Universiti Islam Antarabangsa Malaysia[1]	32 086	6	No
Comprehensive	UNIMAS	1992	Universiti Malaysia Sarawak	17 198	3	No
Comprehensive	UMS	1994	Universiti Malaysia Sabah	25 207	4	No
Focused	UPSI	1922	Universiti Pendidikan Sultan Idris	27 659	5	No
Comprehensive	UiTM	1956	Universiti Teknologi MARA	189 551	34	No
Focused	UniSZA	2005	Universiti Sultan Zainal Abidin	7 977	1	No
Focused	UMT	1979	Universiti Malaysia Terengganu	8 715	2	No
Focused	USIM	1998	Universiti Sains Islam Malaysia	13 022	2	No
Focused	UTHM	1993	Universiti Tun Hussein Onn Malaysia	15 319	3	No
Focused	UTeM	2000	Universiti Teknikal Malaysia Melaka	12 593	2	No
Focused	UMP	2002	Universiti Malaysia Pahang	8 904	2	No
Focused	UniMAP	2001	Universiti Malaysia Perlis	10 415	2	No
Focused	UMK	2007	Universiti Malaysia Kelantan	6 443	1	No
Focused	UPNM	2006	Universiti Pertahanan Nasional Malaysia	2 783	0	No
			Total enrolment	**560 359**	**100**	

1. Also known as the International Islamic University Malaysia.

Sources: MOE (2015a), "Public institutions of higher education (PIHE)", www.moe.gov.my/en/ipta for the list of public universities and their type, as well as the enrolment data; WIPO (2014), *Patent Cooperation Treaty Yearly Review*, www.wipo.int/pct/en/activity for top ten PCT applicants and Internet search for the year of creation of each university.

General trends

Overall, Malaysia invests much more in tertiary education than its peers in the region. Malaysia's government expenditure for tertiary education relative to GDP stood at 2% in 2009 and 1.5% in 2013, whereas Korea invests around 0.6% and Singapore 1%. Enrolment rates in both public and private universities have increased substantially. For undergraduate programmes, enrolment has surpassed the half million mark, which represents an increase of 7% (EPU, 2015a). The enrolment for PhD degrees increased by 56.3% from 2010 to 2013, while at the master's level, enrolment increased by 31.7% (EPU, 2015a) (Figure 4.10). Academic performance for students at the bachelor level in public HEIs has improved, with 17.5% of graduates attaining cumulative grade point average scores of 3.49 and above in 2013, compared to 13.6% in 2010.

However, in terms of overall quality of university education as measured by international rankings, Malaysia's position has improved within the region but is still far from joining the top 100 universities of Asia or the world according to the QS World University rankings. This is in great contrast to universities of a similar age in

Hong Kong (China), India, Singapore and even Saudi Arabia, which have made the top 100 in the Asian rankings over the last few years. In the QS World University Rankings (2014/15) report, Universiti Malaya was ranked 151st and rated with five stars and is generally described as a world-class university in a broad range of areas, enjoys a high reputation and has cutting-edge facilities and an internationally renowned research and teaching faculty.[32] In the Times Higher Education World University Rankings 2015-16, Universiti Tecknologi Malaysia ranked in the 401-500 range, while the Universiti Kebangsaan Malaysia, the Universiti Putra Malaysia and Universiti Sains Malaysia rank in the 601-800 interval.

R&D activities and funding

Research

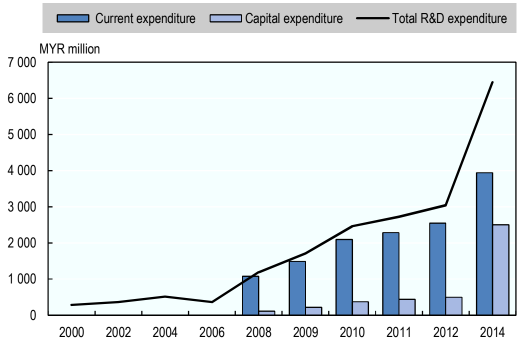
HEIs play a central role in Malaysia's innovation system: 80% of the nation's R&D research personnel are found in HEIs, accounting for 28.67% of the total R&D expenditure in 2012 (MASTIC, 2014c). More than half of the R&D infrastructure is located at university labs. Within the NHESP Beyond 2020, the government developed a plan to enhance the R&D capacity of universities. With this new development, the government has set goals to develop and strengthen research capacity and innovation to international standards.[33] In an effort to enhance the research capacity of universities as well as their role in building a knowledge economy, HEIs have seen their R&D expenditure growing steadily over the last decade (Figures 4.9 and 4.10). Research expenditure was multiplied by 11 between 2000 and 2012. In 2014, it reached MYR 6 445.48 million – which was twice the amount invested in 2012. The increase could be due to the number of participating higher learning institutions, which was 58 in 2014, as compared to 49 in 2012 (MASTIC, 2016).

From 2006 onwards (e.g. passage of the Ninth Malaysia Plan, 2006-10), R&D expenditure at HEIs grew at an average annual growth rate of 27.6%, reaching MYR 6445.48 million (about USD 1.659 billion) in 2014. Of this, about 38% went to capital expenditure.

An important strategic change in the orientation of R&D occurred between 2012 and 2014. In 2014, applied research increased significantly – doubling the amount of basic research, whereas two years earlier applied and basic research displayed similar levels of funding. In relative terms, the importance of basic research (44.36% to 29.64%) and experimental development research (13.62% to 7.80%) have decreased over the 2008-14 period to the benefit of applied research. This trend is explained by the increased focus on applied research in government funding of university research.

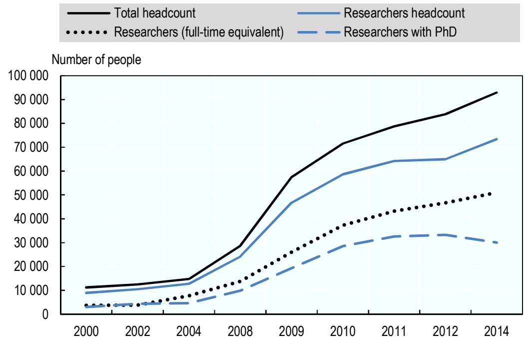
In tandem with R&D funding, the number of R&D personnel employed at HEIs has expanded rapidly since 2006 (Figure 4.10). Before 2006, the numbers were fairly stagnant, with a total headcount of 13 007 (of which 12 152 were researchers). The total number of full-time equivalent (FTE) researchers almost tripled from 2008 to 2010 and continued increasing from 2010 to 2014, reaching 51 097.26. The headcount of R&D personnel reached 92 975 – almost three times the figure reported in 2008 (34 859). Malaysia now surpasses Indonesia, Singapore and Thailand – the latter of which actually substantially decreased the number of researchers. The proportion of female to male researchers has been almost equal since 2010 (50.46% in 2014) – much higher than other ASEAN economies. The percentage of PhDs in total researchers has recently decreased, from 51% in 2012 to 22.34 % in 2014 (MASTIC, 2016).

Figure 4.9. **Evolution of R&D expenditure in higher education institutions**



Sources: MASTIC (2001, 2005, 2009, 2013, 2016), *National Surveys of Research and Development*.

Figure 4.10. **Evolution of R&D personnel and researchers (FTE and headcount) in higher education institutions**



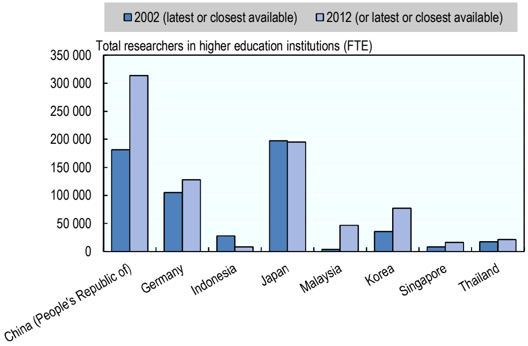
Sources: MASTIC (2001, 2005, 2009, 2013, 2016), *National Surveys of Research and Development*.

The ratio of R&D expenditure per researcher, however, is much lower compared to Malaysia's counterparts (Figure 4.12). In other words, university researchers in countries like Singapore or Thailand have much more resources at the individual level – e.g. four times more in Singapore and twice the amount in Korea. This is essentially due to the substantial expansion of R&D funding for higher education institutions, an increase that has been higher than the number of R&D personnel. This trend may suggest that the R&D resource allocation is weakly linked to planning of human resources for R&D. This may reflect a weak interaction between policy design and actual implementation of programmes at institutions.

The main source of funding for R&D (Figures 4.13 and 4.14) remains the government, although its importance is in decline – from 91.3% in 2008 to 58.22% in 2014). The part of HEIs has also decreased, from 17% in 2009 to 8.7% in 2012 (data for 2014 are not available). The second and third most important sources of funding for R&D in 2012 were internal sources (8.7%) and foreign sources (7.87%). Compared to previous years, foreign sources and other sources have gained in importance, moving from less than 1% in 2011 to 7% and 8% in 2012. Business enterprise remains a weak source of financing for R&D (4.76% in 2014). This is a sign of a weak connection with industry in the undertaking of research activities. OECD countries on average display lower ratios of government funding (39% on average in 2013) and higher internal financing (48% of R&D comes from the HEIs themselves) (Figure 4.14) A higher ratio of funding by the business sector also prevails in more advanced economies (7%).

According to MASTIC indicators (MASTIC, 2014a), 37% of R&D conducted at HEIs in 2012 was allocated to engineering and technology research, followed by natural sciences (17%) and social sciences (10%). These were the three top areas in R&D. In terms of publication activity (total national), engineering and technology is also the first domain of publication (23% for the period 2010-14), followed by computer sciences and medicine (12% each in total publications).

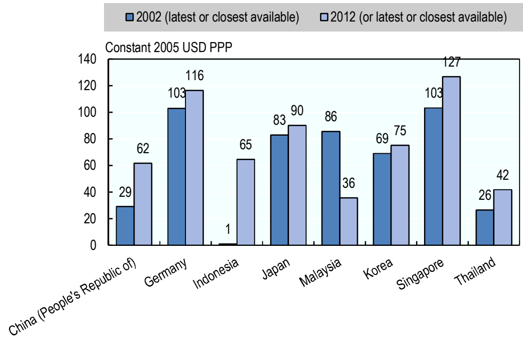
Figure 4.11. **Total researchers in higher education institutions, 2002 and 2012**



Note: Data for Malaysia correspond to 2014. Data for Indonesia and Thailand correspond to 2009 and 2011, respectively. For the start of the period (2002), data for Indonesia and Thailand correspond to 2001 and 2003, respectively.

Source: UNESCO (2016), *UIS.Stat* (database), http://data.uis.unesco.org.

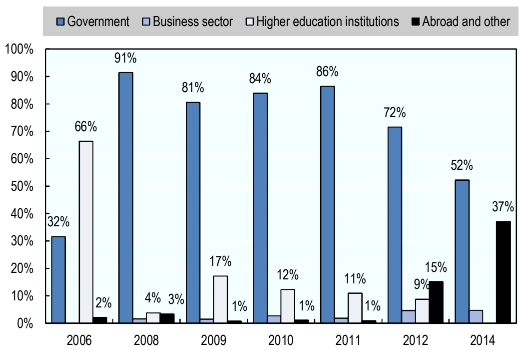
Figure 4.12. **R&D expenditure per researcher in higher education institutions, 2002 and 2012**



Note: For Malaysia, expenditures refer to 2003 whereas researchers to 2002. For the second period, data refer to 2012 in order to compare with other country data. For Thailand, expenditure in the first period refer to 2004 and researchers to 2003. For the second period, researchers refer to 2009 and expenditure to 2010. For Indonesia, expenditure reported for 2012 refer to expenditure of 2010 and researchers of 2009.

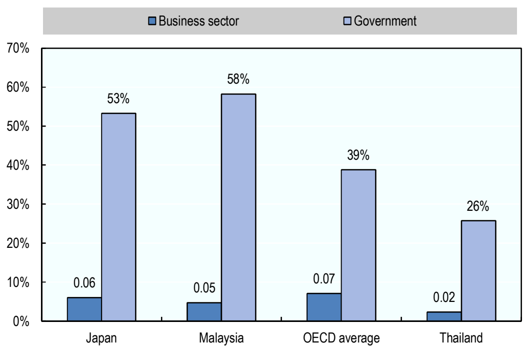
Source: UNESCO (2016), *UIS.Stat* (database), http://data.uis.unesco.org .

Figure 4.13. **Sources of funding for R&D performed by higher education institutions, evolution over the period 2006-16**



Sources: MASTIC (2001, 2005, 2009, 2013, 2016), *National Surveys of Research and Development.*

Figure 4.14. **Sources of funding for R&D performed by higher education institutions in 2013 or latest available**



Note: Data for Japan and the OECD average refer to 2013; data for Malaysia refer to 2014; data for Thailand refer to 2011.

Source: UNESCO (2016), *UIS.Stat* (database), http://data.uis.unesco.org; OECD (2014), *OECD Science, Technology and Industry Outlook 2014*, http://dx.doi.org/10.1787/sti_outlook-2014-en.

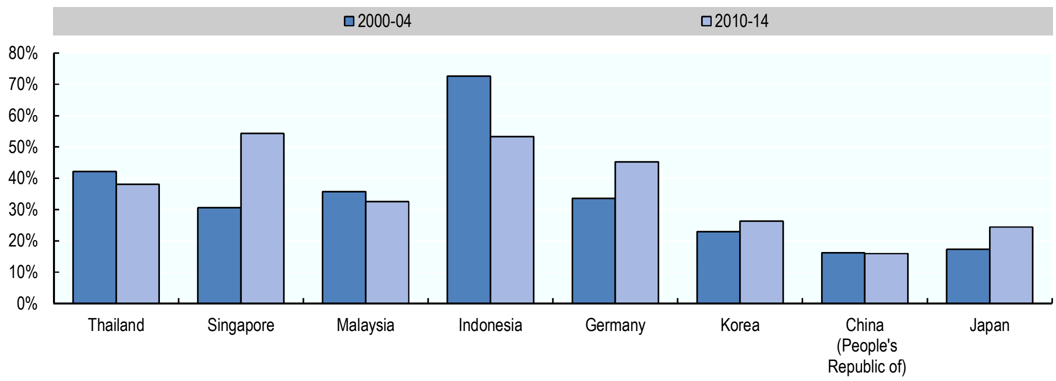
Results

In terms of scientific performance, Malaysia has dramatically expanded its number of scientific publications over the last decade. However, scientific publication is highly concentrated in a few universities (Figure 4.15), with the Universiti Malaya, the Universiti Sains Malaysia and the Universiti Putra Malaysia representing 76% of the total output produced by the top 15 institutions over the period 2001-11. The Malaysian Palm Oil Board is the prime research organisation, which has moved up to rank 13, according to a recent bibliometrics study (MASTIC, 2012).

Yet in spite of the increased scientific production, the quality of publications remains low compared to other countries. In 2011, there were 4.85 cites per document (according to SCImago and based on Scopus data) whereas Singapore recorded an average of 12.7 cites (per paper), Thailand 6.82, Indonesia 5.99 and Korea 8.33. Malaysian researchers need to improve the quality and impact of their research.

In addition, growth in scientific publication has not been accompanied by a significant increase in international collaboration in science (Figure 4.15). According to SCImago (data from Scopus), the percentage of international co-authorship actually decreased between the early 2000s and 2010s. Over the period 2000-04, 35.6% of publications involved international co-authorship whereas in 2010-14 this figure decreased to 32.6%. Furthermore, the h-index indicates that most of Malaysia's top universities have a lower ranking than those of international collaborators with a comparable article output. This is consistent with the lower cites per document (than peer countries) discussed above.

Figure 4.15. **International collaboration in science: International co-publication ratio (relative to total publications), 2000-14**



Source: SCImago (2007), *Country Rankings* (database), www.scimagojr.com/countryrank.php.

There has also been an enormous increase in university patenting in recent years. Universities applied for 81 local patent applications in 2005, whereas in 2012 this figure jumped to 407, thereby increasing the share of university patenting from 16% in 2005 to 35% in 2012 (Table 4.10). Furthermore, 314 patents were granted between 2010 and 2013. The leading universities in terms of patent applications include Universiti Sains Malaysia, University Malaya, Universiti Putra Malaysia and Universiti Teknologi Malaysia.[34] Two public research institutions are amongst the top patent applicants of the country: the National R&D Centre in ICT of Malaysia and the Malaysian Palm Oil Board. In particular, the National R&D Centre in ICT of Malaysia has been the top PCT

Malaysian applicant in the past few years, with a difference of more than 100 PCT applications.

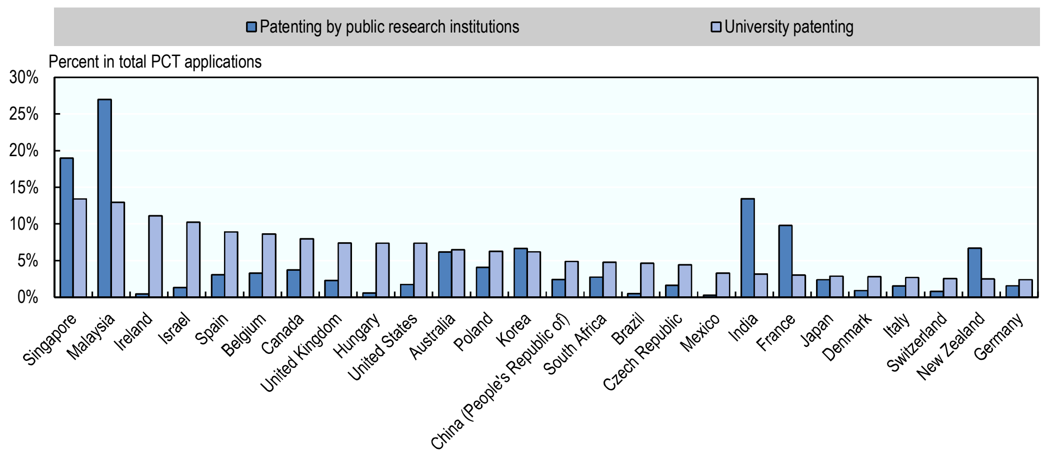
Table 4.10. **Local patent applications by type of applicant, 2005-12**

	Total applications by residents	Universities (public and private)	Share	Public research institutes	Share
2005	522	81	16%	38	7%
2006	531	94	18%	40	8%
2007	670	165	25%	109	16%
2008	864	272	31%	151	17%
2009	1 234	547	44%	204	17%
2010	1 275	574	45%	222	17%
2011	1 136	442	39%	164	14%
2012	1 160	407	35%	177	15%

Source: MASTIC (2014a), *Malaysia Science, Technology and Innovation (STI) Indicators Report 2013*, http://mastic.mosti.gov.my/documents/10156/38ae84ca-b8a0-4edb-a5b8-d30aa8c016e6.

Malaysia ranks high among developing countries in terms of patenting by universities and public research universities (Figure 4.16). For the period 1980-2010, the highest rates of university patenting as measured by international patenting indicators (e.g. patent filings through the Patent Cooperation Treaty [PCT]) were for Singapore (13% of total PCT filings), Malaysia (13%), Ireland (11%) and Israel (10%). The countries with the highest participation of public research institutes (PRIs) in PCT patent filings were Malaysia (27%), Singapore (19%), India (14%) and France (10%). China and South Africa reported the highest university rates within middle-income countries with 5% of PCT filings (Zuniga, 2011; WIPO, 2011).

Figure 4.16. **Patenting by universities and public research organisations in PCT applications, 1980-2010**



Note: Only countries having at least 1 000 PCT filings were included with at least 2.4% of university patenting in total patent applications (PCT filings).

Source: WIPO (2015b), *WIPO IP Statistics Data Center* (database), http://ipstats.wipo.int/ipstatv2.

Technology transfer and commercialisation

In Malaysia, commercialisation of public research began with the Sixth Malaysia Plan (1991-95) (EPU, 1990), which emphasised that public R&D programmes should become more market oriented by exploiting the commercialisation of research and technology (Chandran, 2010). Several funding programmes have been launched since to support and facilitate technology commercialisation and technology transfer at publicly-funded research institutions.

Despite a much larger and increasing number of patent applications (and other intellectual property rights), the commercialisation rate of research from universities and public institutions has until recently remained limited. Exceptions are to be found in the intellectual property rights (IPR) portfolio of some Malaysian key research actors, such as the Universiti Sains Malaysia and Universiti Putra Malaysia, as well as, on the public research institute (PRI) side, the Malaysian Palm Oil Board and the Rubber Research Institute of Malaysia (Chandran, 2010). For instance, the Malaysian Palm Oil Board generated USD 1.43 billion and has the highest commercialisation rate, at 30.6%.

Universities face a variety of challenges in the pursuit of technology transfer and commercialisation activities (OECD, 2015a):[35]

- poorly structured technology transfer offices and information process
- lack of demand-oriented research and poor intellectual property management
- bureaucracy
- lack of relevance of university R&D to industry
- lack of co-operation with industry in general
- lack of information on technology and appropriate markets for inventions
- insufficient government support and incentives, including financial ones
- lack of skilled personnel, absorptive capacity and human capital in SMEs that hamper university-industry knowledge flows and innovation more generally
- lack of funding at various stages of the commercialisation process (e.g. prototype, marketing, etc.).[36]

With recent advances in university autonomy and wider flexibility in their intellectual property policy, commercialisation has been eased to some extent but some obstacles remain (OECD, 2015c). Among the most important barriers to improving the rate of commercialisation are the lack of relevance of R&D projects to industry and the lack of funding at the various stages of the commercialisation process (Chandran, 2010). Strengthening links with industry through governing and steering committees (e.g. research boards and strategies) should be leveraged not only because of financial constraints, but more fundamentally because curricula research should address economic (and societal) demands.

Among the knowledge factors, the limited pool of qualified personnel is also seen as particularly detrimental to innovation activities. The lack of solid intermediary support at some universities implies that technology transfer and commercialisation initiatives fall under the responsibility of scientists themselves – in potential detriment of teaching and the pursuit of research activities per se. To reduce administrative hurdles derived from being part of the public administration, they should establish their own wholly owned subsidiary holding to operate more flexibly with industry. Leading universities have also started to adopt new strategies, moving from previous efforts aimed more at creating spin-offs to licensing, an activity that is often done by universities' subsidiaries. The reason for moving away from spin-offs was the high cost involved (OECD, 2015a).

Governance

Malaysian HEIs are governed by legislation, including the Universities and University Colleges Act (1971, amended 1996), the National Higher Education Council Act (1996), and the Malaysian Qualifications Agency Act (2007), which is in charge of accreditation and quality control. The first two were enacted with the purpose of providing for the establishment, organisation and management of public HEIs and to plan and formulate national policies and strategies for the development of HEIs. The education system overall is highly centralised and follows a top-down approach, with the federal government led by the Ministry of Education. The Council for Science and Education controls and regulates most of the operational decisions and policy strategy of the sector.

The Ministry of Education oversees HEIs (both public universities and private higher educational institutions), community colleges, polytechnics and other government agencies involved in higher education activities, such as the Malaysian Qualifications Agency, the National Higher Education Fund Corporation (Perbadanan Tabung Pendidikan Tinggi Nasional, PTPTN), the Tunku Abdul Rahman Foundation (Yayasan Tunku Abdul Rahman) and others.

Major reforms in the governance and strategy of the higher education sector started in 2007 with the launch of the National Higher Education Strategic Plan (NHESP) Beyond 2020 and the National Higher Education Action Plan 2007-2010.[37] These policy programmes outlined detailed strategic plans for the transformation of higher education in Malaysia with the purpose of fostering academic excellence in education and achieving global standards. A major goal of this programme is to make Malaysia an international hub for higher education in Southeast Asia. The roadmap contained in the NHESP has focused on reinforcing the delivery system via three key areas: 1) strengthening HEIs by giving them more autonomy; 2) enhancing research and innovation and improving the quality of teaching and learning; and 3) encouraging lifelong learning and increasing access to and equity in higher education.

Autonomy of universities

The autonomy of public universities has been enhanced over time but remains weak, as only a few universities have been granted autonomy. Strategic decisions are mostly taken at the ministry level, particularly concerning financial matters, tuition fees and hiring procedures. Since the Universities and University Colleges Act of 1971 came into effect, the Ministry of Education is responsible for closely regulating student admissions, course structures and curricula, staff appointments, remunerations, and financial management. The current practice of centralised administration has hindered the potential of change in higher education institutions and limited (or slowed down) their capacity to implement reforms and institutional strategies. Supervisory burdens and inefficiencies still continue to hinder the responsiveness of universities.

Measures have been undertaken through the legal framework to transfer administrative powers to HEIs through their boards of directors (ADB, 2012). The Universities and University Colleges Act replaced university councils with university boards of directors. This, however, only had a mild success. The board of directors continues to function as a university council and has neither the status nor the authority to act as a true corporate board (ADB, 2012). The amendments to the Universities and University Colleges Act in 2008 also intended to provide a greater level of autonomy and accountability to public universities. More recently, the *Malaysia Education Blueprint 2015-2025 (Higher Education)* (hereafter "Higher Education Blueprint 2015-25) (MOE, 2015b) envisages enhancing the decision-making power of universities (transferring competences from the ministry) and building the capacity and capabilities of university boards and institutional leaders to take on increased responsibilities.

In recent years, the government has been promoting autonomy on a merit-based approach in which being granted autonomy depends on institutional performance and governance achievements, as reported by quality rankings and governance assessments. The University Code of Good Governance and the University Good Governance Index have been adopted to help measure the level of readiness of Malaysian public universities for greater autonomy. The purpose of the University Code of Good Governance is to measure university governance best practices, while the University Good Governance Index measures the readiness for autonomy implemented in management, academic management and admissions.[38]

Autonomy is now linked to new internal funding obligations. Enhancing the autonomy of universities is one of the proposed strategies for enhancing the cost-effectiveness of higher education funding in Malaysia and for dealing with the expected reduction in government funding. The two other proposed reforms to enhance cost-effectiveness in HEIs focus on: 1) strengthening industry and research collaboration; and 2) enhancing the performance culture in teaching and research. The NHESP Beyond 2020 outlines the strategies needed for universities to subsidise their income from internal resources and directly link these achievements with autonomy concession.[39] Strategy Paper 10 (EPU, 2015c) emphasises the financial sustainability of HEIs. Within public universities, a more commercial and entrepreneurial approach has become prominent, but this has taken time to be formally implemented.[40]

Since August 2015, UNIMASS has been given more autonomy for deciding what to do and how to accomplish it (including the level of wages of professors, etc.). In exchange, new funding rules apply. Now 70% of funding comes from the government's annual block funding (covering operational expenses, and including staff salaries) and 30% is self-generated (industry, Ministry of Education and MOSTI grants, some post-graduate education fees).[41] Likewise, the qualification as "research university" involves (enhanced) autonomy, in addition to facilitating access to additional funding (for R&D). As a result, autonomy is not uniform across the sector; the best-performing institutions are able to persevere with more ease compared to new and smaller institutions.

In 2012, autonomous status was accorded to five research universities, namely the Universiti Malaya, Universiti Kebangsaan Malaysia, Universiti Sains Malaysia, Universiti Putra Malaysia and Universiti Teknologi Malaysia. These universities are empowered to manage student admissions directly, including intake announcements, receiving and processing applications, student selection and appeals. In 2013, three more universities – the Universiti Utara Malaysia, International Islamic University Malaysia and Universiti Malaysia Sarawak – became autonomous. In 2014, the number of public universities granted autonomy reached 12, with the addition of the Universiti Teknologi Mara, Universiti Teknikal Malaysia Melaka, Universiti Sains Islam Malaysia and Universiti Malaysia Terengganu.

Although these research institutions have been granted autonomy, this has not yet translated into any meaningful improvement of their operations, management or financial sustainability. It may, however, be too early to detect any major improvements. Furthermore, the governing boards of most of these universities still lack representation by professionals and captains of industry. Continued dependence on government funding and exigencies to gradually increase self-funding might pose complications for many universities.

Funding and evaluation

Funding from the government comes mainly from Ministry of Education and MOSTI grant schemes, although sometimes it is from other sources (i.e. the Ministry of Environment for renewable energy projects). The annual block funding provided by the Ministry of Education covers full professors' and associate professors' salaries. This includes research, as professors are expected to spend about 50% of their time conducting research. Every year a detailed proposal is made to the government for the following year's budget in order to obtain block funding.

The Tenth Malaysia Plan stated the necessity of reducing the proportion of government funding to public universities – in line with the government's objective to decrease the public deficit to 3% of GDP. It went on to say that public universities must seek alternative funds to improve the quality of teaching and research (EPU, 2010). Block funding will be decreased and internal sources of finance are expected to gradually compensate and finance operating costs. New funding mechanisms will link the allocation of block funding to performance outcomes, such as the number of undergraduates and postgraduates, research projects and commercialisation (Box 4.5). New funding schemes (performance-based funding) were announced in 2010 and 2014 with the release of the Higher Education Blueprint 2015-25 (MOE, 2015b) and the Eleventh Malaysia Plan (Box 4.5). Key initiatives of the Higher Education Blueprint 2015-25 include: improving the funding formulae for public HEIs by replacing block grants with performance-based and per student funding; implementing five-year (3 + 2 years) performance (outcome-based) contracts and targeting government investment in priority areas.

The government has emphasised that these financial reforms are crucial for achieving the desired transformation in HEIs as envisioned in the National Higher Education Plan Beyond 2020. Starting in 2015, all public universities are now required to generate 25% of their own operating costs (self-finance + funds obtained from competitive grant schemes). This obligation will increase to generating 75% of their own budgets by 2025. Concerns have been expressed regarding whether these percentages and the timeline are realistic and whether such an approach is feasible for all types of universities.

The Malaysian higher education sector has recently taken some important steps in evaluating its universities. Several assessment instruments have been introduced, such as rating mechanisms including SETARA and MyQUEST,[42] to assess the quality of undergraduate education and provide transparency. Introduced in 2011, MyQUEST (Malaysian Quality Evaluation System for Private Colleges) evaluates private colleges in terms of the quality of students, programmes, graduates, resources and governance. It is expected that the use of these ratings will help to ensure that financial flows to HEIs are transparent, thereby promoting accountability. Following international practice, SETERA (Rating System for Higher Education Institutions in Malaysia) looks at new performance indicators in addition to student enrolment and quality of teaching and learning, publications, R&D, patents, and licenses, among others.

Box 4.5. **Performance-based funding of higher education institutions: Current reforms**

For the years to come, the government will continue reforming the funding and governance of higher education institutions (HEIs) and will strengthen performance-based funding. According to the Higher Education Blueprint 2015-25 (MOE, 2015b), key initiatives for reform include: improving the funding formulae for public HEIs by replacing block grants with performance-based and per student funding; implementing five-year (3 + 2 years) performance (outcome-based) contracts and targeting government investment in priority areas; strengthening quality assurance in the private sector; linking access to student loans with the performance and quality standards of HEIs; and incentivising the creation of endowment funds, as well as encouraging contributions to higher education, for example through the provision of matching grants for higher learning institutes during the initial fundraising period.

Starting in 2016, the government will withhold 5% of the total funding for universities. This reserve fund will be given to the universities after they meet their key performance index (KPI) and have complied with extra competency, productivity, performance and success. The fund will comprise input-based funding (3%) and performance-based funding (2%). The current 5% reserved fund will be increased on a yearly basis and is expected to reach 40% in 2025 when the Malaysia Higher Education Blueprint 2015-25 (MOE, 2015b) will be fully implemented. In addition, a portion of the direct block grant for R&D and innovation given to HEIs will be converted into a voucher scheme for the industry to outsource its R&D and innovation to industry centres of excellence (ICoEs).

Sources: EPU (2015a), *Eleventh Malaysia Plan*, http://rmk11.epu.gov.my/index.php/en.

Another evaluation instrument is the Malaysian Research Assessment Instrument (MyRA). MyRA helps the Ministry of Education monitor the annual block funding. It covers a comprehensive set of key performance indicators (post-graduate education, research publications, citations, consulting fees, industry contracts, etc.).[43] This assessment determines the amount of annual block funding a university can obtain the following year. Six universities – five public and one private – received the six-star rating of the MyRA for the year 2014-15.[44] In 2015, for the first time, a MyRA audit panel visited all public universities on-site to complement the 2014 performance assessment.[45]

According to a study by Ahmad, Farley and Naidoo (2014), the funding reforms have had a positive impact on public universities and their organisation. In particular, their study found that the funding reforms have enabled public universities to be more proactive in implementing government programmes. Focus group interviews revealed that public universities seem to have embraced the changes brought about by the funding reforms. In spite of difficulties in implementing the NHESP Beyond 2020 and the National Higher Education Plan 2007-2010, the majority of the participants viewed these reforms as necessary for improving the standard of higher education and displayed positive and optimistic attitudes (ibid.).

Research strategies

To foster excellence in research and competition among universities for research funding, the Ministry of Education created the qualification of "research university" (Table 4.9) following a research and governance assessment of universities in 2012. Today there are five research universities where the research capacity of the higher education sector is concentrated; the remaining universities are classed as non-research universities, which means they concentrate on teaching. The five research-focused public universities receive between USD 26.5 million and USD 53 million annually (MYR 50-100 million) in block grants; 5-10% of that money is dedicated to technology transfer (OECD, 2015a).

Overall, many of Malaysia's HEIs are quite new, particularly private universities, and only a few have recently developed sophisticated research capabilities. A number of university research programmes are classified as "centres of excellence", which have to meet selective performance criteria and are evaluated periodically using traditional academic indicators, such as the number of publications in peer reviewed journals with high impact factors. Centres of excellence have undergone a rigorous evaluation by the Ministry of Education and meet certain performance indicators.

An additional classification, the Higher Institution Centre of Excellence (HICoE), was created in 2009, whereby a small number of centres of excellence have been selected based on the quality of their research and outputs produced. The first evaluation exercise was undertaken in 2008. Out of 142 applications, 6 centres of excellence in 5 public HEIs met the stringent requirements for becoming an HICoE. The purpose of the HICoE qualification is to identify the best of the best centres of excellence in HEIs at the national level and encourage them to work towards becoming global leaders in their research areas. This implies that HICoEs will be supported financially and will pioneer R&D and innovation agendas in key areas, particularly in fundamental research and human capital development.

The Ministry of Education's strategy is to push these six HICoEs to make a quantum leap towards internationalisation. These centres of excellence include the UM Centre of Research for Power Electronics, Drives, Automation and Control at the University of Malaya; the National University of Malaysia's (UKM) Medical Molecular Biology Institute at the National University of Malaysia; the Institute for Research in Molecular Medicine; the Institute of Biosciences at Putra University of Malaysia; the Centre for Drug Research at the Science University of Malaysia; and the Accounting Research Institute at the MARA University of Technology.

To conclude, HEIs have undergone a radical transformation to foster excellence in higher education and research. Measures have been taken to improve the quality of the education system and encourage institutional reforms in universities through the promotion of a new culture of performance and result-driven management. These efforts are part of a wider policy agenda to continuously upgrade HEIs and their quality, as well as the impact of higher education on Malaysian society and the economy.

Among the key challenges and issues that HEIs encounter on their path to establishing academic excellence, competitive research and technology transfer, as expressed in new policy directives, are:

- Growing financial constraints: Decreasing federal funding will require more focus on internal and industry funding, which will entail additional resources or competencies that many universities (especially non-research ones) might still not have – e.g. industry partners and networks, spinoffs, etc. It is important therefore to help universities find the appropriate and realistic financial model according to their competencies and ambitions.
- Weak involvement of industry in governance and curricula: Participation of industry on governing boards is still a pending task as well as industry's involvement in the definition of curricula (and programmes). Strengthening links

with industry through governing and steering committees (e.g. research boards and strategies) should be leveraged not only because of financial constraints, but more fundamentally because curricula and knowledge produced should address economic (and societal) demands.

- Incipient collaboration with industry in innovation activities: Enhancing universities' impact on economic development will entail strengthening industry-science linkages, more relevant research for industry and widening the array of interactions. The latter involves increasing collaboration in research and widening the channels of knowledge transfer – e.g. joint PhDs, training, consulting services, product development and engineering activities, among others.
- Race to patent, growing costs of protection and lack of technology strategy: Although greater intellectual property (IP) activity is an encouraging factor for commercialisation, a growing patent portfolio may also be the sign of a lack of an IP strategy. An increase in patent grants will require new financial means to cover the costs of protection (renewal fees). A strategy for selecting and filtering inventions for patenting is lacking and this may require policy action at a higher level. More fundamentally, the definition of a technology transfer strategy (and policy framework at the institutional level) that correctly balances IP and non-IP forms of technology transfer and realistically addresses business needs is yet to be developed in most institutions.

Public research institutes

Structure

Public research institutes (PRIs) play a critical role in the process of innovation and technology diffusion in Malaysia and are key components of sectorial innovation systems, such as agriculture, electronics, health and forestry, among others. Malaysia's PRIs perform mainly downstream or applied research and their objectives are essentially to serve the needs of their respective Malaysian stakeholders or departmental remits. By 2011, there were 29 PRIs, which share the mandate to act as the interface between science, industry and society (Table 4.11). Of the 29 PRIs, 1 is a company under MOSTI, 3 are statutory bodies with a governing board reporting to sectorial ministries, 2 are cess funded, and the remainder are departments or institutes of ministries.

The PRI landscape is much more complex and irregular than that of public universities. PRIs differ with regard to institutional forms and governance, size and resources, and performance. Some institutions have a long scientific tradition but diverse public missions and disciplinary specialisations. They are extremely diverse in size, age, fields of research and oversight. MOSTI has no direct authority in determining their research agendas. Most of them have a sectorial focus covering a wide range of areas including natural resources (agriculture, palm oil, rubber, cocoa, forest, etc.); industry and engineering (electronics, industrial productivity); healthcare (medical research); or other selected fields (nuclear technology, remote sensing, economics, etc.).

The Malaysian Agricultural Research and Development Institute, Malaysian Palm Oil Board, Malaysian Rubber Board, Malaysian Cocoa Board and Forest Research Institutions Malaysia are key PRIs that support the commodity sector at the technological frontier. In order to strengthen the local technological capability and capacity in the manufacturing sector, several PRIs and their complementary institutions have been established to provide research and services related to industry and engineering. For example, the Malaysia's national R&D centre in ICT (MIMOS) focuses on electronics and information technology development, while the Standards and Industrial Research Institute of Malaysia and the Malaysia Productivity Corporation were established to help improve productivity.

Table 4.11. **Selected public research institutes in Malaysia**

Name	Research field	Institutional status	Ministry in charge
MIMOS Berhard	ICT	Corporate	MOSTI
Malaysian Agricultural Research and Development Institute (MARDI)	Agriculture	Government	MAABI
Malaysian Palm Oil Board (MPOB)	Palm oil	Government	MPIC
Malaysian Rubber Board (MRB)	Rubber	Government	MPIC
Malaysian Cocoa Board (MCB)	Cocoa	Government	MPIC
Forest Research Institutions Malaysia (FRIM)	Forest	Government	MNRE
Standards and Industrial Research Institute of Malaysia (SIRIM)	Standards	Corporate	MOF
Malaysia Productivity Corporation (MPC)	Management research	Corporate	MITI
Institute for Medical Research (IMR)	Medicine	Government	MOH
Institute for Health Systems Research (IHSR)	Medicine	Government	MOH
Institute for Public Health (IPH)	Medicine	Government	MOH
Institute for Health Management (IHM)	Medicine	Government	MOH
Clinical Research Centres (CRC)	Medicine	Government	MOH
Institute for Health Behavioural Research (IHBR)	Medicine	Government	MOH
National Heart Institute (IJN)	Medicine	Corporate	MOF
Agro Biotechnology Institute	Biotechnology	..	MOSTI

Note: MOSTI = Ministry of Science, Technology and Industry; MOH = Ministry of Health; MPIC = Ministry of Plantations Industries and Commodities, MNRE = Ministry of Natural Resources and Environment; MAABI = Ministry of Agriculture and Agro-based Industry; MOF = Ministry of Finance; MITI = Ministry of International Trade and Industry.

Sources: Thiruchelvam, Mohamad and Ng (2011), "Higher educational reforms and institutional responses: The role of public universities in promoting innovation in Malaysia"; relevant institutional web pages.

There are also a number of PRIs that have been assigned to safeguard the quality of healthcare of Malaysians, such as the Institute for Medical Research and the National Heart Institute. In addition to the extensive number of PRIs mentioned above, there are also numerous PRIs that have been established for the advancement of science, technology and innovation in selected fields, such as Nuclear Malaysia which provides nuclear technology research facilities; the Malaysian Remote Sensing Agency for the use of remote sensing technology in national planning, development and resource management; and the Malaysian Institute of Economic Research, which provides expertise in economic, financial and business-related issues.

Governance and funding

In terms of governance/oversight, PRIs can be classified into three different categories: ministry division, statutory and corporations limited by guarantee. Their autonomy is subject to their status. For a ministry division PRI, the governing ministry has complete oversight regarding the management, funding and regulatory issues governing the individual institutions (NSRC, 2013). Statutory PRIs are created by an act of the Malaysian parliament (e.g. the Malaysian Agricultural Research and Development Institute was created by the MARDI Act of 1969) that stipulates how the PRI is managed and funded. Statutory PRIs are usually governed by an independent board of trustees though they may receive their funding from a number of sources, including agencies and "cess", which is a tax applied to particular industries. While statutory PRIs are typically seen as having much more autonomy than ministry division PRIs, both are subject to personnel policies and practices as stipulated by the Public Service Department. Governed by the Company Act of 1965, corporations limited by guarantee are government-owned corporations and are considered to have the highest degree of autonomy among PRIs; they are not subject to the Public Service Department's hiring and personnel policies. For example, corporations limited by guarantee are also governed by an independent board of trustees (NSRC, 2013).

Over the years, several PRIs have expanded their scope by engaging in new activities and disciplines, albeit somewhat missing the focus of the original mission for which they were created. Changing policy priorities and regulations, the multiplication of funding sources and agencies, as well as pressure to strengthen commercialisation have contributed to this trend. As a result, PRIs have encountered more difficulties than universities in ensuring consistency and expanding R&D capacity over the years.

This context has hindered overall performance and undermined specialisation and focus in core competencies. Although a number of PRIs have demonstrated their capacity to develop useful technologies, particularly those dedicated to commodities, connection with the economic sector remains very uneven and unsatisfactory. The purpose and role of PRIs (develop tools for policies, monitor regulations, facilitate technology transfer, etc.) is, in fact, not always clearly defined.

In an effort to enhance the efficacy and efficiency of public sector organisations, the government has initiated the corporatisation of several public research-related institutions since the 1990s, such as the Standards and Industrial Research Institute of Malaysia, the MIMOS and Technology Park Malaysia. With this restructuring, research organisations were expected to enhance infrastructure and equipment and better provide R&D services to the private sector. The Malaysia Institute of Microlectronics System has clearly expanded capacity and become a major technology provider for a wide array of sectors, from government (e.g. education) and the private sector.

A major handicap to the evolution of PRIs is the lack of clarity in the specific role that they should play in national strategic plans. As discussed in the National Science and Research Council's Public Research Assets (PRA) Performance Assessment conducted in 2012 (NSRC, 2013), the Tenth Malaysia Plan did not mention a clear responsibility for public research organisations in the implementation of the plan's recommendations. Goals and a definition of means are thus left up to individual ministries and programmes.

The National Science and Research Council made several recommendations in its 2013 PRA assessment, including: the need to create a Research Management Agency under the National Science and Research Council in order to improve the management of public research; to establish an industry research nexus as a platform for public research and industry collaboration in order to improve the relevance and marketability of public research; to review, restructure and realign PRIs; and to enhance human capital and related funding, and improve the research ecosystem and culture. A new Science Act, linked to the creation of a Research Management Agency, is also on the agenda. The Prime Minister also announced the Science to Action (S2A) initiative for the implementation of the National Policy on Science, Technology and Innovation (NSTIP) as one of the key strategic thrusts of the forthcoming Eleventh Malaysia Plan (2016-20). One of the objectives of S2A is to strengthen public services and governance to ensure an environment that will facilitate the development and uptake of science and technology. The government recently established the National Science, Technology and Industry Council, which aims to rationalise the many science- and industry-based councils (OECD, 2014).

Research and development

The role of PRIs in R&D activities in Malaysia has remained low since the early 2000s. In 2014, only 8.21% of R&D conducted in Malaysia was performed in PRI labs. This can be explained, in several cases, by the higher relative importance of advisory and monitoring services (and technology transfer activities) in many of these institutions. This situation also reflects a weaker position of the sector in embracing new national innovation and technology plans, and a lack of upgrading *vis-à-vis* global standards of PRIs.

PRIs in Malaysia essentially focus on applied R&D, which accounts for 74% of their research (MASTIC, 2014). Expenditure for experimental development decreased from MYR 371.56 million in 2011 to MYR 36.3 million in 2012 but then increased in 2014, reaching MYR 58.70 million. This trend widely differs from the situation in 2000 when both applied and experimental development registered similar levels of expense (MYR 191.2 and MYR 184.95 million).

Compared to higher education institutions, the evolution of the R&D expenditure of PRIs has been less dramatic – flows contracted in 2004 and 2006, as well as in 2009 after a mild increase in 2008 (MASTIC, 2014c). This trend is explained by a lack of consistency in funding schemes (e.g. limited medium- and long-term funding), as well as difficulties in ensuring medium-term funding given the multiplicity of sources on which PRIs depend. Several public institutions were reclassified as private or semi-government agencies,[46] which might have also affected the contraction registered in 2012. PRIs have unfortunately held a weak position or a non-explicit role in the design of national strategies and funding programmes.

According to the National R&D Survey, the three most important areas of research of PRIs are natural sciences – representing 28.1% of expenditure in 2012 – followed by biotechnology (27.4%), and agriculture and forestry (26.3%). Following these fields are medical and health sciences (9.30) and engineering and technology (6.6%). This pattern differs from 2008 when agricultural sciences dominated the R&D expenditure of PRIs (Thiruchelvam, Mohamad and Ng, 2011).

The government is the main source of finance for R&D in PRIs, providing, on average, more than 90% of funding over the years (MASTIC, 2014a). In 2012, the federal government contributed 97% of funding. In 2014, this figure fell to 60.4%. Although increasing in importance, the business sector and foreign sources only play a minor role: they represented 0.38% and 0.56% of the funding sources, respectively. While mainly reliant on public funding, some institutions have also received important additional funding from the private sector. For example, Malaysia's Cancer Research Initiatives Foundation has individual and corporate donors such as Sime Darby and PETRONAS (OECD, 2013a).

The evolution in terms of research personnel is also less consistent than in the case of HEIs. From 7 777 headcounts recorded in 2000, total research personnel was 4 556 in 2006, and has shown an upward trend since, reaching 8 339 in 2012. Of this amount, about half are researchers (4 045), followed by support staff (2 386) and technicians (1 908). The proportion of female researchers reveals steady growth since 2000, reaching 53.4% of research personnel in 2012 – a substantial increase since 2000 when it was 29.8%.

Expenditure in public agricultural research has also encountered fluctuations over the years, but more modestly than other areas and sectors. Growth in public agricultural research capacity occurred across all institutional categories from 2007 to 2010 (ASTI, 2015). In 2010, the country's main public agricultural R&D agency, the Malaysian Agricultural Research and Development Institute (MARDI), accounted for a quarter of national agricultural research investments, while commodity boards accounted for almost half (ibid.) and 36% of human resource capacity. MARDI, administered by the Ministry of Agriculture and Agro-based Industry, encompasses 3 branches (research, technology transfer and commercialisation, and operations) and oversees 29 regional research stations. In 2010, MARDI's expenditures totalled MYR 183 million (USD 106 million; PPP, both in 2005 constant prices) (Flaherty and Abu Dardak, 2013). Research capacity levels remained fairly stable throughout the 1980s and early 1990s, but declined slightly in the late 1990s. In 2004, staffing levels began to increase, although inconsistently, and reached 578 full-time equivalents (FTEs) in 2010.

Despite MARDI's central role in agricultural R&D, the commodity-based research agencies spent twice as much on agricultural research, representing almost half the national total. These centres include the Malaysian Palm Oil Board, the Malaysian Cocoa Board and the Malaysian Rubber Board. These agencies are better funded than MARDI due to the high value of export crops and related commodity-based resources (e.g. cesses), but they employ fewer researchers (a combined 305 FTEs in 2010). Employing 207 FTE researchers in 2010, the Malaysian Palm Oil Board is the largest of the three agencies; the Malaysian Cocoa Board and the Malaysian Rubber Board are similarly sized, employing 53 and 45 FTE researchers in 2010, respectively. Two of Malaysia's states, Sabah and Sarawak, exercise a greater degree of autonomy and, as such, operate their own research agencies.[47] A number of other government research agencies operate in Malaysia, the largest being the Forestry Research Institute Malaysia, which employed 202 FTE researchers in 2010. Other agencies include the Department of Veterinary Services (44 FTEs) and the Malaysian Institute for Nuclear Technology Research (22 FTEs).

Evaluation and performance-based management

To date there is no equivalent of MyRA, the research assessment instrument by the Ministry of Higher Education for universities, for PRIs. This is clearly an example of the disparity in the rhythm of modernisation between universities and PRIs, and is largely rooted in the lack of a co-ordinating agency of the public research system and policies. A monitoring and performance evaluation mechanism has not yet been established – a step that relates to the need to redefine and clarify the mission and objectives (expected outputs and activities) of PRIs. Instruments for evaluating improvements in governance do not yet exist either. Evaluation of R&D allocations has started moving from R&D disbursements (expenditure approach) to outputs.

However, as in many other respects, there is a wide heterogeneity between PRIs. Some of them have established some monitoring and evaluation processes. For instance, at the MPOB, all the research projects are evaluated and approved by the Programme Advisory Committee (PAC), comprised of local and international experts and palm oil industry scientists. This committee, which meets every year, is tasked with ensuring that the research carried out by MPOB researchers are based on the industry's needs and is scientifically sound. This committee also evaluates the progress of research. When problems are identified, the PAC can recommend an International Review Panel to critically evaluate the programme and provide recommendations.

Results

In terms of scientific and technological performance – according to the new metrics such as patents, licensing revenue and contracts – PRIs appear to lag behind universities. This is not surprising given the lower level of importance placed on scientific production at many of these research institutions. The total number of papers published by PRIs over the period 2001-11 was 1 778 in the Thomson Reuters' *Web of Science Database* (MASTIC, 2014a). The leading institution is the Malaysian Palm Oil Board (395 papers), followed by the Forestry Research Institute Malaysia (357 papers), the Institute for Medical Research (321) and Agensi Nuklear Malaysia (256) (MASTIC, 2014a).

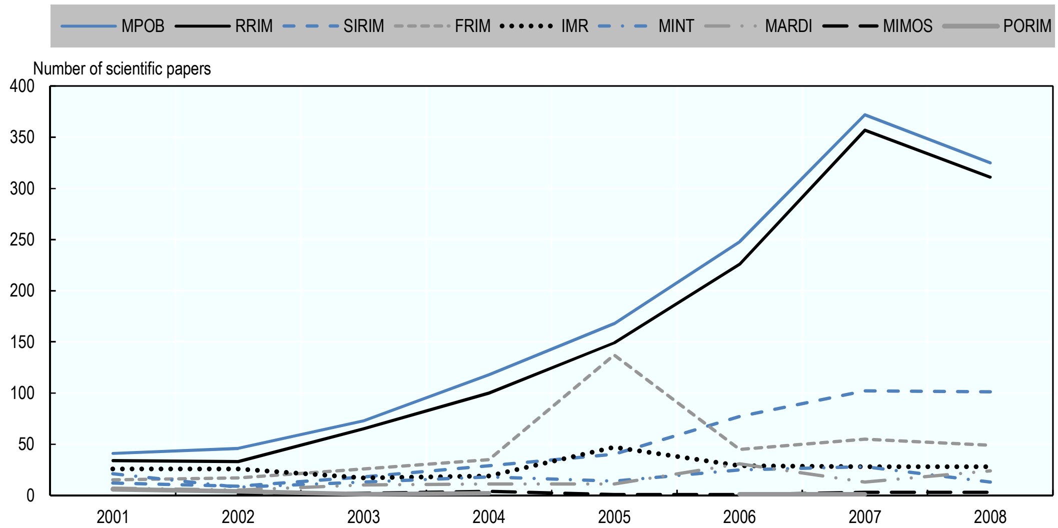
PRIs also show fewer numbers of patents than universities. In 2012, local patent filings by PRIs represented only 15% of total patent applications made in MyPO (MASTIC, 2014a). This is, however, more than a twofold increase from 2005 (7% of national patent filings). In 2012, PRIs had 39 patents granted while HEIs received 158. In total, the portfolio of granted patents summed 187 patents, whereas HEIs owned 680 in total (MASTIC, 2014c). In terms of other IP rights, HEIs declared 416 trademarks and 44 industrial designs while PRIs claimed 47 and 4, respectively.

A remarkable institution with growing patenting and technology applications is the National R&D Centre in ICT of Malaysia (MIMOS), a PRI corporatised in the 1990s. Today, MIMOS Berhad is Malaysia's forefront technology provider of information and communications technology, industrial electronics technology, and nano-semiconductor technology. In 2013, it ranked 12th among the top public research institutes in the world in terms of PCT filings. Over the past ten years, MIMOS has filed more than 900 intellectual property rights in various technology domains and across key socio-economic areas. In 2011, it represented 43% of Malaysian PCT filings. PCT patent filing has steadily been growing since 2007, when there were not any PCT patent applications. MIMOS remains a strategic agency under the umbrella of the Ministry of Science, Technology and Innovation (MOSTI).

Behind this patenting performance is the change in strategy experienced by MIMOS in 2006 with the redefinition of its mission[48] and increased emphasis on IP generation and commercialisation activities. The institution's key performance indicators call for it to make 100-120 patent filings per year from its three areas of R&D: applied research, advanced technology and application development – no basic research. With increased threats of budget cuts in the future, the incentive for MIMOS to raise revenue from commercialisation has increased even further. Another critical challenge for MIMOS is ensuring the successful adoption of its technologies along with the limited capacity of national SMEs to take advantage of inventions.

In practice, the nature of technology transfer undertaken at many PRIs may differ somewhat from that at universities given the different approach to research and objectives. It is also quite diverse in the types of modes and intensity across PRIs. According to several studies, PRIs have a better success rate than universities in transferring the results of (applied) research to industry and agricultural producers. MARDI, for instance has a good track record, commercialising 14.3% of its products. It has a division for technology transfer and commercialisation that provides technical services and scales up the new technologies it has developed. MARDI collaborates with private companies, undertaking contract research and providing test beds to entrepreneurs. Its Entrepreneur Development Programme has involved 200 SMEs, helping them to develop businesses based on agri-technology.

Figure 4.17. **Evolution in the number of scientific papers by public research institutes in Malaysia**



Note: MPOB = Malaysian Palm Oil Board; RIIM = Rubber Research Institute of Malaysia; SIRIM = Standards and Industrial Research Institute of Malaysia; FRIM = Forest Research Institutions Malaysia; IMR = Institute for Medical Research; MINT = Malaysian Institute for Nuclear Technology Research; MARDI = Malaysian Agricultural Research and Development Institute; MIMOS = National R&D Centre in ICT of Malaysia; PORIM = Palm Oil Research Institute of Malaysia.

Source: MASTIC (2012), *Science and Technology Knowledge Productivity in Malaysia: Bibliometrics Study*.

Yet according to metrics, only a few PRIs are formally engaged in technology commercialisation and other technology transfer activities. A recent evaluation has noted some improvements in performance, but also highlighted some overlaps and institutional inflexibilities that prevent scale-dependent research and more long-term collaboration with industry (NRSC, 2013).

In general terms and with the exception of a few cases, research institutes seem to be less prepared to pursue commercialisation and IP activity than universities (OECD, 2015a). PRIs face greater administrative barriers, budget cuts on research and a less adaptive culture that until recently put little emphasis either on collaboration with the private sector or on producing IP. These institutions, however, have very different profiles, and this situation calls for a careful appreciation of their outcomes and achievements. The focus on IP and its revenue might not necessarily be the most pertinent way to evaluate the technology transfer activities in PRIs, while comparison with universities should be made with care and achievements should probably not be measured under the same criteria. Several PRIs undertake transfer of technologies of a public good nature, which are distributed freely or at a low price, especially when serving the purposes of ministries/departments. As an example, MARDI distinguishes between two different types of technology. It does not charge a licence fee for "public good" technologies, whereas "industrial good" technologies bring in royalties (ibid.).

An in-depth assessment of PRIs' knowledge and technological activities should help determine their focus and activities, as well as the best ways to impact stakeholders through the transfer of knowledge and technology. For some PRIs, traditional forms of knowledge transfer such as advisory services and technology extension (e.g. adaptation of existing technologies and their diffusion) might remain highly demanded by customers/stakeholders while for others enhancing technology commercialisation through IP and licensing (those with growing research capacity) may be a new step within their revised strategic plan and mission. Overall, an assessment (or audit) of their activities and mission, and potential for evolution, should help clarify their roles and engagements and help define budget planning for their modernisation. Again, reforming governance and moving to new steering funding through performance-driven mechanisms and evaluation in PRIs is critical for research and commercialisation outcomes.

To summarise, the pace at which PRIs have been evolving in terms of governance reforms and modernisation has been varying across institutions. Universities have been pushed towards adopting international standards, diversifying their sources of funding, and new institutional reforms with respect to governance and autonomy are recently being implemented. Funding for research has increased dramatically, following a strategic plan. In contrast, PRIs have been largely left to themselves to define their trajectories.

PRIs have encountered the following difficulties in improving their efficiency and moving to global standards:

- persistent deficiencies in funding (e.g. dispersion of sources and unstable trend) and high fluctuations in the availability of funding streams have been detrimental to the accumulation of experience and the stability necessary to build vibrant research communities and long-term research agendas
- changing missions (widening scope) or unclear objectives as defined in their regulatory framework and mission statements have contributed to a growing dispersion in activities and hampered PRIs from concentrating on core competencies
- the lack of a national strategy (and action plan) for their modernisation and for replenishing their resources has slowed the process of transformation
- the lack of accountability and performance evaluation (e.g. including audits by international experts and definition of performance objectives and metrics to monitor results periodically).

Without a revision of their regulatory frameworks and governance, as well as a comprehensive reinforcement of their capabilities and relevance, PRIs' impact could remain weak and uneven across institutions. The reform of PRIs needs to entail efforts at the individual and sectorial level. At the institutional level, PRIs urgently need to update/redefine their mission and roles, revise their governance and efficiency, and improve their research management and accountability.

With regard to capacity replenishment, research, technology and human capital resources need to be strengthened based on an in-depth assessment of public research institutes' technological competences, bottlenecks and potential. A study on "Enhancing the Effectiveness of Research and Development Institutions" has recently been launched by the EPU and the Prime Minister's Department. On the basis of the results of this in-depth assessment, which are expected by the end of December 2016, strategies will be proposed to enhance the effectiveness of these institutions and eliminate overlapping of functions of the R&D institutions as stipulated in the Eleventh Malaysia Plan. It is also pivotal to provide the means and funding resources in a more efficient way, particularly avoiding duplication and fragmentation. Strengthening equipment and infrastructure would benefit from collective co-ordination and planning – via a co-ordinating agency –

that would allow tracking the inventory, their (shared) use and increase the cost-benefit ratio by avoiding duplication. Monitoring of technology transfer activities and institutional reforms (and skills) to foster technology transfer at public research institutes might also benefit from a central entity to facilitate the even acceleration of progress in these areas.

Notes

1. In particular electronics, which accounted for 88.3% of the E&E value added in 2014. Electrical equipment contributed the rest.
2. This sector includes primary, agro-based and other resource-based industries.
3. This includes the manufacture of petrochemicals, oleochemicals, refined petroleum, palm oil, rubber gloves, tyres and prophylactic products.
4. The upward trend at the beginning of the year 2000 is partly related to the rise of commodity prices. The fall of the price of oil has changed the distribution since.
5. Since 2014, the definition of SMEs has been broadened so that more domestic firms can benefit from the specific government support programmes and schemes. Since 2014, the companies in manufacturing with sales below MYR 50 million (previously MYR 25 million) or less than 200 employees (previously 150 employees) fall under the SME category. Service sector SMEs are companies with sales turnover below MYR 20 million or less than 75 employees.
6. It even increased in 2014 (to a difference of factor 3.3) but the change of definition of SMEs does not allow for meaningful comparisons.
7. Improving the quality of products/services is the main motive for 31% of SMEs surveyed by the Associated Chinese Chambers of Commerce and Industry of Malaysia (ACCCIM, 2012).
8. Out of a total of 8 000 foreign-owned companies located in Malaysia.
9. Genting Bhd (other consumer services – including tourism and casino business) and YTL Corporation Bhd (electricity, gas and water utilities) employing, respectively, 58 000 and 9 000 workers, over 70% of which are located abroad.
10. All sectors considered, financial institutions and investment holdings are the largest Malaysian companies, in particular Maybank (sales of USD 8.1 billion in 2014), CIMB Group (USD 6.6 billion) and Public Bank (USD 4.9 billion), which range respectively 1st, 2nd and 4th in terms of market capitalisation, see Forbes (2016).
11. State-owned enterprises are defined by the OECD as enterprises where the state has significant control, through full, majority or significant minority ownership (OECD, 2015c). Government-linked companies are defined as companies that have a primary commercial objective and in which the Malaysian government has a direct controlling stake (PGC, 2015a).
12. Petroliam Nasional Bhd (PETRONAS) and Sime Darby Bhd.

13. Proton's R&D expenditure accounted for 8% of its sales in 2005 and nearly 76% of the total R&D expenditure of industry. In 2014, its R&D expenditure amounted to MYR 66.9 million and it employed 600 research engineers in its R&D centre.

14. The increase of business expenditures in absolute and relative terms from 56.7% in 2011 to 64.5% in 2012 is due to the reclassification of five former government research institutes as business companies (MASTIC, 2014a).

15. The previously mentioned change of classification of five government research institutes as business companies in 2012 might also have affected the structure of expenditures.

16. Adapters are defined as firms that only upgraded machinery and equipment or introduced new technology in the last two years; an adopter has upgraded an existing product line or entered new markets; a creator has undertaken some of these activities and has filed patents/utility models or copyright protected materials.

17. 9% of GDP according to Jomo and Edwards (1993), compared with 40% for agriculture and 6% for mining (Peninsular Malaysia only).

18. The sub-sector "global innovation for local markets" comprises chemicals and pharmaceuticals, transport equipment, machinery, and electrical appliances. The sub-sector "global technologies/innovator" includes computers and office machinery; semiconductors and electronics; medical, optical and other precision equipment.

19. These services include research and development (R&D), management consulting, information and communications services, human resource management and employment services, legal services (including those related to intellectual property rights), accounting, financing, and marketing-related service activities (OECD, 2006).

20. "Modern services" comprises knowledge-intensive financial, business and ICT services.

21. In the region, only Indonesia has a higher measure of "upstreamness", whereas latecomer Viet Nam moved significantly downstream between 2000 and 2012.

22. In 2015 (January-September), 93% of the cumulated volume of the 62 investment projects in the E&E industry came from foreign sources (MIDA statistics: www.mida.gov.my/env3/uploads/FactsFiguresPDF/JanSept2015/byIndustry.pdf).

23. See, for instance, the case of SanDisk, which recently established an R&D facility in Penang for the development of advanced packaging and testing. In the same sector, Carsem Malaysia is reported to have upgraded its technology and R&D in advanced semiconductor packaging and testing (EPU, 2014). The most ambitious R&D activities, such as the development of new integrated circuits designs, seems to happen mostly in the MIMOS research institutes available for companies to adopt commercially (ibid.).

24. See the Malaysian Investment Development Authority website at: www.mida.gov.my/home/industry-news/posts.

25. Research surveys and case studies of vertical "productivity spillovers" within GVCs tend to show that backward linkages have a stronger positive effect on the suppliers positioned upstream from the MNEs than forward linkages toward customer sectors (see Havranek and Irsova, 2011). The review and reprocessing of the data of a wide number of studies indicates that recipient countries' firms benefit from greater spillovers when the technological gap to the multinationals' headquarter countries is smaller (ibid.). This might be interpreted in terms of required absorption capacity.

26. Data until November. See: www.myipo.gov.my/web/guest/paten-statistik (accessed 8 January 2016).

27. 50% in 2012 and 36% in 2011. However, these figures include the research institutes incorporated as legal companies (in particular the top local applicants MIMOS, the Malaysian Palm Oil Board and the Malaysian Rubber Board), hence significantly inflating the proportion of companies.

28. With 4 companies among the top 100 applicants, Chinese Taipei is the only Southeast Asian country represented on this list.

29. The oil and gas company PETRONAS and its R&D subsidiary, the Universiti Teknologi PETRONAS. MIMOS, the Malaysian Palm Oil Board and the Malaysian Rubber Board, although legally incorporated, are considered as research institutes here.

30. See also the following related publications: Newman, Shapira and A. Porter (2004); Shapira et al. (2006); Hegde and Shapira (2007); Kay, Youtie and Shapira (2014).

31. The Education Act 1996 (Act 550), the Private Higher Educational Institutions Act 1996 and the National Council of Higher Education Act 1996.

32. Universiti Kebangsaan Malaysia and Universiti Teknologi Malaysia were ranked 259th and 294th while Universiti Sains Malaysia and Universiti Putra Malaysia were 309th and 376th. As for the QS World University Rankings by subject, in 2014, Universiti Sains Malaysia ranked 31st in environmental studies, while Universiti Malaya, Universiti Kebangsaan Malaysia and Universiti Putra Malaysia were ranked within 51-100 for various subjects.

33. The government's goal is to ensure that at least 6 public universities are able to be classified as research universities by 2020, with 20 centres of excellence receiving international recognition and 10% of the research commercialised (Ministry of Higher Education, 2007).

34. In 2012, USM was among the top 50 university applicants, with 39 PCT applications, one position behind Duke University (also with 39) and 6 positions higher than Cambridge University (with 36). USM moved from 10 and 16 PCT applications in 2010 and 2011 respectively, to 39 in 2012 (MASTIC, 2014a).

35. See also Chandran, Farha and Veera (2008); Chandran and Wong (2011); Thiruchelvam, Mohamad and Ng (2011); and Chandran (2010).

36. This is confirmed by the results of the National R&D Survey 2012 (MASTIC, 2014a), where the lack of funding for and the high costs of innovation activities are considered by innovating Malaysian companies to be the main factors hampering innovation activities.

37. This plan was organised in four phases: Phase 1: Laying the foundation (2007-10); Phase 2: Strengthening and enhancement (2011-15); Phase 3: Excellence (2016-20); and Phase 4: Glory and sustainability (beyond 2020).

38. Public universities are audited in four designated areas, namely governance, finance, wealth creation, human resources. Based on the results of these evaluations, the government determines their readiness for autonomous status.

39. In Phase 3 (from 2016 to 2020) the government will expect comprehensive/focused universities to supplement 25% of their operating expenditure and 5% of development expenditure, with research universities supplementing 30% of their operating expenditure and 10% of development expenditure.

40. The authorisation to engage in commercial activities started in the mid-1990s. In 1995, five of the oldest public universities in Malaysia were corporatised, which allowed them to enter into business ventures with the aim of generating their own funds. Such a commercial approach permitted academics to become involved in income generation through consultancy activities.

41. So far it has not been difficult for UNIMAS to fulfil the 30% self-financing requirement. Overall financing has remained stable. Although the 70/30 ratio objective is new, the university is confident that its funding will remain stable, since in the past it has consistently achieved the 30% self-financing goal.

42. SETARA was implemented in 2009 to measure the performance of undergraduate teaching and learning in universities and university colleges in Malaysia. It uses a six-tier scale, with Tier 6 identified as "outstanding" and Tier 1 as "weak".

43. Four main parameters are used for the purpose of evaluation: 1) human capital; 2) publication; 3) patents and intellectual property rights; and 4) income generation.

44. The public universities are: Universiti Malaya, Universiti Sains Malaysia, Universiti Kebangsaan Malaysia, Universiti Putra Malaysia and Universiti Teknologi Malaysia, while the private university is Universiti Teknologi PETRONAS.

45. Previously this system operated through self-assessment and reporting to the Ministry of Education's Department of Higher Education every six months.

46. The following organisations were reclassified as business enterprises: Astronautic Technology, SIRIM, Cyber Security Malaysia, Sarawak Biodiversity Centre and Craun Research.

47. Sarawak's public agencies include the Department of Agriculture (14 FTEs), the Forest Research Centre (6 FTEs), the Fisheries Research Institute-Sarawak (10 FTEs) and an autonomous non-profit agency, the Sarawak Biodiversity Centre (32 FTEs), established to advise the government on policy. Research activities in Sabah are conducted at the Department of Agriculture (27 FTEs) and the Department of Fisheries (2 FTEs). Further information is provided in ASTI (2015).

48. Redefined in 2006, MIMOS' vision is to become the premier applied research centre in frontier technologies, and to transform the landscape of the Malaysian indigenous industries. Towards this end, MIMOS' mission is to pioneer information and communication technologies (ICT) to grow globally competitive indigenous industries. MIMOS' R&D activities are focused on ten technology thrust areas: advanced analysis and modelling, advanced computing, intelligent informatics, information security, knowledge technology, microenergy, microelectronics, nano-electronics, psychometrics, and wireless communications.

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