A major challenge for the region will be to draw on its scientific knowledge base to maintain and expand the range of high-tech exports in increasingly competitive global markets.

Tim Turpin, Jing A. Zhang, Bessie M. Burgos and **Wasantha Amaradasa**

A worker harvests fresh produce from a three-storey greenhouse at the Sky Greens vertical farm in Singapore in 2014. As part of a government drive to increase self-reliance in the production of leafy vegetables, Sky Greens has received some research support.
Photo: © Edgar Su/Reuters

27 · Southeast Asia and Oceania

Australia, Cambodia, Cook Islands, Fiji, Indonesia, Kiribati, Lao People's Democratic Republic, Federated States of Micronesia, Malaysia, Myanmar, Nauru, New Zealand, Niue, Palau, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Thailand, Timor-Leste, Tonga, Tuvalu, Vanuatu, Viet Nam

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INTRODUCTION

The region has largely withstood the global crisis

The countries covered by the present chapter[1] together account for over 9% of the world's population. Taken as a group, they produced 6.5% of the world's scientific publications (2013) but only 1.4% of global patents (2012). GDP per capita at current prices ranges from just under PPP$ 2 000 in Kiribati to PPP$ 78 763 in Singapore (Figure 27.1). Australia and Singapore together produce four-fifths of the region's patents and publications.

Economically, the region fared comparatively well through the global financial crisis of 2008–2009. Although growth rates dipped in 2008 or 2009, a number of countries avoided recession altogether, including Australia (Figure 27.2). As a consequence, pressures on budgets for science and technology (S&T) have not been as severe as predicted back in 2010. Timor-Leste even recorded insolent growth rates up until 2012, buoyed by foreign direct investment (FDI) that peaked at 6% of GDP in 2009 before falling back to just over 1.6% in 2012.

According to the World Bank's Knowledge Economy Index, there has been a general slip in overall rankings in Southeast Asia since 2009. New Zealand and Viet Nam are the only ones to have improved their position. Some, such as Fiji, the Philippines and Cambodia, even slipped considerably over this period. Singapore continues to lead the region for the innovation component of the same index and Australia and New Zealand that for education. The Global Innovation Index tends to rank countries in a similar order.

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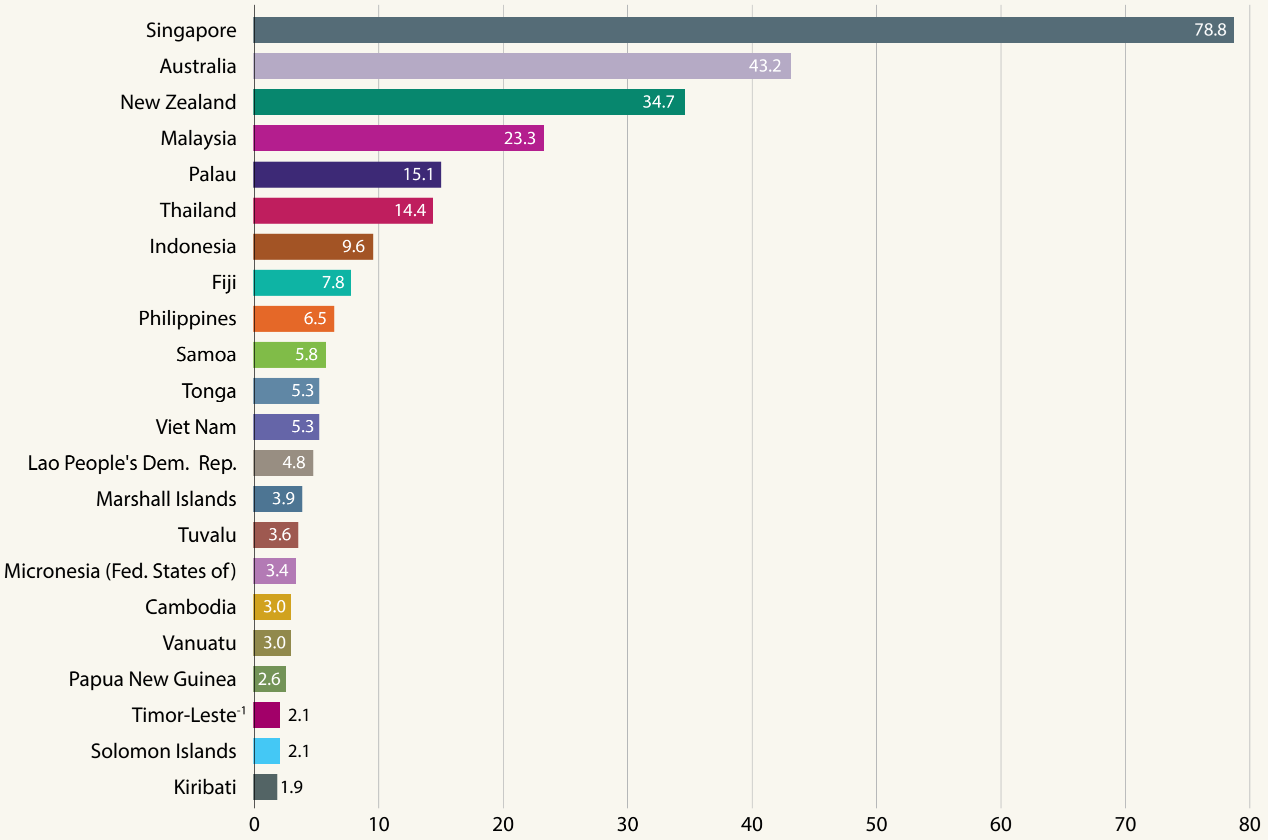
1. Malaysia is covered in greater detail in Chapter 26.

Figure 27.1: **GDP per capita in Southeast Asia and Oceania, 2013**

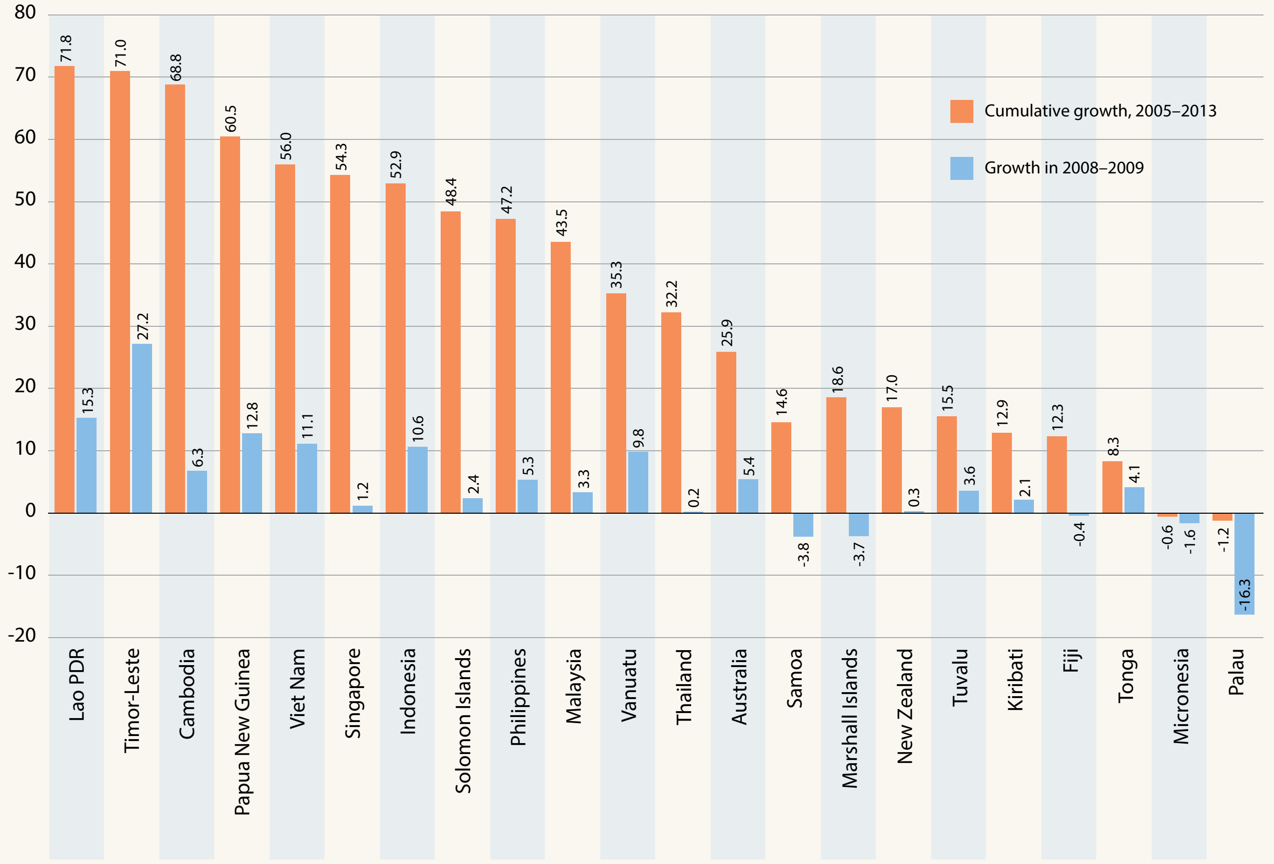
In thousands of current PPP$



-n = data are for *n* years before reference year

Source: World Bank's World Development Indicators, April 2015

Figure 27.2: **Trends in GDP growth in Southeast Asia and Oceania, 2005–2013**



Note: For Timor-Leste, the most recent data are for 2012, not 2013.
Source: World Bank's World Development Indicators, April 2015

Strong growth in internet access since 2010 has levelled out the disparity between countries to some extent, although connectivity remained extremely low in the Solomon Islands (8%), Cambodia (6%), Papua New Guinea (6.5%), Myanmar (1.2%) and Timor-Leste (1.1%) in 2013 (Figure 27.3). Advances in mobile phone technology have clearly been a factor in the provision of internet access to remote areas. The flow of knowledge and information through internet is likely to play an important role in the more effective dissemination and application of knowledge across the vast Pacific Island nations and least developed countries of Southeast Asia.

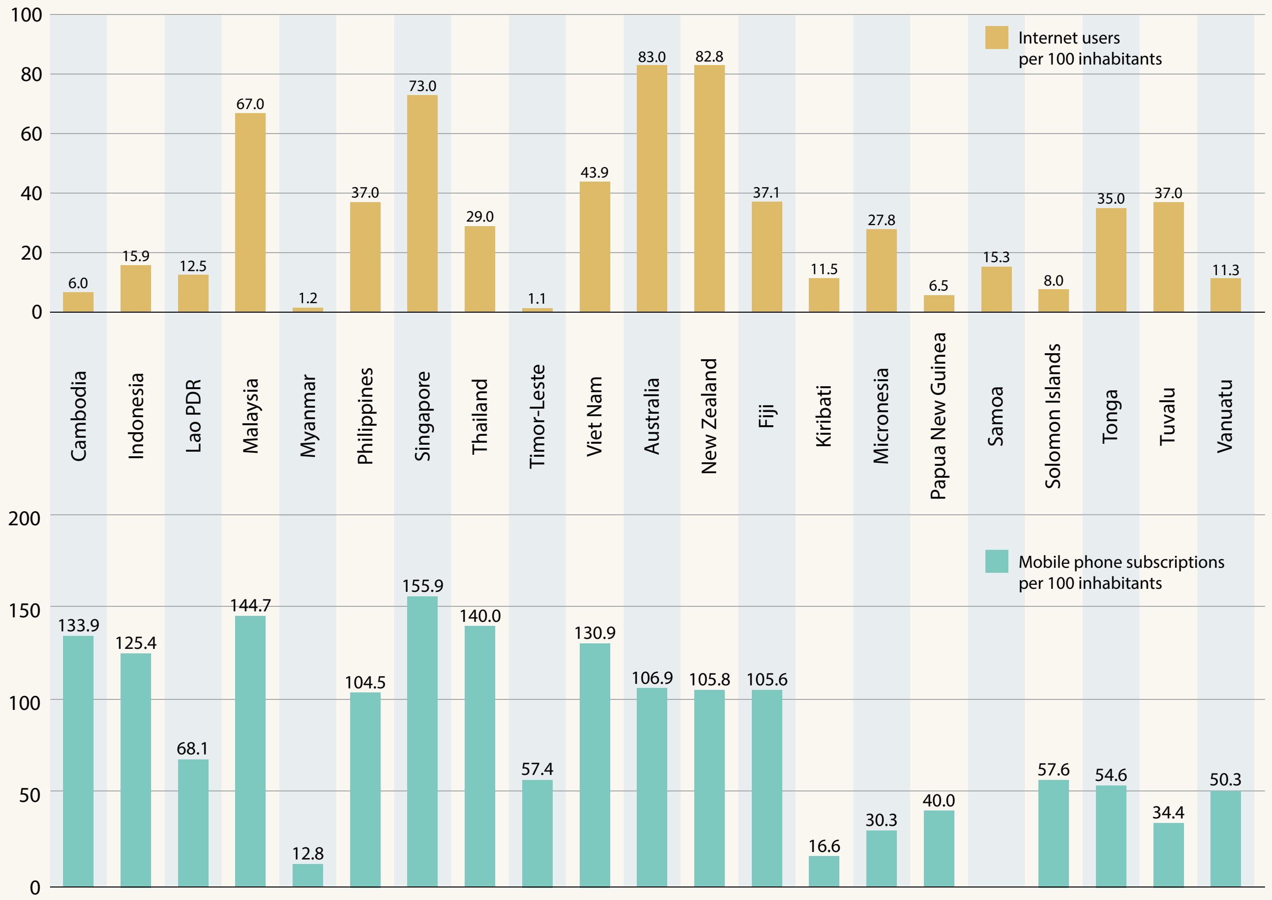
Political change at national and regional levels

Thailand has been experiencing political instability for the past five years, culminating in a military coup in 2014 and erratic economic growth. Indonesia, by contrast, has enjoyed a period of comparative stability with economic growth of about 4% on average since 2010; the government elected in 2014 has introduced a number of fiscal and structural reforms designed to encourage investment (World Bank, 2014). These reforms should help accelerate business R&D, which was already showing solid growth in 2010.

Myanmar has been undergoing a period of democratic reform since 2011, which has prompted the easing of international sanctions. The return of US and European Union (EU) trade privileges has already generated significant investment growth across many sectors. A foreign investment law passed in 2012, followed in January 2014 by a Special Economic Zone Law, provides incentives for export-oriented industries. Myanmar's geostrategic location between India and China, coupled with the creation of the Association of Southeast Asian Nations (ASEAN) Economic Community in 2015, has led the Asian Development Bank to predict an 8% growth rate per year for Myanmar through the next decade.

Australia's incoming government in September 2013 coincided with a steep decline in the value of its natural resources, as demand for minerals eased in China and elsewhere. As a consequence, the new government sought to reduce public spending, in order to balance its 2014–2015 budget. Science and technology were among the many casualties of this cost-cutting exercise. On 17 June 2015, Australia signed a free trade agreement with China which removes almost all import duties. 'It is the highest degree

Figure 27.3: **Internet and mobile phone access in Southeast Asia and Oceania, 2013 (%)**



Source: International Telecommunications Union

of liberalization of all the free trade agreements China has so far signed with any economy', commented China's commerce minister Gao Hucheng at the signing (Hurst, 2015).

A common market by the end of the year

The ASEAN countries intend to transform their region into a common market and production base with the creation of the ASEAN Economic Community by the end of 2015. The planned removal of restrictions to the cross-border movement of people and services is expected to spur co-operation in science and technology. Moreover, the increased mobility of skilled personnel within the region should be a boon for the development of skills, job placement and research capabilities within ASEAN member states and enhance the role of the ASEAN University Network (Sugiyarto and Agunias, 2014). As part of the negotiating process, each member state may express its preference for a specific research focus. The Laotian government, for instance, hopes to prioritize agriculture and renewable energy. More contentious are proposals to develop hydropower on the Mekong River, given the drawbacks of this energy option (Pearse-Smith, 2012).

TRENDS IN STI GOVERNANCE

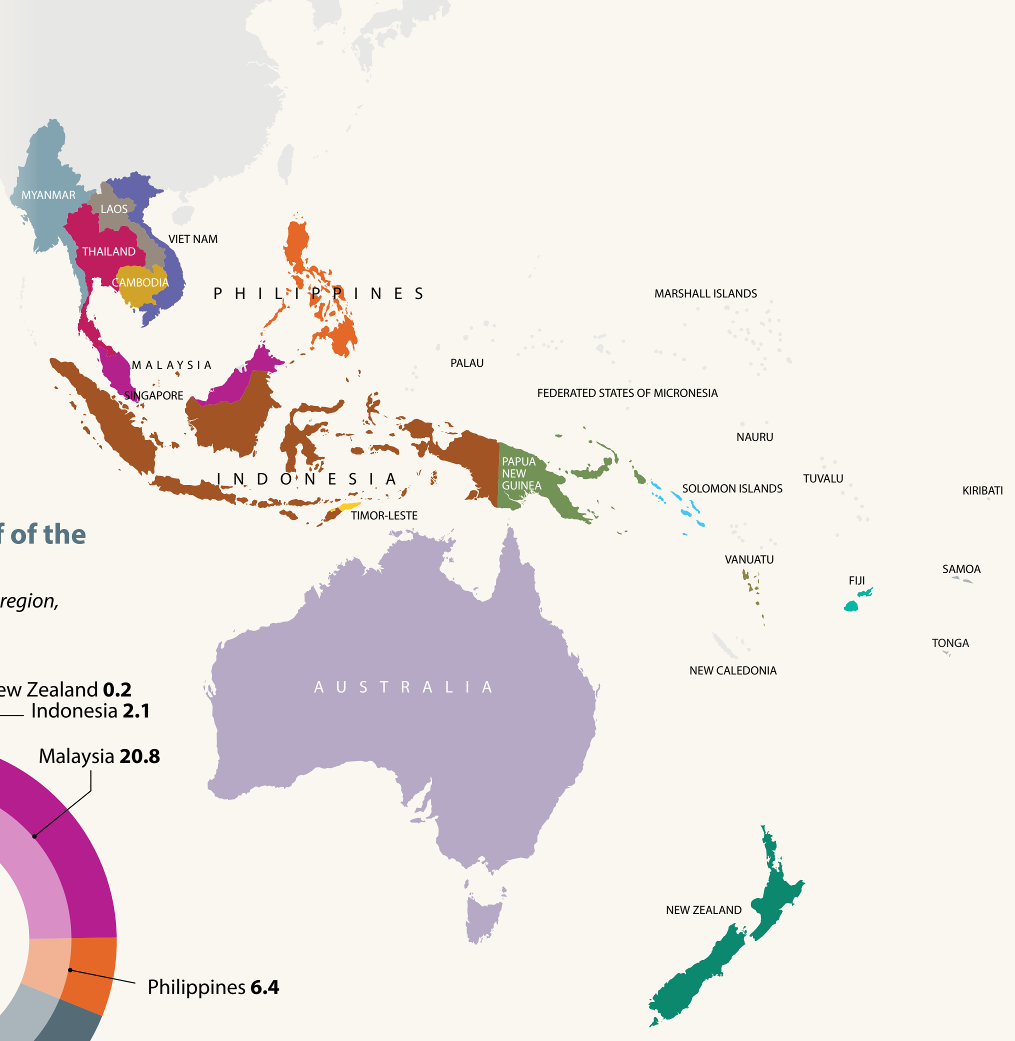
High-tech exports have defied predictions

In spite of pessimistic predictions, high-tech exports across the region have performed well since 2008. Overall, high-tech exports from all countries in the region increased by 28%. However, the situation has not been uniform. Between 2008 and 2013, almost all countries increased the value of their exports. For Malaysia and Viet Nam, the increase was significant: high-tech exports from Viet Nam increased almost tenfold. The Philippines, by contrast, recorded a reduction of nearly 27% over the same period.

Four countries dominate the export of high-tech products from the region. Singapore accounts for nearly 46% and Malaysia just under 21% (Figure 27.4). Malaysia, Singapore, Thailand and Viet Nam together account for 90% of high-tech exports from the region. Two product categories dominate these exports: computers/office machines (19.3%) and, above all, electronic communications: (67.1%). It is likely that these export products included a considerable proportion of re-exported components, so these data should be interpreted accordingly. Although Singapore and Malaysia record a

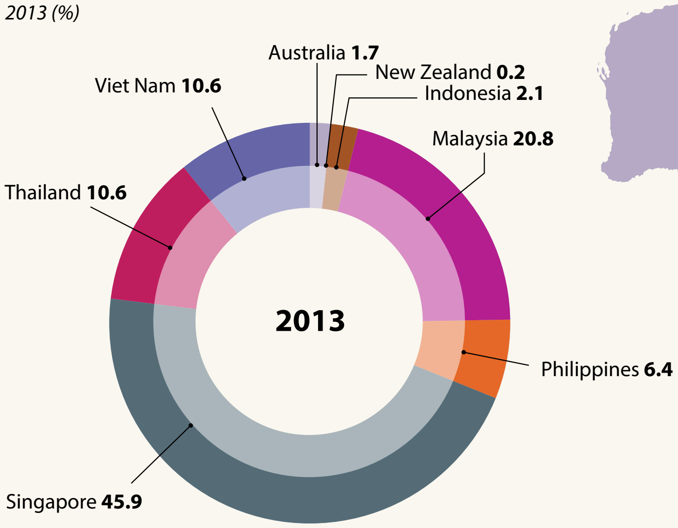
Figure 27.4:

Trends in high-tech exports from Southeast Asia and Oceania, 2008 and 2013



Singapore exports almost half of the region's high tech goods

National shares of high-tech exports from the region, 2013 (%)



Note: The regional shares of Cambodia, Fiji, Kiribati, Myanmar, Palau, Papua New Guinea, Samoa, the Solomon Isalnds, Timor-Leste, Tonga and Vanuatu are close to zero.

45.9%

Singapore's share of the region's high-tech exports in 2013

20.8%

Malaysia's share of the region's high-tech exports in 2013

10.6%

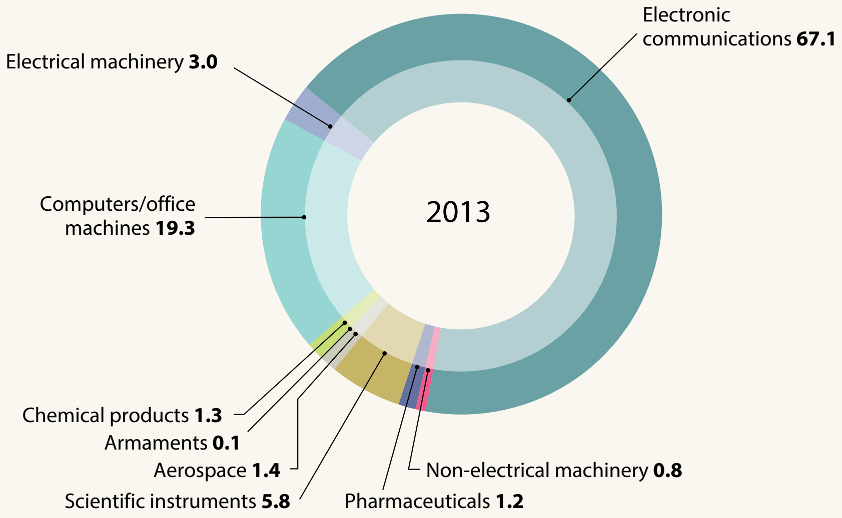
Respective shares of Thailand and Viet Nam in the region's high-tech exports in 2013

1.7%

Australia's share of the region's high-tech exports in 2013

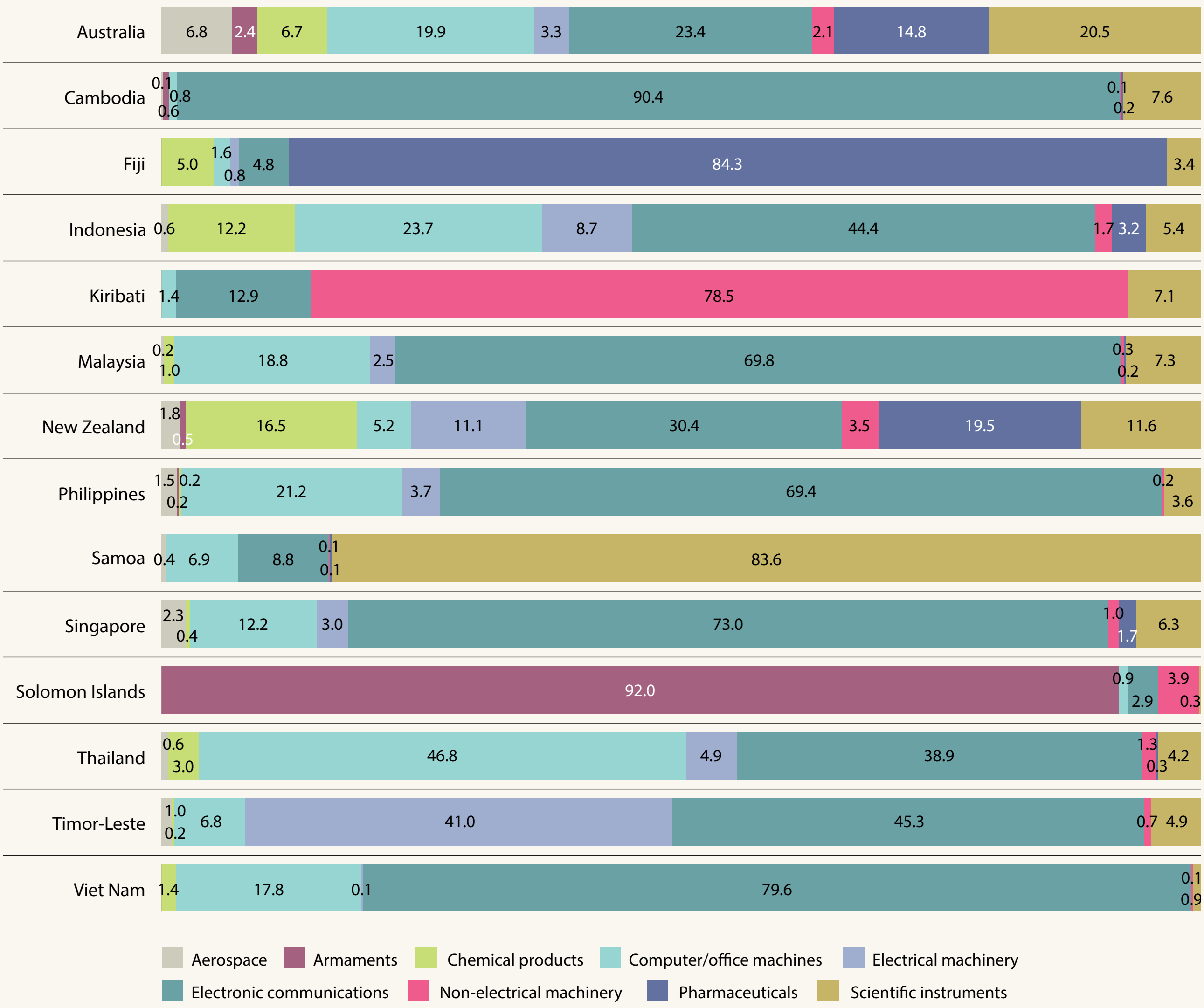
Share of electronic communications in the region's high-tech exports (%)

Total exports from the region by type, 2013



Electronic communications dominate high-tech exports

National high-tech exports by type, 2013 (%)



Growth in high-tech exports has been fastest in Cambodia and Viet Nam, exports have receded in the Philippines and Fiji

US$ millions

	High-tech exports (US$ millions)		Change (US$ millions)	Change (%)
	2008	2013		
Australia	4 340.3	5 193.2	852.9	19.7
Cambodia	3.8	76.5	72.7	1 913.6
Fiji	5.0	2.7	-2.3	-45.7
Indonesia	5 851.7	6 390.3	538.6	9.2
Malaysia	43 156.7	63 778.6	20 622.0	47.8
New Zealand	624.3	759.2	134.9	21.6
Philippines	26 910.2	19 711.4	-7 198.8	-26.8
Samoa	0.3	0.2	-0.1	-40.6
Singapore	123 070.8	140 790.8	17 719.9	14.4
Thailand	33 257.9	37 286.4	4 028.5	12.1
Viet Nam	2 960.6	32 489.1	29 528.5	997.4
Total	240 181.9	306 482.5	66 300.7	27.6

Source: United Nations' Comtrade database comparatively high proportion of business sector R&D, it is likely that much of the research associated with computers/office machines and electronic communications could be undertaken globally, rather than locally. Both countries host numerous large multinational companies. Australia also has a high proportion of business sector funding but, in Australia's case, this is largely a product of R&D undertaken in, and on behalf of, the mining and minerals sector.

Although scientific output has increased in global terms, there has been no overall rise in the level of patenting across the region. The region has even receded for this metric: Southeast Asia and Oceania produced 1.4% of the world's patents in 2012, compared to 1.6% in 2010, largely owing to the drop in patents registered from Australia. Four countries accounted for 95% of the patents obtained by the region: Australia, Singapore, Malaysia and New Zealand. The significant rise in high-tech exports across some countries in the region is at odds with the comparatively small global proportion of patenting activity. A major challenge for the region will be to draw on its scientific knowledge base to maintain and expand the range of high-tech exports in increasingly competitive global markets.

Squaring science policy with sustainable development still a challenge

A tension between the competing objectives of scientific excellence and scientific practice characterizes much of the region. In most countries, there is a clear desire to link S&T policies to innovation and development strategies. In the industrialized economies of Australia, New Zealand and Singapore, investment in science is viewed, in policy terms, as a component of national innovation strategies. Making science subservient to economic objectives at the policy level nevertheless carries a danger of underserving the many ways in which science can underpin socio-economic and cultural development, such as in health, education or in addressing global sustainability challenges.

Among developing economies, science policy is generally linked to development strategies yet, in this context too, there is a tension between assessments of scientific capacity through measures such as citation and development priorities. Among the poorer countries such as Cambodia, Lao PDR and Timor-Leste, or transition economies such as Myanmar, the development imperative is evident in recent policy documents which focus on harnessing human capital to serve basic development needs. International projects can be a way of reconciling limited national means with sustainable development goals. For instance, the Asian Development Bank funded a project to develop the use of biomass in three of the six countries located[2] in the Greater Mekong Subregion between 2011 and 2014: Cambodia, Lao People's Democratic Republic (PDR) and Viet Nam.

Many of the less economically developed countries are struggling to steer their own scientific efforts toward sustainable development, at a time when the United Nations' Sustainable Development Goals are about to take over from the Millennium Development Goals in late 2015. They could begin by encouraging their scientists to focus more on attaining local goals for sustainable development, rather than on publishing in high-profile international journals on topics that may be of lesser local relevance. The difficulty with this course of action is that the key metrics for recognizing scientific quality are publications and citation data. The answer to this dilemma most likely lies in the need to recognize the global nature of many local development problems. As pointed out by Perkins (2012):

> *We are dealing with problems without boundaries and we underestimate the scale and nature of their consequences at our collective peril. As global citizens, the research and policy communities have an obligation to collaborate and deliver, so arguing for national priorities seems irrelevant.*

TRENDS IN R&D

Developing research personnel high on the agenda

Across the region, human resources for S&T are primarily concentrated in Australia, Malaysia, Singapore and Thailand. The strongest concentration of researchers is to be found in Singapore, which, with 6 438 full-time equivalent (FTE) researchers per million inhabitants in 2012, is well ahead of all G7 countries (Table 27.1). Technicians across the region are most concentrated in Australia and New Zealand, reflecting a pattern found in other mature economies, but Singapore has a much lower concentration. One of the driving forces for the freer flow of skills across ASEAN member States has been the demand from Malaysia and Singapore for ready access to technical personnel from elsewhere in the region. Malaysia and Thailand are both suppliers and recruiters of skilled personnel, as are the Philippines in some specialist fields. The freer flow of skilled personnel across ASEAN after 2015 should benefit both supplier and recruiter nations.

In terms of research training, Malaysia and Singapore stand out for their significant investment in tertiary education. Over the past decade, the share of their education budget devoted to tertiary education has risen from 20% to over 35% in Singapore and 37% in Malaysia (Figure 27.5). These two countries also happen to have the greatest share of PhD candidates among university students. In most countries, new institutions have sprung up to accommodate the growing demand for higher education.

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[2] the other three being China, Myanmar and Thailand

Table 27.1: **Research personnel in Southeast Asia and Oceania, 2012 or closest year**

	Population ('000s)	Total researchers (FTE)	Researchers per million inhabitants (FTE)	Technicians per million inhabitants (FTE)
Australia (2008)	21 645	92 649	4 280	1 120
Indonesia (2009)	237 487	21 349	90	–
Malaysia (2012)	29 240	52 052	1 780	162
New Zealand (2011)	4 414	16 300	3 693	1 020
Philippines (2007)	88 876	6 957	78	11
Singapore (2012)	5 303	34 141	6 438	462
Thailand (2011)	66 576	36 360	546	170

Source: UNESCO Institute for Statistics, June 2015

There is also a growing pattern of subregional university collaboration. The ASEAN University Network established in the late 1990s now consists of 30 universities across the ten ASEAN countries. It has served as a model for more recent spin-offs, such as the Pacific Island Network constituted in 2011, which consists of ten Pacific universities operating across five countries. In parallel, many Australian and New Zealand universities have established campuses at universities across the region.

Four countries have a high proportion of tertiary students enrolled in science degrees: Myanmar (23%), New Zealand and Singapore (each with 14%) and Malaysia (13%). Myanmar also has the highest proportion of women enrolled in tertiary education, in general. It will be interesting to see if Myanmar manages to maintain this high proportion of women among students as it pursues its transition.

Women constitute half of researchers in Malaysia, the Philippines and Thailand but remain an unknown quantity in Australia and New Zealand, for which there are no recent data (Figure 27.6). More than half of researchers are employed by the higher education sector in most countries (Figure 27.7). Academics even make up eight out of ten researchers in Malaysia, suggesting that the multinational companies on its soil either do not count a majority of Malaysians on their research staff or do not conduct in-house R&D. The notable exception is Singapore, where half of researchers are employed by industry, compared to between 30% and 39% elsewhere in the region. In Indonesia and Viet Nam, the government is a major employer of researchers.

Better R&D data as vital as greater investment

Although data on gross domestic expenditure on R&D (GERD) are rather sketchy and date back several years in many cases – or are even non-existent for the smallest Pacific Island states – they still illustrate the blend of scientific capacity across Southeast Asia and Oceania. Singapore has ceded its regional lead for R&D intensity, which shrank from 2.3% to 2.0% of GDP between 2007 and 2012, having been overtaken by Australia, which has maintained a steady investment level of 2.3% of GDP in R&D (Table 27.2). Australia's dominant position may be short-lived, however, as Singapore plans to increase its GERD/GDP ratio to 3.5% by 2015.

A comparatively high share of R&D is performed by the business sector in four countries: Singapore, Australia, the Philippines and Malaysia (see Chapter 26). In the case of the latter two, this is most likely a product of the strong presence of multinational companies in these countries. Since 2008, many countries have boosted their R&D effort, including in the business enterprise sector. However, in some cases, business expenditure on R&D is highly concentrated in the natural resource sector, such as mining and minerals in Australia. The challenge for many countries will be to deepen and diversify business sector involvement across a wider range of industrial sectors.

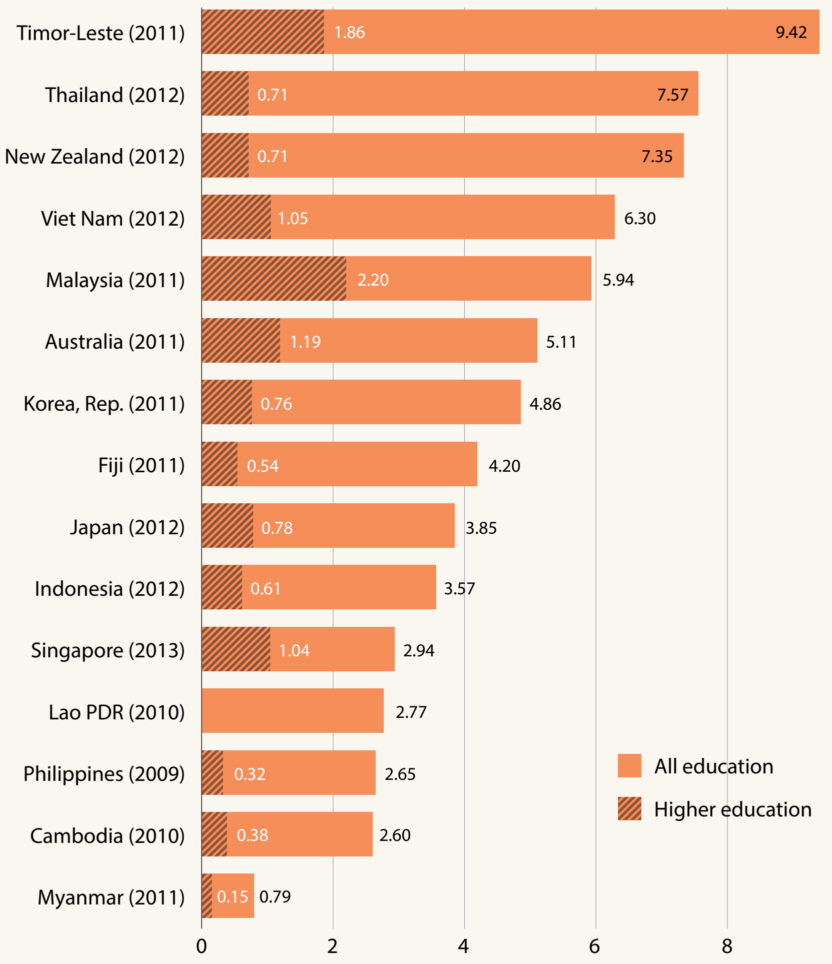
An emerging Asia–Pacific knowledge hub

The number of scientific publications catalogued in the Web of Science by the countries under study showed healthy growth between 2005 and 2014, some Asian countries even recording annual growth of 30% or more (Figure 27.8). Fiji and Papua New Guinea were the main contributors to publications from the Pacific Island states. Whereas Australia and New Zealand publish more in life sciences, the Pacific Islands tend to focus on geosciences. Southeast Asian countries specialize in both.

Figure 27.5: **Trends in higher education in Southeast Asia and Oceania, 2013 or closest year**

Five countries devote more than 1% of GDP to higher education

As a share of GDP, 2013 (%)



2.20%

Share of GDP devoted to higher education by Malaysia in 2011

0.15%

Share of GDP devoted to higher education by Myanmar in 2011

19.9%

Average share of spending on higher education in Southeast Asia and Oceania within education expenditure (%)

3.3%

Average share of the population enrolled in higher education in Southeast Asia and Oceania (among countries listed in the table below)

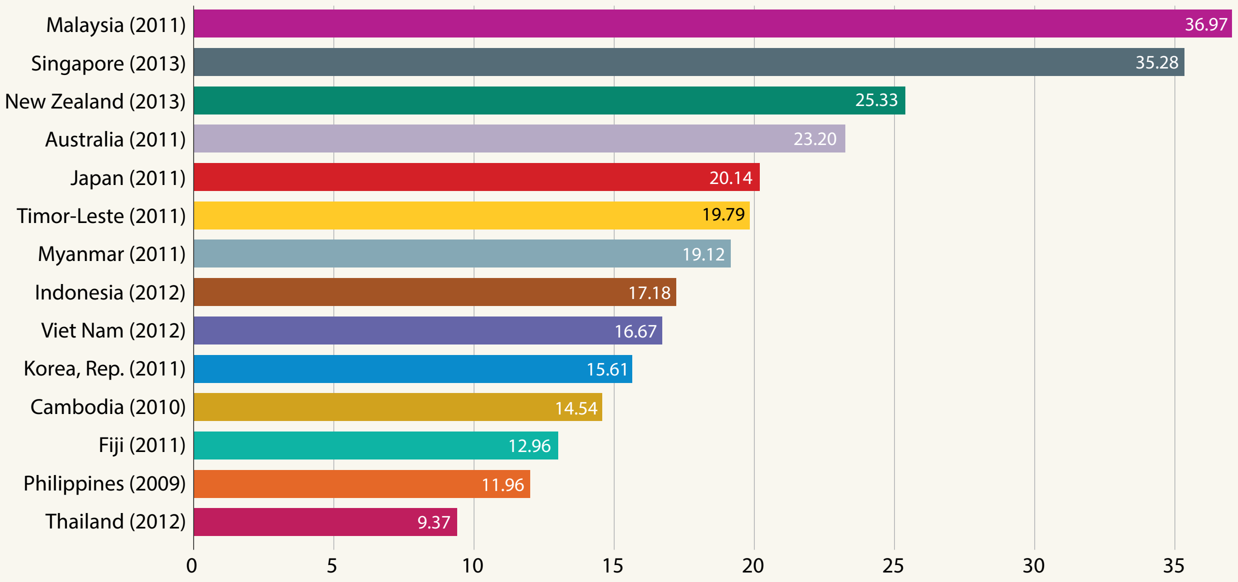
Australia and New Zealand count the greatest share of tertiary students among the total population

	Year	Tertiary enrolment, all fields	Share of total pop. (%).	Tertiary enrolment in scientific disciplines	Share of science in tertiary enrolment (%)
Australia	2012	1 364 203	5.9	122 085	8.9
New Zealand	2012	259 588	5.8	36 960	14.2
Singapore	2013	255 348	4.7	36 069	14.1
Malaysia	2012	1 076 675	3.7	139 064	12.9
Thailand	2013	2 405 109	3.6	205 897	8.2^{-2}
Philippines	2009	2 625 385	2.9	–	–
Indonesia	2012	6 233 984	2.5	$433\ 473^{-1}$	8.1
Viet Nam	2013	2 250 030	2.5	–	–
Lao PDR	2013	137 092	2.0	$6\ 804^{-1}$	5.4^{-1}
Cambodia	2011	223 222	1.5	–	–
Myanmar	2012	634 306	1.2	148 461	23.4

-n = data are for *n* years before reference year

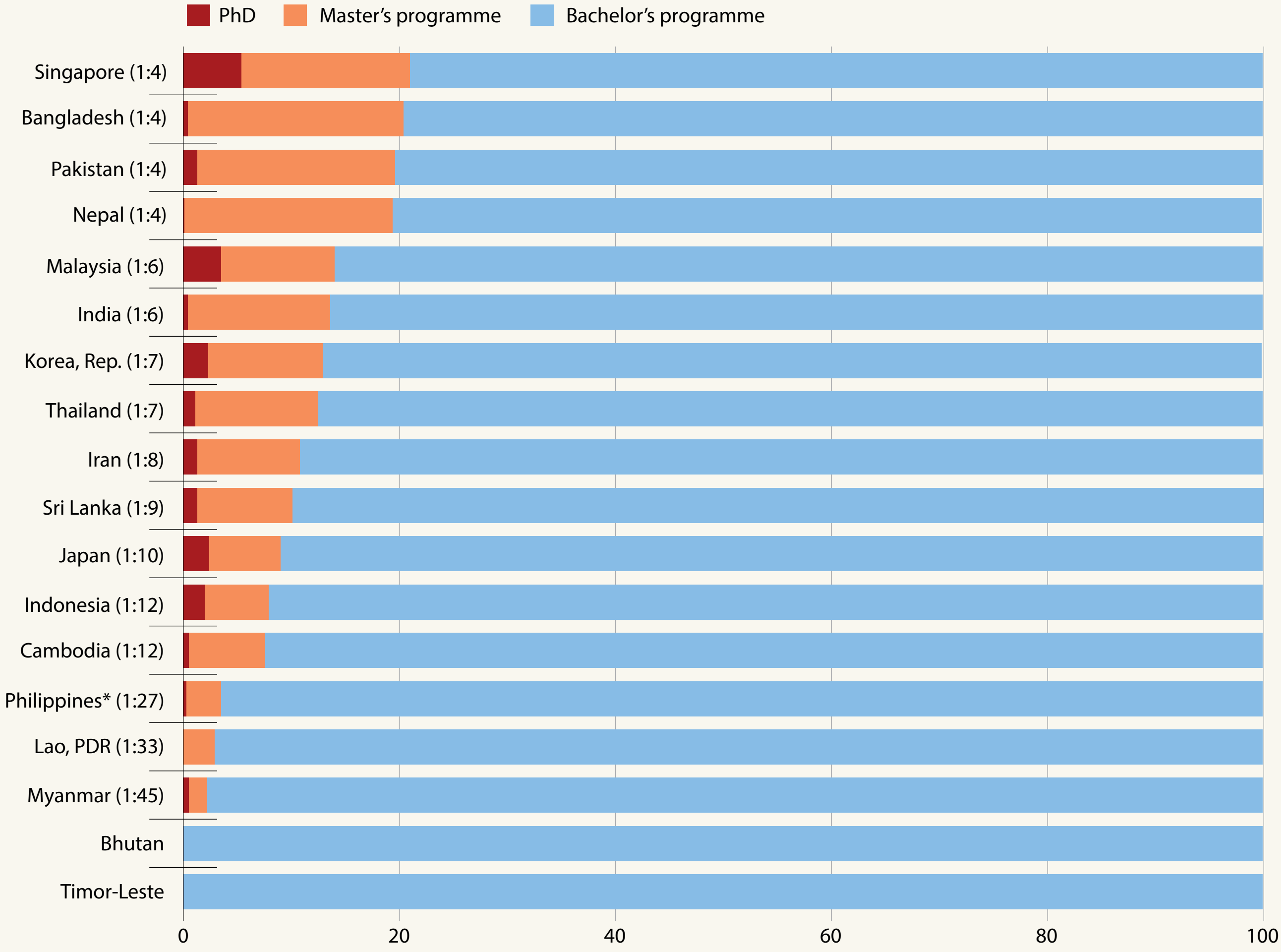
More than one-third of education spending goes on higher education in Malaysia and Singapore

As a share of total public expenditure on education, 2013 or nearest year (%)



Singapore and Malaysia have the greatest share of PhD students among university students

University enrolment in Asia by level of study, 2011, selected countries



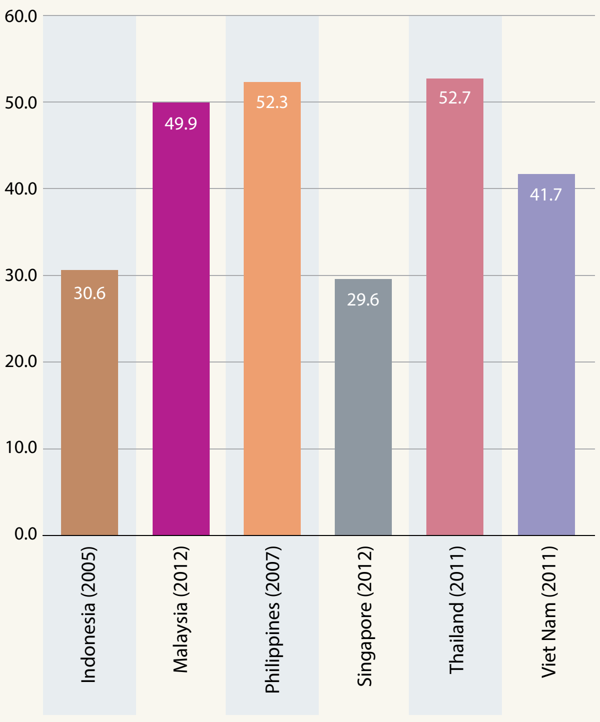
* Data for the Philippines are for 2008.

Note: Between brackets is the ratio of enrolment in master's/PhD programmes to bachelor's programmes.

Source: UNESCO Institute for Statistics, June 2015; for university enrolment in Asia: UIS (2014)

Figure 27.6: **Women researchers (HC) in Southeast Asia, 2012 or closest year (%)**

Head counts



Source: UNESCO Institute for Statistics, June 2015

Countries around the Pacific Rim are seeking ways to link their national knowledge base to regional and global advances in science. One motivation for this greater interconnectedness is the region's vulnerability to geohazards such as earthquakes and tsunamis – the Pacific Rim is not known as the Ring of Fire for nothing. The need for greater disaster resilience is inciting countries to develop collaboration in the geosciences. Climate change is a parallel concern, as the Pacific Rim is also one of the most vulnerable regions to rising sea levels and increasingly capricious weather patterns. In March 2015, much of Vanuatu was flattened by Cyclone Pam. Partly to ensure the viability of its agriculture, Cambodia has adopted a *Climate Change Strategic Plan* covering 2014 –2023, with financial support from the European Union and others.

The citation rate for papers published across the region is growing. Between 2008 and 2012, countries from Southeast Asia and Oceania surpassed the OECD average for the number of papers among the 10% most-cited. In some cases, the growth in international co-authorship may be a factor in this positive outcome, as in Cambodia. All but Viet Nam and Thailand have increased their share of internationally co-authored scientific papers over the past decade. For the smaller or transition economies, international collaboration even represents more than 90% of the total, as in Papua New Guinea, Cambodia, Myanmar and some Pacific Island states.

Although collaboration is strongly linked to global knowledge hubs such as the USA, UK, China, India, Japan and France, there is evidence of an emerging Asia–Pacific 'knowledge hub.' Australia, for instance, is one of the top five collaborators for 17 of the 20 countries in Figure 27.8.

The Asia–Pacific Economic Cooperation (APEC) intends to accompany the development of an Asia–Pacific knowledge hub. APEC completed a study[3] in 2014 of skills shortages in the region, with a view to setting up a monitoring system to address training needs before these shortages become critical.

The ASEAN Committee on Science and Technology launched the ASEAN Krabi initiative in 2010, which has since developed the *ASEAN Plan of Action on Science, Technology and Innovation* (APASTI) covering the period 2016–2020. The interesting feature of APASTI is its integrated approach to science, technology and innovation (STI); it seeks to raise competitiveness across the region by contributing to both social inclusion and sustainable development. APASTI is scheduled to be adopted by ASEAN member states by the end of 2015; it identifies eight thematic areas:

- Focusing on global markets;
- Digital communication and social media;
- Green technology;
- Energy;
- Water resources;
- Biodiversity;
- Science; and
- 'Innovation for life'.

In parallel, schemes such as the annual ASEAN–European Union Science, Technology and Innovation Days are reinforcing dialogue and co-operation between these two regional bodies. The second of these days took place in France in March 2015 and the third is scheduled to take place in Viet Nam in 2016. In 2015, the theme was Excellent Science in ASEAN. Some 24 exhibitors presented research from their institution or enterprise. There were also sessions on scientific topics and two policy sessions, one on the evolution of the ASEAN Economic Community and the second on the importance of intellectual property rights for the Pacific region. This annual forum was launched within the Southeast Asia–EU Network for Biregional Co-operation project (SEA–EU NET II) funded by the EU's Seventh Framework Programme for Research and Innovation. A network to foster policy dialogue between the EU and the Pacific region has been launched within the same framework programme (see p. 725).

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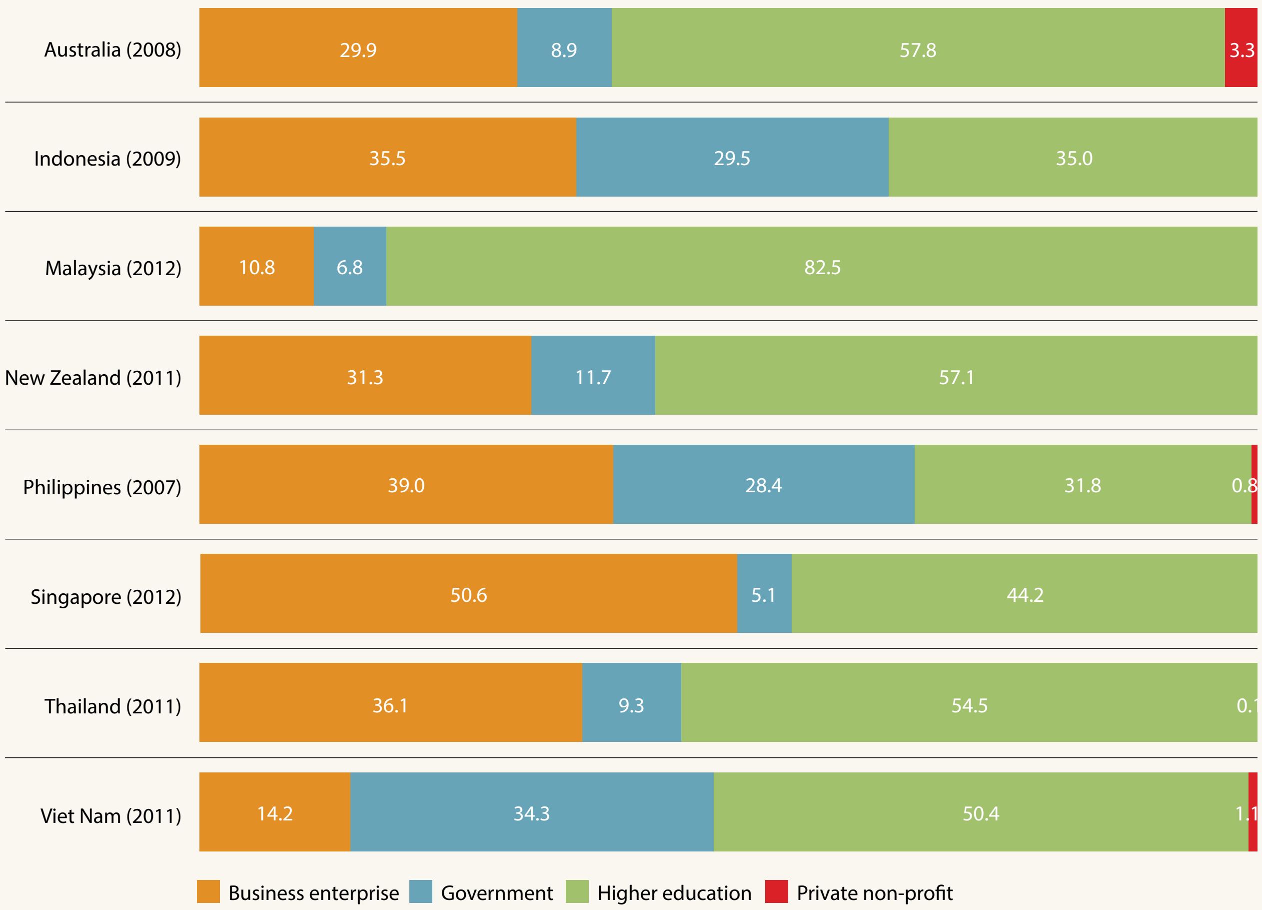
[3] See: http://hrd.apec.org/index.php/APEC_Skills_Mapping_Project

Figure 27.7: **Researchers (FTE) in Southeast Asia and Oceania by sector of employment, 2012 or closest year (%)**



Note: The data for Viet Nam are by head count.

Source: UNESCO Institute for Statistics, June 2015

Table 27.2: **GERD in Southeast Asia and Oceania, 2013 or closest year**

	As % of GDP	Per capita PPP$	Share performed by business (%)	Share funded by business (%)
Australia (2011)	2.25	921.5	57.9	61.9^{-3}
New Zealand (2009)	1.27	400.2	45.4	40.0
Indonesia (2013*)	0.09	6.2	25.7	–
Malaysia (2011)	1.13	251.4	64.4	60.2
Philippines (2007)	0.11	5.4	56.9	62.0
Singapore (2012)	2.02	1 537.3	60.9	53.4
Thailand (2011)	0.39	49.6	50.6	51.7
Viet Nam (2011)	0.19	8.8	26.0	28.4

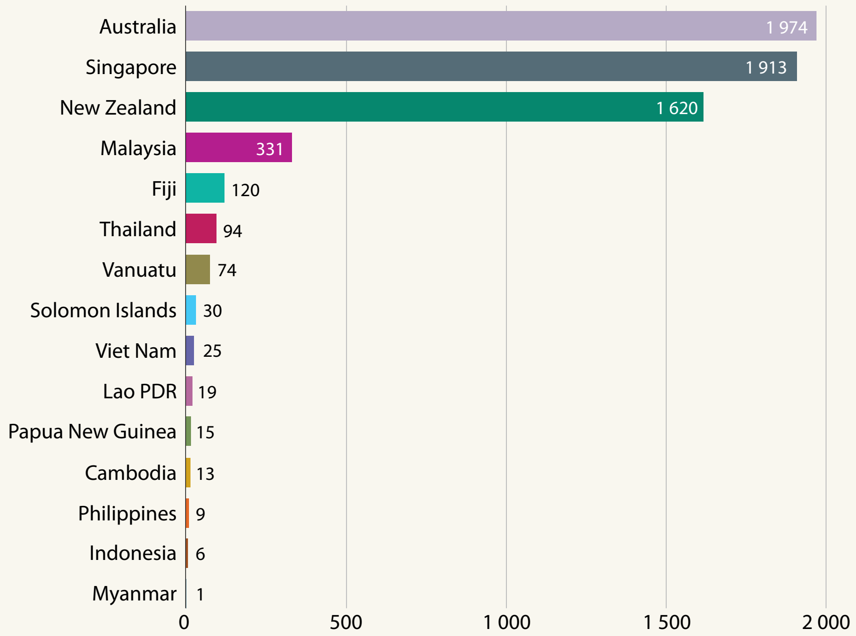
* national estimate

Source: UNESCO Institute for Statistics, June 2015

Figure 27.8: **Scientific publication trends in Southeast Asia and Oceania, 2005–2014**

Scientists from Australia, Singapore and New Zealand are the most prolific

Publications per million inhabitants in 2014



60.1%

Malaysia's annual growth rate for the number of publications, 2005–2014

31.2%

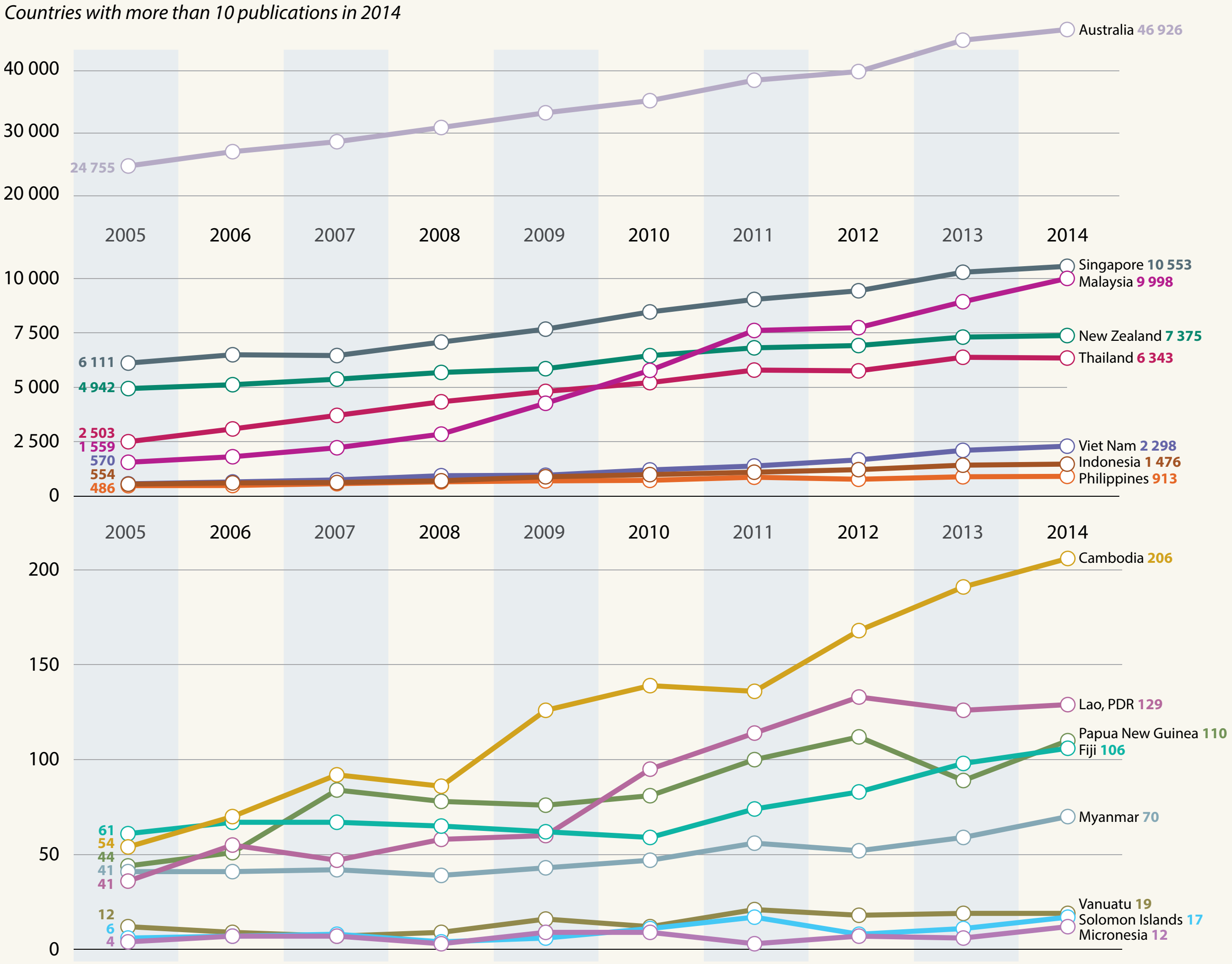
Average annual growth in publications from Viet Nam, Cambodia and Lao PDR, 2005–2014

7.8%

Average annual growth in publications from Australia, New Zealand and Singapore, 2005–2014

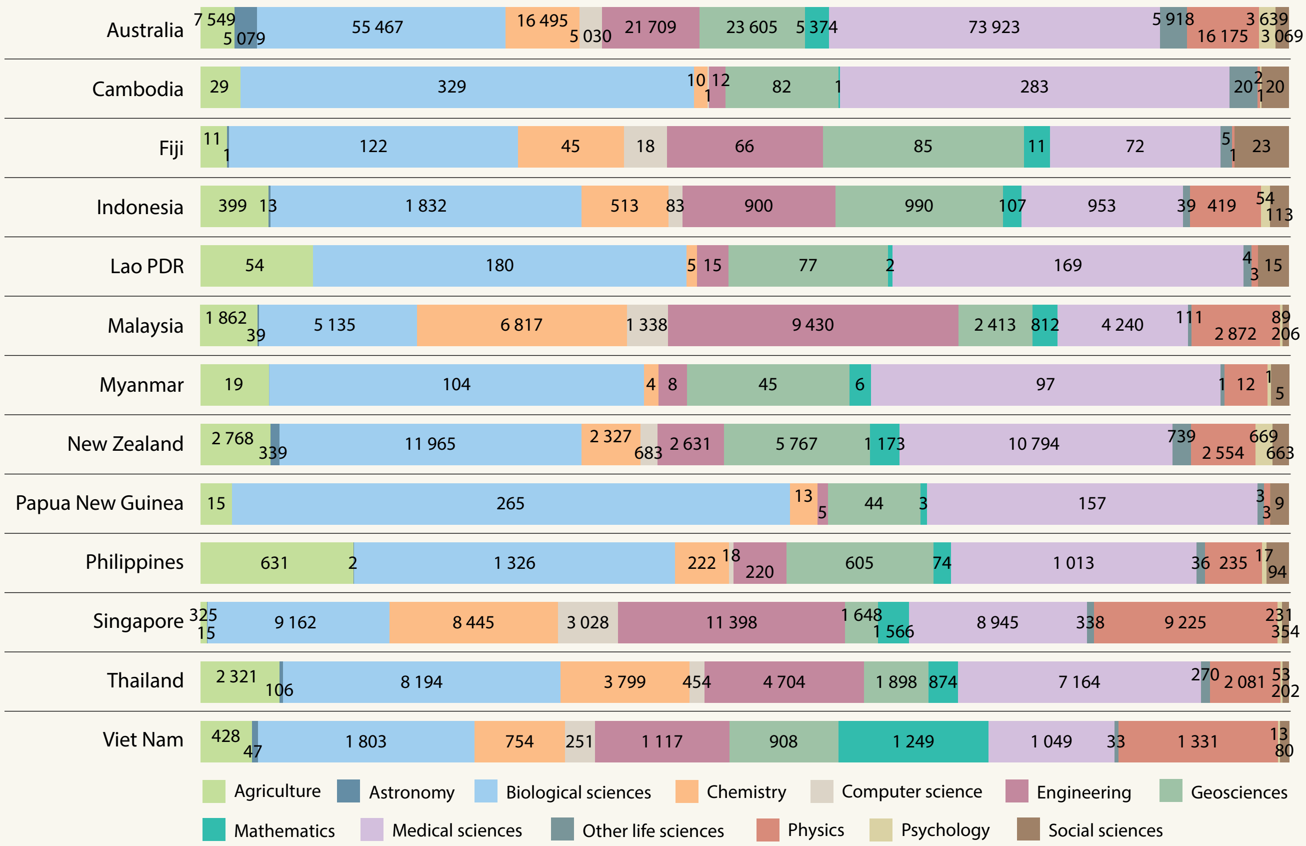
Steady growth in the most prolific countries

Countries with more than 10 publications in 2014



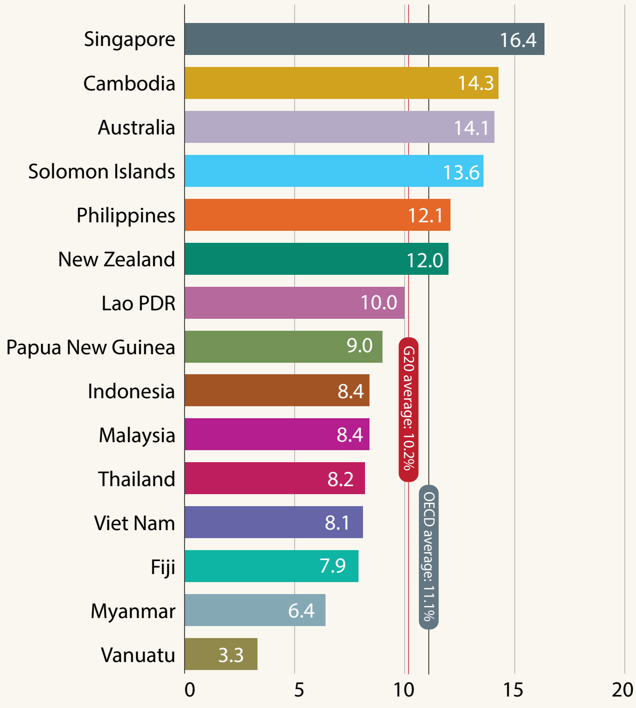
Engineering dominates in Malaysia and Singapore, life sciences and geosciences elsewhere

Countries with more than 20 publications in 2014; cumulative totals by field, 2008–2014



Note: Unclassified articles are excluded.

Six countries topped the OECD average for the share of papers among the 10% most cited between 2008 and 2012



Five countries topped the OECD average for the average citation rate between 2008 and 2012

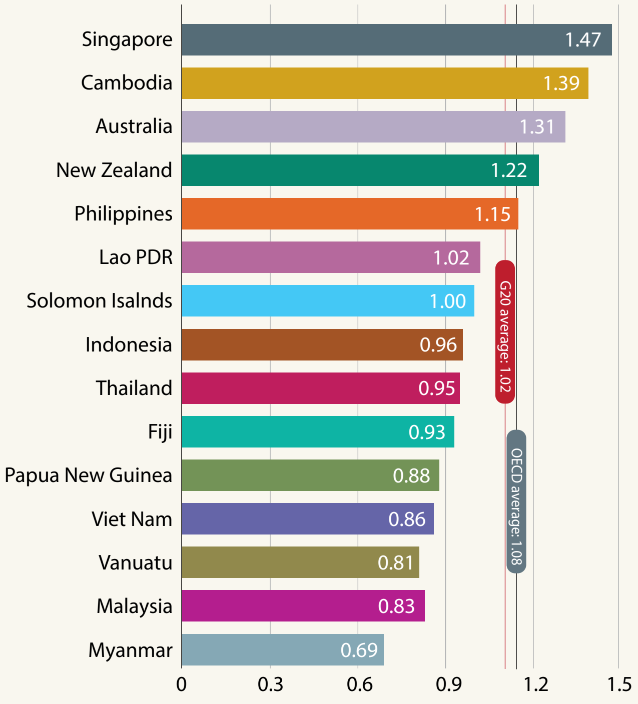


Figure 27.8 *(continued)*

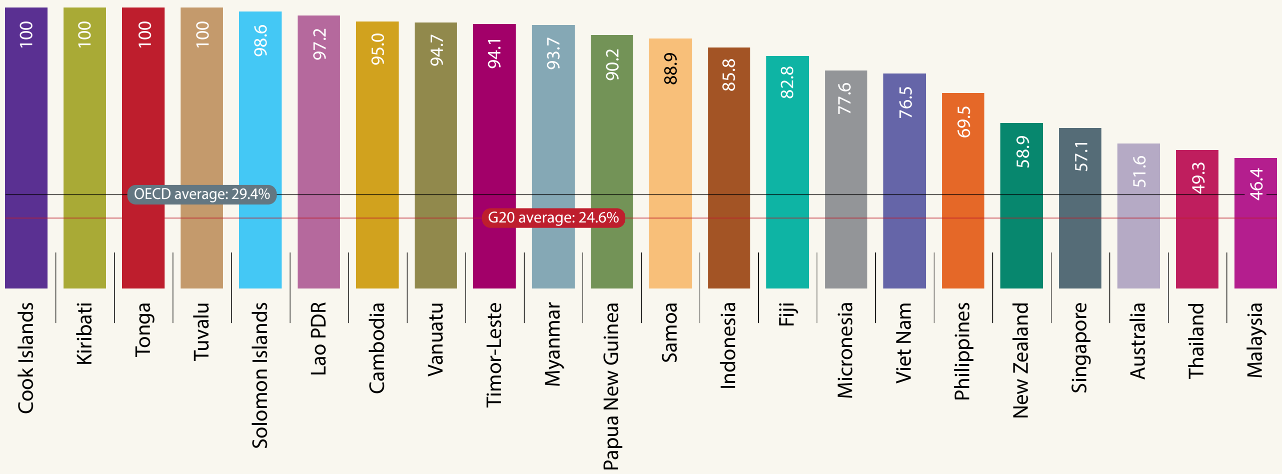
Countries collaborate with a wide range of partners

Main foreign partners, 2008 –2014 (number of papers)

	1st collaborator	2nd collaborator	3rd collaborator	4th collaborator	5th collaborator
Australia	USA (43 225)	UK (29 324)	China (21 058)	Germany (15 493)	Canada (12 964)
Cambodia	USA (307)	Thailand (233)	France (230)	UK (188)	Japan (136)
Cook Islands	USA (17)	Australia/ New Zealand (11)		France (4)	Brazil/Japan (3)
Fiji	Australia (229)	USA (110)	New Zealand (94)	UK (81)	India (66)
Indonesia	Japan (1 848)	USA (1 147)	Australia (1 098)	Malaysia (950)	Netherlands (801)
Kiribati	Australia (7)	New Zealand (6)	USA/Fiji (5)		Papua New Guinea (4)
Lao PDR	Thailand (191)	UK (161)	USA (136)	France (125)	Australia (117)
Malaysia	UK (3 076)	India (2 611)	Australia (2 425)	Iran (2 402)	USA (2 308)
Micronesia	USA (26)	Australia (9)	Fiji (8)	Marshall Islands (6)	New Zealand/ Palau (5)
Myanmar	Japan (102)	Thailand (91)	USA (75)	Australia (46)	UK (43)
New Zealand	USA (8 853)	Australia (7 861)	UK (6 385)	Germany (3 021)	Canada (2 500)
Papua New Guinea	Australia (375)	USA (197)	UK (103)	Spain (91)	Switzerland (70)
Philippines	USA (1 298)	Japan (909)	Australia (538)	China (500)	UK (410)
Samoa	USA (5)	Australia (4)	Ecuador/Spain/ New Zealand/France/ China/Costa Rica/Fiji/ Chile/Japan/Cook Islands (1)		
Singapore	China (11 179)	USA (10 680)	Australia (4 166)	UK (4 055)	Japan (2 098)
Solomon Islands	Australia (48)	USA (15)	Vanuatu (10)	UK (9)	Fiji (8)
Thailand	USA (6 329)	Japan (4 108)	UK (2 749)	Australia (2 072)	China (1 668)
Tonga	Australia (17)	Fiji (13)	New Zealand (11)	USA (9)	France (3)
Vanuatu	France (49)	Australia (45)	USA (24)	Solomon Islands/ New Zealand/ Japan (10)	
Viet Nam	USA (1 401)	Japan (1 384)	Korea, Rep. (1 289)	France (1 126)	UK (906)

Small or fledgling science systems have very high rates of foreign collaboration

Share of papers with foreign co-authors, 2008–2014



Note: Data are unavailable for some indicators for the Cook Islands, Kiribati, Micronesia, Niue, Samoa, Tonga and Vanuatu.

Source: Thomson Reuters' Web of Science, Science Citation Index Expanded; data treatment by Science–Metrix

COUNTRY PROFILES

AUSTRALIA

End of commodities boom squeezing S&T budgets

Australia continues to play a significant role in STI across the region. Its universities remain a draw for aspiring scientists and engineers from the region and it counts the highest absolute number of FTE researchers and technicians, as well as the highest GERD/GDP ratio (2.25%) and a dynamic business sector which contributes almost two-thirds of GERD (Table 27.2). In 2014, Australia accounted for 54% of the region's papers in the Web of Science (Figure 27.8).

The national innovation system is not without its weaknesses, however. As Australia's Chief Scientist Ian Chubb recently noted, although Australia ranked 17th out of 143 countries in the Global Innovation Index in 2014, it ranked 81st as a converter of raw innovation capability into the output that business needs, namely new knowledge, better products, creative industries and growing wealth. In 2013, Australia's high-tech exports contributed just 1.7% of the total from Southeast Asia and Oceania, ahead of only New Zealand, Cambodia and the Pacific Island states (Figure 27.4). In contrast to many of the ASEAN countries, Australia is not very engaged in product assembly in the global electronics value chain; this illustrates why comparisons of high-tech exports by countries in the region need to take into account the position of each economy in global high-tech production and export.

Australia's economic success in recent decades has been driven largely by the resources boom, primarily in iron ore and coal. Importantly, this has also driven much of R&D investment: 22% of business expenditure on R&D in 2011 concerned the mining sector, which also contributed 13.0% of GERD. The mining sector accounted for 59% of Australian exports in 2013, nearly two-fifths of which consisted in iron ore. Since 2011, the global price for iron ore has dropped from US$ 177 to less than US$ 45 per tonne (July 2015). A major factor behind the fall has been the reduced demand from China and India. Although prices are predicted to stabilize or even rise through 2015, the impact on Australian foreign earnings from this major export sector has been substantial. As a consequence, science in Australia has been hit both by cuts made to R&D expenditure in the mining and minerals sector and by cuts in public funding for science overall.

A new policy direction

Between 2010 and 2013, the majority of policy reports focused on innovation. This has not changed with the current government. The review of the Australian Co-operative Research Centre programme announced in 2014, for instance, has been mandated to explore ways of boosting Australia's productivity and national competitiveness.

The coalition government headed by Tony Abbott has nevertheless introduced changes in the overall direction of STI policy since coming to power in September 2013. In a context of reduced government revenue since the end of the commodities boom, the government's 2014–2015 budget made severe cuts to the country's flagship science institutions. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) faces a reduction of AU$ 111 million (3.6%) over four years and a loss of 400 jobs (9%). The Cooperative Research Centres programme survives but its funding has been frozen at current levels and will be reduced further by 2017–2018. In addition, a number of programmes fostering innovation and commercialization have been abolished. These include some long-running initiatives such as Enterprise Connect, the Industry Innovation Councils and Industry Innovation Precincts. The current government has replaced these incentive schemes with five industry-specific growth centres. The creation of these centres was announced in the government's 2014–2015 budget. Each is to be endowed with a budget of AU$ 3.5 million over four years with a focus on:

- Food and agriculture;
- Mining equipment and services;
- Oil, gas and energy reserves;
- Medical technologies and pharmaceuticals; and
- Advanced manufacturing.

The success of the centres will be measured by business-focused metrics such as increased investment, employment, productivity and sales, reduction in bureaucratic red-tape, improved industry–research linkages and a greater number of businesses integrated into international value chains, in line with the new approach established by the Minister of Industry and Science, Ian Macfarlane, in 2014.

There has been a decisive shift in the present government's approach away from renewable energy and carbon reduction strategies. The Australian carbon tax introduced by the previous Labour government has been abolished and, in the 2014–2015 budget, the government announced plans to abolish the Australian Renewable Energy Agency (ARENA) and the Clean Energy Finance Corporation. ARENA was established in July 2012 to promote the development, commercialization and dissemination of renewable energy and enabling technologies; it incorporated the Australian Centre for Renewable Energy, which had opened in 2009. However, both ARENA and the Clean Energy Finance Corporation were established by acts of parliament and, although the minister responsible advised parliament in October 2014 that the government was committed to abolishing both agencies, the present government has been unable to obtain majority support from the upper house to repeal the relevant acts.

Not all government research programmes lost out in the 2014–2015 budget. The Antarctic programme was one of its beneficiaries, with provision for a brand new AU$ 500 million icebreaker. This move supports the government strategy of turning the island of Tasmania into a regional hub for Antarctic research and services.

There has also been a shift in priorities in favour of medical research, with the planned establishment of an AU$ 20 billion medical research fund. The fund's creation hinged on a government proposal to abolish free medical treatment under the Medicare system for low-income households, a system that has been in place for two decades, and to replace Medicare with a 'co-payment' levy. The controversial new levy was ultimately defeated in parliament. The proposal is revealing of the current government's philosophy that science is a cost to be recovered from users, rather than a strategic national investment.

The approach to science in the 2014–2015 budget attracted concern from key stakeholder groups. The budget has been described as 'short-sighted' and 'destructive' by the CSIRO and as 'worse than we even imagined' by the Cooperative Research Centres Association. One of Australia's leading professors, Jonathan Borwein, has observed that 'there is more to science than medical research'. In May 2015, the government announced an additional AU$ 300 million in funding for the National Collaborative Research Infrastructure Strategy and committed further financial means in the federal budget for the medical research fund proposed in the 2014–2015 budget.

Another policy development has emerged from a May 2015 review of the Cooperative Research Centres programme. The review recommended a sharper commercial focus and the introduction of shorter-term (three years) co-operative research projects within the overall programme. These recommendations have all been accepted by the current government. Given that no additional funding has been announced for the programme, the sharper commercial focus in future may well come at the expense of the public good at those co-operative research centres oriented towards areas such as climate change and health.

One recent initiative that has drawn support from the scientific community is the creation of a National Science Council to be chaired by the prime minister. Although the Chief Scientist proposed that this would 'help provide strategic thinking for science', the Academy of Science argued that the new council would not compensate for the lack of a science minister. This was a reference to the decision made in December 2014 to entrust the Minister for Industry with the portfolio for science.

Announced in October 2014, the government's *Industry Innovation and Competitiveness Agenda* introduces initiatives to enhance science, engineering and mathematics education but only in the context of how this can contribute to the nation's industrial and economic prospects. There is currently little policy discussion about the importance of science for enhancing the nation's knowledge base or tackling pressing health and environmental problems of both national and global dimensions.

Universities have come to dominate public research

Australian science has historically been built around a strong government research system with four main pillars: the CSIRO, Australian Institute of Marine Science, Australian Nuclear Science and Technology Organisation and the Defence Science and Technology Organisation. State agriculture departments have historically also played a role in agricultural research.

In recent years, however, the university system has become the main focus for government-funded research. Over 70% of the value of public sector research in Australia is now performed by universities, equivalent to 30% of GERD. University research is dominated by medical and health sciences (29%), engineering (10%) and biological sciences (8%). The government research sector, which now performs only 11% of GERD, focuses primarily on the same fields, with the notable addition of agricultural research (19%). The other shares are medical and health sciences (15%), engineering (15%) and biological sciences (11%). This research focus is reflected in the statistics (Figure 27.8).

The government's role has shifted away from supporting public research institutions to becoming a major funder, regulator of standards and assessor of research quality. Many R&D functions formerly carried out by government research agencies have been transferred to the private sector or to universities. This has changed the nature of public funding away from direct appropriations towards a grant system operated through agencies such as the Australian Research Council and the National Health and Medical Research Council, the Cooperative Research Centres Programme and the Rural R&D corporations. The latter corporations, which have been in place now for over 70 years, are a unique Australian mechanism combining public funding with matching producer levies. Government policy emphasizes relevance to industry when allocating competitive research grants, research block grants, doctoral scholarships and university admissions (Australian Government, 2014).

As a consequence, much contemporary policy debate is focusing on how to direct the expanding university research capabilities towards the business sector.

A report commissioned by the Chief Scientist reveals that 11% of Australia's economy relies directly on advanced physical and mathematical sciences, contributing AU$ 145 billion to annual economic activity (AAS, 2015). As we have seen, the strengths of the university and government sectors lie elsewhere and, although the current government intends to foster research of relevance to industry, its focus is on ocean and medical sciences.

The Chief Scientist has also drawn attention to some underlying structural issues in the Australian innovation system, such as the cultural barriers that inhibit both risk-taking behaviour and the flow of people, ideas and funding between the public and private sectors. Laying better pathways between science and its applications will be an urgent challenge for the next decade, if Australia is to emulate more innovative economies.

An academic sector with a regional focus

There are currently 39 Australian universities, three of which are private. In 2013, they had a collective roll of 1.2 million students, 5% of whom (62 471) were enrolled in a master's or PhD programme. This is a much lower percentage than elsewhere in Asia, including Singapore, Malaysia, the Republic of Korea, Pakistan and Bangladesh (Figure 27.5). Moreover, more than 30% of postgraduate students come from overseas and more than half of them (53%) are enrolled in science and engineering fields. This suggests that Australia is producing only a modest number of home-grown scientists and engineers, a trend which may be ringing alarm bells in some policy circles but also underscores Australia's role as a regional hub for the training of scientists.

The growing regional centrality of the Australian higher education system is also reflected in co-authorship trends for scientific publications. Australian authors figure among the top five collaborating countries with all Pacific countries covered in the present chapter and seven out of the nine Southeast Asian countries. The overwhelming international evidence is that collaboration is essential for solving industrial and social problems. Australia is thus uniquely well placed, thanks to its globally recognized public research system and high level of international collaboration (52%). There are sound underlying reasons for seeking to maintain this national leading edge.

In parallel, the Asian region is rapidly gaining scientific strength. An interesting debate has emerged recently, in which some argue that funding priorities should be directed towards supporting regional research strengths relative to Asian universities. From this perspective, a more nuanced set of priorities emerge, led by ecology, the environment, plant and animal science, clinical medicine, immunology and neuroscience.

A twin challenge for STI

The challenge for STI in Australia is twofold. First, in order to realize the imperative of moving the economy towards more value-added production, there is a need to align public investment in R&D with emerging opportunities for innovative products and services. For example, the declining pre-eminence of coal as the main source of energy for driving global production opens up new scientific opportunities for alternative energies. A decade ago, Australian R&D was well-placed to be at the forefront of this frontier field. Since then, other countries have overtaken Australia but the potential for it to be a leader in this field remains. The proposed industry growth centres and the long-running Cooperative Research Centres programme offer the structure and scientific capacity to underpin such development but the government will also need to utilize policy better to minimize the business-sector risk, in order to capitalize on the science sector's strength in these areas.

An associated challenge will be to ensure that science does not become the hand-maiden of industrial and commercial development. It is Australia's strengths in science and the solidity of its institutions that have enabled the country to become a key regional knowledge hub.

CAMBODIA

A growth strategy that is working

Since 2010, Cambodia has pursued its impressive transformation from a post-conflict state into a market economy. Growth averaged 6.4% per year between 2007 and 2012 and the poverty rate shrank from 48% to 19% of the population, according to the Asian Development Bank's *Country Partnership Strategy 2014–2018*.

Cambodia exports mainly garments and products from agriculture and fisheries but is striving to diversify the economy. There is some evidence of expansion in value-added exports from a low starting point, largely thanks to the manufacture of electrical goods and telecommunications by foreign multinationals implanted in the country.

Higher spending on education, little on R&D

Public expenditure on education accounted for 2.6% of GDP (2010), compared to 1.6% in 2007. The share going to tertiary education remains modest, at 0.38% of GDP or 15% of total expenditure, but it is growing. Despite this, Cambodia still ranks lowest in the region for the education dimension of the World Bank's Knowledge Economy Index.

According to the UNESCO Institute for Statistics, GERD accounts for approximately 0.05% of GDP. As in many of the world's least developed economies, there is a strong reliance on international aid. The regulatory environment in which non-governmental organizations (NGOs) operate is currently a focus of parliamentary debate in Cambodia. It will be interesting to see if any potential legislative change to the regulations reduces R&D investment from the not-for-profit sector.

Scientific publications grew by 17% on average between 2005 and 2014, a rate surpassed only by Malaysia, Singapore and Viet Nam (Figure 27.8). They came from a low starting point, however, and had a narrow focus: the majority focused on biological and medical sciences in 2014.

A first national strategy for S&T

Like many low-income countries, Cambodia has been held back by the limited co-ordination of S&T across ministries and the absence of any overarching national strategy for science and development. In 2010, the Ministry of Education, Youth and Support[4] approved a *Policy on Research Development in the Education Sector*. This move represented a first step towards a national approach to R&D across the university sector and the application of research for the purposes of national development.

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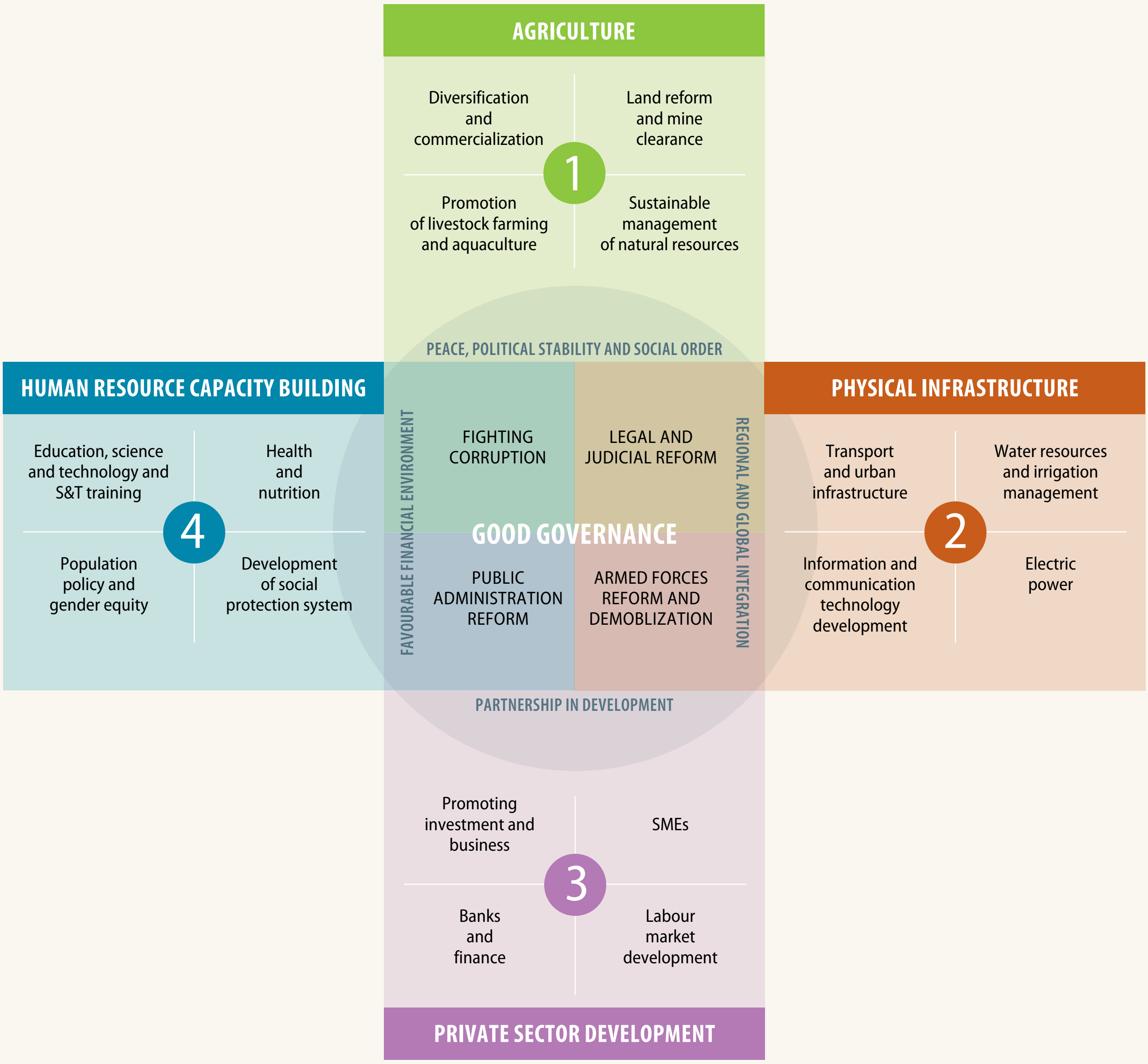
[4] A National Committee for Science and Technology representing 11 ministries has been in place since 1999. Although seven ministries are responsible for the country's 33 public universities, the majority of these institutions come under the umbrella of the Ministry of Education, Youth and Support.

Figure 27.9: **Cambodia's rectangular development strategy, 2013**



Source: Royal Government of Cambodia (2013) *Rectangular Strategy for Growth, Employment, Equity and Efficiency: Phase III.* September, Phnom Penh

This policy was followed by the country's first *National Science and Technology Master Plan 2014–2020*. It was officially launched by the Ministry of Planning in December 2014, as the culmination of a two-year process supported by the Korea International Cooperation Agency (KOICA, 2014). The plan makes provision for establishing a science and technology foundation to promote industrial innovation, with a particular focus on agriculture, primary industry and ICTs.

Another indication that Cambodia is taking a more co-ordinated approach to S&T policy and its integration into the country's wider development plans is Phase III of the government's *Rectangular Development Strategy*, which got under way in 2014. Phase III is intended to serve as a policy instrument for attaining the objectives of the new *Cambodia Vision 2030,* which aims to turn Cambodia into an upper-middle economy by 2030, and the country's *Industrial Development Policy 2015–2025*. The latter were both foreshadowed in the *Rectangular Development Strategy* of 2013, which is significant for having identified specific roles for science (Figure 27.9). The *Industrial Development Policy 2014–2025* was launched in March 2015 and complemented related medium-term strategies, such as the *National Sustainable Development Strategy for Cambodia*, published in 2009 with support from the United Nations Environment Programme and Asian Development Bank, and the *Climate Change Strategic Plan 2014–2023,* published with support from European international development agencies.

A need for a stronger human resource base

The *Rectangular Development Strategy* sets out four strategic objectives: agriculture; physical infrastructure; private sector development; and human capacity-building. Each of these objectives is accompanied by four priority areas for action (Royal Government of Cambodia, 2013). A role for science and technology has been defined in one or more of the priority areas for each 'rectangle' (Figure 27.9). Although science and technology are clearly identified as a cross-cutting strategy for promoting innovation for development, it will be important to co-ordinate and monitor the implementation of priority activities and assess the outcome. The key challenge here will be to build a sufficient human resource base in science and engineering to support the 'rectangular' targets.

Cambodia is likely to remain reliant on international research collaboration and NGO support for some time. Between 2008 and 2013, 96% of Cambodian articles involved at least one international co-author, a trend which may explain the high citation rate. Of note is that Cambodians count both Asian (Thailand and Japan) and Western scientists (USA, UK and France) among their closest collaborators (Figure 27.8). One strategic policy issue will be how to align NGO research support on national strategic plans for development.

Another pressing challenge for Cambodia will be to diffuse human capacity beyond the university sector. The country's narrow economic and scientific base offers some opportunity for growth tied to food production. However, the diffused responsibility for science and technology across 11 key ministries presents challenges for effective policy development and governance. Although there is evidence of growing collaboration across some key agricultural institutions, such as the Cambodian Agricultural Research and Development Institute and the Royal University of Agriculture, difficulties persist in extending this type of collaboration to a broader range of institutions.

One difficulty will be to enhance the technological capacity of the many SMEs active in agriculture, engineering and the natural sciences. Whereas the large foreign firms in Cambodia that are the main source of value-added exports tend to specialize in electrical machinery and telecommunications, the principal task for S&T policy will be to facilitate spillovers in terms of skills and innovation capability from these large operators towards smaller firms and across other sectors (De la Pena and Taruno, 2012).

There is little evidence that the Law on Patents, Utility Model Certificates and Industrial Designs (2006) has been of practical use, thus far, to any but the larger foreign firms operating in Cambodia. By 2012, 27 patent applications had been filed, all by foreigners. Of the 42 applications for industrial design received up to 2012, 40 had been filed by foreigners. Nevertheless, the law has no doubt encouraged foreign firms to introduce technological improvements to their on-shore production systems, which can only be beneficial.

INDONESIA

Ambitious targets for this emerging market economy

By far the most populous country in Southeast Asia, Indonesia is emerging as a middle-income economy with appreciable levels of growth but it has not developed a technology-intensive industrial structure and lags behind comparable economies for productivity growth (OECD, 2013). Since 2012, economic growth has slowed (to 5.1% in 2014) and remains well below the East Asian average. Since taking office in October 2014, President Joko Widodo has inherited the ambitious growth targets enshrined in the *Master Plan for Acceleration and Expansion of Indonesia's Economic Development 2011–2025*: 12.7% growth on average from 2010 to 2025, in order to make Indonesia one of the world's ten largest economies by 2025.

According to World Bank projections, economic growth will accelerate somewhat through 2015– 2017. In the meantime, the volume of high-tech exports remains well below the level of Viet Nam or the Philippines. The same goes for internet access. Although investment in tertiary education has risen since 2007 and Indonesia has no lack of university graduates, enrolment in science remains comparatively low.

Moves to develop industrial research

Much of Indonesia's scientific capacity is concentrated in public research institutions, which employed one in four (27%) researchers by head count in 2009, according to the UNESCO Institute for Statistics. Nine institutions come under the umbrella of the Ministry of Research and a further 18 under other ministries. The majority of researchers (55% by head count) are employed by the country's 400 universities, however, four of which figure in the top 1 000, according to the World Ranking Web of Universities. Researchers publish mainly in life sciences (41%) and geosciences (16%), according to the Web of Science (Figure 27.8). The publication rate has grown since 2010 but at a slower pace than for Southeast Asia overall. Almost nine out of ten articles (86%) have at least one international co-author.

One-third of researchers were employed by industry in 2009, including state-owned enterprises (Figure 27.7). A World Bank loan was announced in 2013 to 'strengthen the bridge' between research and development goals by helping research centres to 'define their strategic priorities and upgrade their human resources to match these priorities' (World Bank, 2014). The big challenge will be to nurture the private sector and encourage S&T personnel to migrate towards it.

The government has put incentive schemes in place to strengthen the linkages between R&D institutes, universities and firms but these focus primarily on the public sector supply side. The co-ordination of research activities by different players may be influenced by the National Research Council (*Dewan Riset Nasional*) chaired by the Ministry of Research and Technology, which groups representatives of ten other ministries and has reported to the president since 1999. However, the National Research Council has a modest budget, equivalent to less than 1% that of the Indonesian Institute of Sciences (Oey-Gardiner and Sejahtera, 2011). Moreover, although it continues to advise the Ministry of Research and Technology, it also advises the Regional Research Councils (*Dewan Riset Daerah*) that have assumed greater significance through the Indonesian decentralization process.

Indonesia's innovation effort is weak on two counts. In addition to the very modest role played by the private sector, the GERD/GDP ratio is negligible: 0.08% in 2009. In 2012, as part of the *Master Plan* to 2025's key strategy for 'strengthening human resource capacity and national science and technology,' the Ministry for Research and Technology released a plan to foster innovation in six economic corridors; this plan still places emphasis primarily on the public sector, despite the government's desire to transfer S&T capacity to industrial enterprises. The plan aims to decentralize innovation policy by establishing regional priorities, which nevertheless remain focused on resource-based industries:

- Sumatra: steel, shipping, palm oil and coal;
- Java: food and beverages, textiles, transport equipment, shipping, ICTs and defence;
- Kalimantan: steel, bauxite, palm oil, coal, oil, gas and timber;
- Sulawesi: nickel, food and agriculture (including cocoa), oil, gas and fisheries;
- Bali – Nussa Tengarra (Lesser Sunda Islands): tourism, animal husbandry and fisheries; and
- Papua – Maluku Islands: nickel, copper, agriculture, oil and gas and fisheries.

The predicted additional economic activity in these six corridors has already inspired a policy recommendation for over US$ 300 million to be directed towards new infrastructure development, to improve power generation and transportation. The government has committed 10% of this amount, the remainder having been provided by state-owned enterprises, the private sector and through public–private partnerships.

Since taking office, the Joko Widodo government has been focusing on fiscal reform to improve the business environment. His government has not changed the general direction of S&T policies and thus still plans to transfer part of public investment in R&D to the business sector. Recent regulations have sought to increase the level of value-added production in sectors such as the mobile phone industry. A new initiative intended to promote development at the value-added end of the market is a proposal in the 2015 budget to establish a body which would oversee the development of creative industries such as fashion and design. The overall national structure for managing science policy and public sector investment in science remains largely unchanged.

The multi-donor Programme for Eastern Indonesia SME Assistance (PENSA) is currently being evaluated. PENSA was launched in 2003 with the general objective of expanding opportunities for SMEs in Eastern Indonesia. More recently, the emphasis has shifted towards enhancing the financial capacity of SMEs and reforming the business environment. Consequently, by the time PENSA 2 was launched in 2008, it had become a five-year technical assistance programme with a focus on training commercial bank employees in outreach services and improving the regulatory environment and corporate governance among firms in

Eastern Indonesia. The Business Incubator Technology (BIT) programme for SMEs has taken a more direct approach; by 2010, there were up to 20 BIT units at public universities.

The recent policy shift towards creating six economic corridors and linking S&T to development goals is part of an overall strategy to reduce economic dependence on the nation's natural resources. The current trend towards lower global prices for raw materials instils an added urgency.

LAO PEOPLE'S DEMOCRATIC REPUBLIC

Sustainability of rapid resource-based growth in doubt

Lao PDR is one of the poorest countries in Southeast Asia but, thanks to its rich endowment in natural resources (forestry, hydropower, minerals), its strategic location in the midst of a fast-growing region and policies that exploit these advantages, it has been experiencing rapid economic expansion. In 2013, Lao PDR was rewarded for its efforts to liberalize the economy by being admitted to the World Trade Organization; membership should enable the country to become increasingly integrated in the world economy. Thanks to average annual real growth of close to 7.5% for the past 15 years, the poverty rate has halved to 23% in the past two decades. Concerns have nonetheless been raised as to the sustainability of this resource-based growth (Pearse-Smith, 2012).

Recent data are unavailable for Lao PDR on R&D expenditure and personnel but the number of scientific publications did increase between 2005 and 2014 by 18% a year, albeit from a very low base (Figure 27.8). Almost all publications throughout this period had international co-authors, mostly from Thailand. As with other countries highly dependent on foreign aid and international scientific collaboration, the current focus on local priorities for development may yet be challenged by broader global interests. At present, Lao PDR has the lowest proportion of researchers among ASEAN member states; ASEAN economic integration scheduled for 2015 onwards is likely to provide the country with more opportunities for regional scientific co-operation. The shortage of highly skilled personnel will be less of a challenge for Lao PDR than managing the balancing act of raising the level of skills while simultaneously creating local employment opportunities for the influx of skilled job-seekers.

The premises of an S&T policy framework

As a small economy with a limited capacity in science and engineering, Lao PDR has been actively seeking to build on regional strengths and foster collaboration among Laotian scientists. In 2011, a Ministry of Science and Technology was established. In parallel, representatives of relevant various ministries sit on the National Science Council; the latter was established in 2002 as an advisory board for S&T policy. In 2014, an event was held to improve dialogue between scientists and policy-makers from different sectors of the economy.

Strategies for achieving sustainable development underpin most of the challenges facing Lao PDR. Currently, hydropower and mining account for a large part of the nation's economic output. Balancing the environmental cost with the economic benefit to be gained from these activities will be a challenge.

MYANMAR

A lack of infrastructure to develop markets

Since 2011, Myanmar has been in transition towards a market-based economy. The country is rich in resources such as natural gas (39% of commodity exports), precious stones (14%) and vegetables (12%). Market development is hampered, however, by the lack of infrastructure: telecommunications and internet access remain a luxury and three out of four citizens lack access to electricity.

Geosciences represented 11% of scientific articles between 2008 and 2013, reflecting the importance of fossil fuels for the economy. Two-thirds of Myanmar's modest output nevertheless focused on the biological and medical sciences (Figure 27.8). Nearly 94% of publications had at least one foreign co-author.

There have been some interesting international joint ventures recently involving public and private partners. For example, infrastructure development for the first international standard special economic zone (Thilawa) commenced in 2013 on the outskirts of Yangon. This multi-billion dollar joint venture involves a Japanese consortium (39%), the Japanese government (10%), the Sumitomo corporation and local Myanmar firms (41%), as well as the Myanmar government (10%). Companies in manufacturing, garments, processed foods and electronics industries are among those which plan to establish factories there. Thilawa is expected to be commercially operational by the end of 2015 and should serve as a focal point for future S&T-based collaboration between the public and private sectors.

Pressure on a traditionally solid education system

Historically, Myanmar has enjoyed a solid education sector and comparatively high literacy rates. In recent years, education appears to have suffered, though, from funding shortages and the limited access to international collaboration as a corollary of the sanctions. Overall expenditure on education as a share of GDP fell by about 30% and spending on tertiary education was halved between 2001 and 2011.

There are 161 universities managed by 12 different ministries but researchers claim to have either little or no access to research funding (Ives, 2012). Myanmar nevertheless has the highest proportion of students enrolled in tertiary science degrees (nearly 23%) and the highest proportion of women in science: 87% of all doctoral graduates were women in 2011, including in the sciences.

A need to rationalize the institutional structure of science

The Ministry of Science and Technology has been in place since 1996 but is responsible for only one-third of the country's universities. The Ministry of Education is responsible for a further 64 institutions and the Ministry of Health for another 15. The remaining 21 institutions are the responsibility of nine other ministries. It is very difficult to generate a comprehensive overview of national S&T capability, as there is no single agency responsible for collecting R&D data. The Ministry of Science and Technology has its own database but it reports GERD as accounting for an unrealistic 1.5% of GDP (De la Pena and Taruno, 2012).

One of the biggest challenges facing Myanmar will be to maintain current funding levels for institutional structures that have been in place for some time. It will also be a challenge to reduce the number of ministries responsible for funding and managing the public scientific effort. At present, there appears to be no co-ordinating structure that could serve to align scientific investment with key socio-economic objectives.

NEW ZEALAND

An increasingly Asian–Pacific economy

New Zealand's economy relies heavily on international trade, especially that with Australia, China, the USA and Japan. Exports are dominated by food and beverages (38% in 2013), including some knowledge-intensive products. The main destination for dairy products used to be the UK but, upon integrating the European Economic Community in 1973, the UK also signed up to its common agricultural policy, which effectively excluded external producers from the European market. This forced New Zealand to shift its focus from northern hemisphere markets towards supplying the Asia–Pacific region, which was taking 62% of New Zealand's exports by 2013.

New Zealand is not only one of the few agrarian economies among OECD members. It also has a lower GERD/GDP ratio than many other OECD economies: 1.27% in 2011. Business sector R&D increased slightly between 2009 and 2011 from 0.53% to 0.58% of GDP and thus now contributes just under half of national investment in R&D.

Despite a fairly low R&D intensity, New Zealand scientists are very productive; they authored 7 375 publications in 2014, up by 80% from 2002, with a good citation rate. Globally, New Zealand has the sixth-highest number of scientific articles in relation to GDP, making it the regional leader for this indicator.

International engagement has had a significant impact on New Zealand's national innovation system. Nearly two-thirds of internationalized New Zealand firms undertake at least some type of innovation, such as innovation in goods or services or innovation in marketing methods, whereas only one-third of non-internationalized firms indulge in the same, according to a Business Operations Survey conducted in 2013 by Statistics New Zealand. In the past six years, New Zealand has also upscaled its efforts in science diplomacy (Box 27.1).

Aligning research priorities with national challenges

New Zealand's eight universities play a key role in the country's science system. They account for 32% of GERD, or 0.4% of GDP and employ more than half (57% in FTE) of the country's researchers (2011). In 2010, the government strengthened its own role in the national innovation system by creating a Ministry of Science and Innovation to drive policy-making. In 2012, the ministry was merged with three other agencies, the Ministry of Economic Development, the Department of Labour and the Department of Building and Housing to create what is now the Ministry of Business, Innovation and Employment (MoBIE).

The government established a taskforce in 2010 to reform the country's Crown Research Institutes (CRI), in order to ensure that 'CRIs can best deliver on national priorities and respond to the needs of research users, particularly industry and business' (CRI, 2010). The Crown Research Institutes are the largest dedicated providers of scientific research in New Zealand. Created in 1992, these state enterprises provide core services which earn them operating income. The taskforce's recommendations led to a reform in 2011 which changed the focus of the CRIs from profitability to driving growth and made their priorities more relevant to New Zealand's needs. The CRIs are now responsible for identifying infrastructure needs and formulating policies to provide greater support for innovation, such as through skills development, incentives for business investment in R&D, stronger international linkages and the design of strategies to increase the impact of public research.

Historically, the CRI's priorities have focused on high-value manufacturing services, biological industries, energy and minerals, hazards and infrastructure, environment, health and society. In 2013, the government announced a series of National Science Challenges to identify government priorities for investment in research and provide a more strategic approach to implementing related goals. The first National

Science Challenge in 2010 identified the following ten priority areas for research (MoBIE, 2013):

- Ageing well;
- A better start – improving the potential of young New Zealanders to have a healthy and successful life;
- Healthier lives;
- High value nutrition;
- New Zealand's biological heritage: biodiversity, biosecurity, etc.;
- Our land and water – research to enhance primary sector production and productivity while maintaining and improving the quality of land and water quality for future generations;
- Life in a changing ocean – understanding how to exploit our marine resources within environmental and biological constraints;
- The deep south – understanding the role of the Antarctic and the Southern Ocean in determining our climate and our future environment;
- Science for technological innovation; and
- Resilience to nature's challenges – research into enhancing our resilience to natural disasters.

Box 27.1: **New Zealand: using science diplomacy to make a small voice heard**

Science diplomacy is often viewed as the domain of great powers and associated with megascience projects like the International Space Station. Beneath these high-visibility projects, however, science plays a key role in more discreet and mundane ways in the functioning of the international system.

Under the leadership of Sir Peter Gluckman, Chief Science Advisor to the Prime Minister, New Zealand has been quietly building a number of networks since 2009 that combine science and diplomacy to advance the interests and presence of smaller powers in the international arena. In an era where international economic governance is increasingly seen as the purview of groupings of populous countries like the G8 or the G20, New Zealand's approach acts as a 'canary in the mine' for larger countries, says Prof. Gluckman, alerting them to the particularities of smaller powers which have not always been reflected in the traditional rules-based international architecture.

Science for diplomacy

New Zealand has formed an informal 'coalition of the willing' with other advanced economies of less than 10 million inhabitants. This is a select group: the International Monetary Fund includes just three countries outside Europe in this category: Israel, New Zealand and Singapore. With the addition of the smaller European powers of Denmark, Finland and Ireland, the 'coalition of the willing' currently counts six members.

New Zealand hosts and funds the secretariat of its Small Advanced Economies Initiative. The coalition shares data, analysis, discourse and projects in three areas: public science and higher education; innovation; and economics. A fourth area of co-operation involves 'conversations' between members on how to strengthen national branding and the voice of smaller nations within a broader diplomatic agenda.

Diplomacy for science

As the world's highest emitter of methane per capita, owing to its large population of livestock, New Zealand is particularly keen to promote a science-based international dialogue at the nexus between food security and greenhouse gas emissions from agriculture – agriculture accounting for about 20% of global emissions.

At the climate summit in Copenhagen (Denmark) in 2009, New Zealand proposed creating a Global Research Alliance to Reduce Agricultural Greenhouse Gases. One motivation was also the 'existential concern regarding future market resistance to our farm products'. This alliance currently has 45 members. It is unique in that it is led by scientists, rather than government administrators, in recognition of the fact that countries prefer to spend their research funds within their own border. In Prof. Gluckman's own words, 'here, the diplomatic interests of New Zealand demanded that science be done but, for that science to be done, the diplomats had to create the vehicle then get out of the way.'

Science as aid

In its aid policy, New Zealand makes a special effort to take into account the interests of smaller countries; it focuses on issues such as energy and food security or non-communicable diseases, where the small size of countries is a particular handicap. For instance, New Zealand's priority aid activities in Africa, such as solar-powered electric fence technology, heat-resistant livestock and enhanced forage plant species, all rely on science and its local adaptation.

'I have tried to show how a small country can use science within the diplomatic sphere to protect and advance its interests', says Prof. Gluckman. That argument seems to have borne fruit. New Zealand gained enough support for it to be elected to a non-permanent seat on the United Nations Security Council for the 2015–2016 term.

Source: Based on a lecture given by Prof. Gluckman in June 2015, as part of a summer course on science diplomacy at the World Academy of Sciences.

Read the full speech: www.pmcsa.org.nz/wp-content/uploads/Speech_Science-Diplomacy_Trieste-June-2015-final.pdf

The National Science Challenges fundamentally change New Zealand's research agenda by emphasizing collaboration. Each priority area involves a broad portfolio of multidisciplinary research activities, relying on strong collaboration between researchers and intended end-users, as well as ties to international research.

Challenge funding identified in the 2013 budget provides for an investment of NZ$ 73.5 million (*circa* US$ 57 million) over four years and NZ$ 30.5 million per year thereafter, in addition to the NZ$ 60 million allocated in the 2012 budget. The 2014 budget expanded the Centres of Research Excellence programme and increased the budget for competitive science funding, in order to compensate for the shift in funding to the National Science Challenges. Health and environmental issues remain a key focus for increases through 2015.

Although the government's approach to science policy in the 2014 budget was generally well-received, there is growing concern about an apparent absence of a coherent national strategy for science. Critics have pointed to the need for effective R&D tax credits, for example.

How to make the most of a clean, green brand?

Government investment in science has traditionally been weighted heavily towards primary industries, with the largest sectorial priority, agriculture, receiving 20% of the total. It is thus hardly surprising that scientific publications are concentrated in life sciences (48% of the total in 2014, followed by environmental sciences (14%). A future challenge will be to diversify scientific capacity towards priority areas identified for future growth, such as ICTs, high-value manufacturing and processed primary products, as well as environmental innovation.

As an agricultural trading nation, New Zealand has a great opportunity to embrace 'greener' growth. The government has asked the Green Growth Advisory Group to come up with policy advice on three particularly important topics: how to make the most of a clean, green brand; how to make smarter use of technology and innovation; and how to move businesses towards a lower-carbon economy. The 2012 report by the New Zealand Green Growth Research Trust on *Green Growth: Opportunities for New Zealand* identified no fewer than 21 specific green-growth opportunities in sectors that could enhance New Zealand's competitive advantage in this area, including biotechnology and sustainable agricultural products and services, geothermal energy, forestry and water efficiency.

PHILIPPINES

A desire to reduce disaster risk

Despite a rash of natural disasters in recent years, GDP has pursued moderate growth in the Philippines (Figure 27.2). This growth has been driven largely by consumption that has itself been fuelled by remittances from workers abroad and IT-enabled services, shielding the economy from the lingering weakness of the global economy (World Bank, 2014). Higher economic growth has not substantially reduced poverty, however, which still affects 25% of the population.

The Philippines is one of the world's most vulnerable countries to natural disasters. Every year, between six and nine tropical cyclones make landfall, alongside other extreme events such as floods and landslides. In 2013, the Philippines had the misfortune to lie in the path of Cyclone Haiyan (known as Yolanda in the Philippines), possibly the strongest tropical cyclone ever to hit land, with winds that were clocked at up to 380 kph.

To address disaster risk, the Philippines has been investing heavily in critical infrastructure and enabling tools such as Doppler radars, generating 3D disaster-simulation models from Light Detection and Ranging (LiDAR) technology and the wide-scale installation of locally developed sensors for accurate and timely disaster information nationwide. In parallel, it has been building local capability to apply, replicate and produce many of these technologies.

The decision to promote technological self-reliance to reduce disaster risk is also a feature of the government's approach to inclusive, sustained growth. The revised *Philippine Development Plan 2011–2016* enunciates strategies for using S&T and innovation to boost productivity and competitiveness in agriculture and small businesses, in particular, in sectors and geographical areas dominated by the poor, vulnerable and marginalized.

Building self-reliance in technology

The Department of Science and Technology is the key government institution for science and technology, with policy development being co-ordinated by a series of sectorial councils. Within the framework of the current *National Science and Technology Plan, 2002–2020* (NSTP), the strategic focus is on building technological self-reliance. The *Harmonized Agenda for Science and Technology, 2002–2020* reflects this focus in its approach to problem-solving related to inclusive growth and disaster risk reduction. The *Harmonized Agenda* was presented to the President in August 2014. Although S&T are guided by the NSTP, the *Harmonized Agenda* attempts to provide more detail of how the country can become technologically self-reliant to sustain science and technology beyond the mandate of the current Aquino administration.

The *Harmonized Agenda* focuses on the development of critical technologies such as remote sensing, LiDAR processing, testing and metrology facilities, advanced climate change and weather modelling, advanced manufacturing and high-performance computing. Five centres of excellence are to be established or upgraded by 2020 in biotechnology, nanotechnology, genomics, semiconductors and electronic[5] design.

The five centres of excellence are all government-funded:

- the Centre for Nanotechnology Application in Agriculture, Forestry and Industry (est. 2014) is based at the University of the Philippines Los Baños;
- the Biotech Pilot Plant (est. 2012 and since upgraded) is housed at the University of the Philippines Los Baños;
- the Philippine Genome Centre (est. 2009) is hosted by the University of the Philippines Diliman; it operates two core facilities in DNA sequencing and bioinformatics;
- the Advanced Device and Materials Testing Laboratory is located in the Department of Science and Technology's compound in Bicutan in Taguig City and has been operational since 2013; it houses three laboratories in surface analysis, thermal, chemical and metallurgical analysis;
- the Electronic Product Development Centre will also be located in the Department of Science and Technology's compound in Bicutan in Taguig City; it will provide state-of-the-art design, prototyping and testing facilities for printed circuit boards.

The Technology Transfer Act (2010) is expected to enhance innovation by providing a framework and support system for the ownership, management, use and commercialization of intellectual property arising from government-funded R&D. To better address needs in terms of human capital, the Fast-Tracked Science and Technology Scholarship Act of 2013 expands the coverage of existing scholarship programmes and strengthens the teaching of science and mathematics in secondary schools. The Philippine National Health Research System Act (2013), meanwhile, has formed a network of national and regional research consortia to boost domestic capacity.

A need to scale up the R&D effort

The Philippines trails its more dynamic ASEAN peers for investment in both education and research. The country invested 0.3% of GDP in higher education in 2009, one of the lowest ratios among ASEAN countries (Figure 27.5). After stagnating for the first half of the century, tertiary enrolment leapt from 2.6 million to 3.2 million between 2009 and 2013. The rise in PhD graduates has been even more spectacular, their number having doubled over the same five-year period from 1 622 to 3 305, according to the UNESCO Institute for Statistics.

Concomitantly, the number of FTE researchers per million inhabitants (just 78 in 2007) and the level of national investment in R&D (0.11% of GDP in 2007) remain low by any standards. Bringing science to underpin future innovation and development is likely to remain a challenge until the level of investment rises. This will include leveraging FDI in areas like electronics, in order to move closer to the higher end of the scale for value-added goods in the global value chain.

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[5] Electronic products accounted for 40% of export revenue in April 2013, according to the Semiconductor and Electronics Industry in the Philippines, Inc., which groups 250 Filipino and foreign companies, including Intel.

Box 27.2: **'Scuba' rice for the Philippines**

The Philippines is one of the most vulnerable countries to the impact of climate change and extreme weather patterns. In 2006, damage caused by cyclones and floods cost the rice industry more than US$ 65 million.

Researchers from the Philippine-based International Rice Research Institute (IRRI) and the University of California in the USA have developed flood-tolerant rice varieties known as 'scuba rice' which can withstand up to two weeks of complete submergence in water. Through marker-assisted backcrossing, researchers transferred the flood-tolerant gene SUB1 into valued local rice varieties. This led to the official release of flood-tolerant local rice varieties across Asia, including the Philippines, in 2009 and 2010.

In 2009, the Philippine National Seed Industry Council approved the release of 'scuba' rice, known locally as 'Submarino rice', with the Philippine Rice Research Institute (PhilRice) acting as distributor.

Since its release, Submarino rice has been distributed by the Department of Agriculture to flood-prone areas across the country, in partnership with IRRI and PhilRice. In pilot farms in the Philippines, this variety has been observed to survive floods with a good yield and less fertilizer use than before, since farmlands receive nutrients from the silt brought by floods.

Critics contest this point. They argue that Submarino rice requires 'a high input of chemical fertilizer and pesticides' and that it is therefore 'not affordable by the majority of poor farmers.' They prefer to endorse alternative growing methods, such as the System of Rice Intensification (see Box 22.2).

Source: Renz (2014); Asia Rice Foundation (2011); IRRI–DFID (2010)

The government's current policy of directing STI towards pressing national problems is laudable. Such an approach also reinforces the economic rationale for government intervention in the science system to address market failures and make markets work within the purview of good governance. A key challenge will be to build sufficiently solid infrastructure to sustain current efforts to solve pressing problems. The idea here has been to promote the thinking that the government has to lay down a set of S&T infrastructure for 'core technologies' that it should fund. There is no better example of the virtues of sustained support for research than the International Rice Research Institute based in the city of Los Baños (Box 27.2 on previous page).

SINGAPORE

From emerging to knowledge economy

Singapore is a small country with no natural resources. In the space of a few decades, it has become by far the wealthiest country in Southeast Asia and Oceania, with GDP per capita of PPP$ 78 763 in 2013, double that of New Zealand, the Republic of Korea or Japan.

The economy receded briefly (-0.6% growth) in 2009, after the global financial crisis reduced international demand for exports and tourism, prompting the government to cut corporate taxes and to dig into its reserves to shore up businesses and save jobs. The economy has since been expanding at a somewhat erratic rate, with 15% growth in 2010 but less than 4% annually since 2012.

Although Singapore's R&D intensity is surpassed only by that of Australia among the countries profiled in the present chapter – and then only by a whisker – its R&D effort appears to have been a casualty of the global financial crisis. In 2006, when GERD represented 2.13% of GDP, the government fixed the target of raising this ratio to 3% by 2010. It was approaching this target in 2008 (2.62%) but GERD has since fallen back to 2.02% in 2012. The contraction in business expenditure on R&D (BERD) since 2008 would seem to be largely responsible for this failure (Figure 27.10). Singapore nevertheless remains an international hub for R&D in the Asia–Pacific region. Moreover, it plans to raise GERD to 3.5% of GDP by 2015.

Scientific publications seem to have been less affected by the recession, even if they have progressed at a more pedestrian pace since 2005 than some other Southeast Asian countries (Figure 27.8). Singapore's scientific output emphasizes engineer-ing research (17% of the total) and physics (11%). This is atypical for the region, where life sciences and geosciences tend to dominate. It is also well above the global average for the share of articles devoted to engineering research (13%) and physics (11%).

Since 2010, Singapore's major universities have gained an international reputation. In 2011, the National University of Singapore and Nanyang University were ranked 40th and 169th respectively in the Times Higher Education World University Rankings. By 2014, they had risen to the 26th and 76th positions respectively.

One cause for concern has been the declining density of technicians (Table 27.1). Whereas the proportion of technicians in Thailand and Malaysia has been rising, it receded by 8% in Singapore between 2007 and 2012. Singapore may benefit from the freer flow of skilled personnel to redress this trend, once the ASEAN Economic Community comes into play in late 2015.

Strengthening domestic innovation to complement FDI

Singapore's economic development is strongly dependent on FDI inflows: inward FDI stock stood at 280% of GDP in 2013, according to UNCTAD. This reflects Singapore's success over the past two decades in persuading multinational corporations to invest in high-tech and knowledge-intensive industries.

Over the past two decades, Singapore has adopted a cluster-based approach to developing its research ecosystem, which now combines both innovative foreign multinationals and endogenous enterprises. Singapore's success rests to a large extent on the alignment of policies designed to leverage national development from a strong multinational presence with policies promoting local innovation. Over the past decade, Singapore has invested heavily in state-of-the-art facilities and equipment and offered attractive salary packages to world-renowned scientists and engineers, driving up Singapore's researcher intensity to one of the highest levels in the world: 6 438 per million inhabitants in 2012 (Table 27.1). In parallel, the government has launched vigorous higher education policies endowed with a generous budget – consistently more than 1% of GDP between 2009 and 2013 – to develop intellectual capital and provide research personnel for both foreign and domestic companies.

Government policies have also focused on developing endogenous capabilities for innovation. Several national research institutions have been grouped into hubs and encouraged to establish ties with renowned knowledge hubs abroad, in order to create centres of excellence in two niche areas: Biopolis (for biomedical research) opened in 2003 and Fusionopolis (for ICTs) in 2008.

It was also in 2008 that Singapore's Research, Innovation and Enterprise Council approved the establishment of a National Framework for Innovation and Enterprise (NFIE). NFIE has two core goals: to commercialize cutting-edge technologies developed by R&D laboratories through the creation of start-up companies; and to encourage universities and polytechnics to pursue academic entrepreneurship and transform the results of their R&D into commercial products. Between 2008 and 2012, S$ 4.4 billion (*circa* US$ 3.2 billion) was allocated under NFIE to fund:

- the establishment of university enterprise boards;
- an innovation and capability vouchers scheme (Box 27.3);
- early-stage venture funding (Box 27.3);
- proof-of-concept grants (Box 27.3);
- a disruptive innovation incubator (Box 27.3);
- a technology incubation scheme (Box 27.3);
- incentives for global entrepreneurial executives to move to Singapore (Box 27.3);
- translational R&D grants for polytechnics to help take research to market;
- national intellectual property principles for publicly funded R&D; and
- the creation of innovation and enterprise institutes.

The National Research Foundation works in tandem with NFIE to provide funding for collaborative innovation (Box 27.3). In parallel, innovation and enterprise institutes have been established to provide an organizational context in which to nurture partnerships and develop funding proposals; that hosted by Singapore Management University, for instance, provides a forum where academics and commercial enterprises can meet. Potential partners can receive guidance from the institute when seeking grants from the National Research Foundation to develop business concepts and seed grants for early-stage development.

The government agency A*STAR has been sponsoring a new initiative for a Smart Nation since November 2014. The aim is to develop new partnerships across the public and private sectors, with a view to strengthening Singapore's capabilities in cybersecurity, energy and transport, in order to 'green' the country and improve public services. In 2015, A*STAR's Institute for Infocomm Research signed an agreement with IBM for the creation of innovative solutions in the areas of big data and analytics, cybersecurity and urban mobility as a contribution to the Smart Nation initiative. In December 2014, the minister in charge of the Smart Nation initiative, Vivian Balakrishnan, had explained[6] the rationale behind the scheme at the opening of the Singapore Maker Festival. The current shift from mass production to mass customization of technology such as mobile phones, combined with lower prices for hardware, the generalization of sensors and easy connectivity, had placed data and innovation at an individual's fingertips, she said. The minister undertook to

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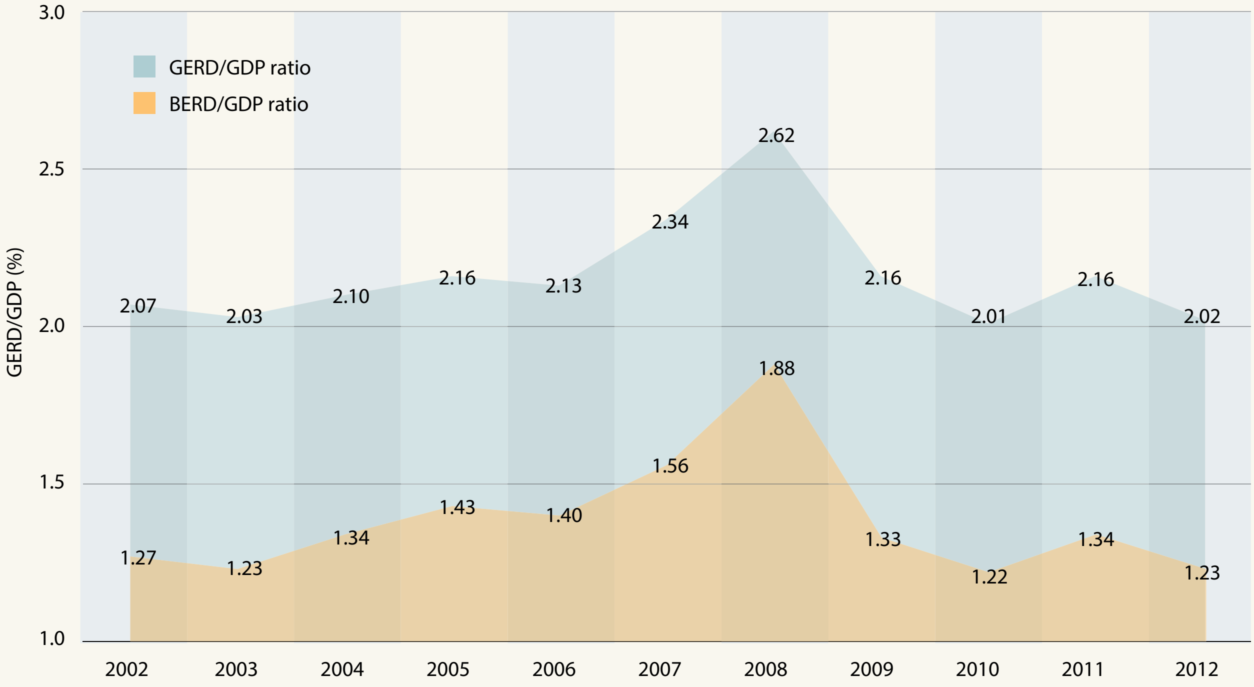
[6] **6.** See: www.mewr.gov.sg/news

Figure 27.10: **Trends in GERD in Singapore, 2002–2012**



Source: UNESCO Institute for Statistics, June 2015

Box 27.3: **Innovative ways of financing innovation in Singapore**

The National Research Foundation offers enterprises financial support through the following schemes to encourage them to engage in collaborative innovation.

The Incubator for Disruptive Enterprises and Start-ups (IDEAS)
IDEAS was launched jointly by the National Research Foundation and Innosight Ventures Pte Ltd, a Singapore-based venture capital firm. The idea behind IDEAS was to build on the Technology Incubation Scheme established in 2009. Through IDEAS, start-ups with disruptive innovation potential are identified and offered guidance during their early stages. They receive an investment of up to S$ 600 000, 85% of which is provided by the National Research Foundation and the remainder by the incubator. An investment committee evaluates the start-ups. In 2013, the government announced that it would be providing up to S$ 50 million, in order to stimulate the early-stage investment ecosystem.

Innovation and Capability Voucher
Introduced in 2009, the Innovation and Capability Voucher is intended to facilitate the transfer of know-how from knowledge institutions to SMEs. The scheme provides SMEs with funding grants of up to S$ 5 000 to enable them to procure R&D or other services from universities or research institutes.

The scope of the scheme was extended in 2012 to allow the vouchers to be applied in human resource or financial management. The policy expectation is that projects or services purchased from research institutions will lead to upgrades in technology and new products or processes, enhancing knowledge and skills in the process.

Early Stage Venture Fund
Through this fund, the National Research Foundation invests S$ 10 million on a 1:1 ratio in seed venture capital funds that invest in Singapore-based, early-stage high-tech companies.

Proof of Concept Grants
The National Research Foundation administers this scheme, which provides researchers from universities and polytechnics with grants of up to S$ 250 000 for technological projects at the proof-of-concept stage. The government runs a parallel scheme for private enterprises (Spring Singapore).

Technology Incubation Scheme
The National Research Foundation co-invests up to 85% (capped at S$ 500 000) in Singapore-based start-up companies that are being incubated by seeded technology incubators that themselves provide investee companies with physical space, mentorship and guidance.

Global Entrepreneur Executives
This co-investment scheme has been designed to attract high-growth and high-tech venture-backed companies. It targets ICTs, medical technology and clean technology. The objective is to encourage companies to relocate to Singapore. The National Research Foundation invests up to US$ 3 million in matching funding in eligible companies.

Innovation Cluster Programme
This scheme provides funding to strengthen partnerships across businesses, research performers and government in technological areas with potentially large markets. Four plans to develop innovation clusters were funded under this programme in 2013, in diagnostics; speech and language technologies; membranes; and additive manufacturing. Grants for collaborative projects focused on establishing shared infrastructure, capacity-building and on bridging gaps along the value chain.

Source: http://iie.smu.edu.sg; www.spring.gov.sg; www.guidemesingapore.com

make 'as much data as possible' available to the public and promised that, in return, 'if you have got a product or a service that will make life better, pitch it to us'. A Smart Nation Programme Office is being set up in the Prime Minister's Office to bring citizens, the government and industrial players together to identify issues, co-develop prototypes and deploy these effectively.

According to the National Research Foundation, Singapore's long-term goal is to become 'one of the most research-intensive, innovative and entrepreneurial economies in the world, in order to create high-value jobs and prosperity for Singaporeans'. The main challenge for the immediate future will be to expand the role of business enterprises in research and innovation. Singapore's business expenditure on R&D (BERD) is lower than that of R&D-intensive nations with a similarly small population, such as Finland, Sweden or the Netherlands. What distinguishes the latter is the presence of large home-grown multinationals which fund the bulk of BERD. Singapore's BERD, on the other hand, is spread over a far larger number of companies, meaning that a broader segment of industry must be engaged in R&D to increase BERD.

Another challenge will be to sustain the country's advantages and further accelerate collaborative research to internationalize innovation to an even greater extent. One of Singapore's strengths is its capacity to forge influential public–private and public–public partnerships within a compact and integrated research system. Singapore is about to embark upon the next five-year funding tranche for R&D, entitled *Research, Innovation and Enterprise 2020*. This programme will continue to place heavy emphasis on collaborative partnerships within the open innovation paradigm that has worked so well for Singapore up until now, in pursuit of its vision of becoming Asia's innovation capital.

THAILAND

Private sector invests most in value-added chemical goods

Thailand experienced growth of just 27% between 2005 and 2012. Socio-political unrest through the latter part of 2013 and a military *coup d'état* in May 2014 placed the economy at a crossroads. The World Bank (2014) expects consumer and investor confidence to recover once the situation stabilizes. The Thai economy is, nevertheless, likely to remain one of the slowest-growing in Southeast Asia until at least 2016, according to the IMF.

Recent governments have considered it a top priority to promote high-tech manufacturing, in order to stimulate demand. There is certainly evidence of growth in services. However, raising R&D capacity in Thailand will depend very much on private-sector investment, which has accounted for about 40% of GERD in recent years. Given the country's GERD/GDP ratio of 0.39% in 2011, industrial R&D remains low key but this picture could be changing: the Minister of Science and Technology issued a statement in May 2015 claiming a 100% increase in GERD to 0.47% of GDP in 2013 that had been largely driven by private-sector investment.[7]

In light of these statistics, the comparatively high proportion of high-tech exports from Thailand, which account for 10.6% of the total from Southeast Asia and Oceania (Figure 27.4), suggests that high-tech goods may be designed elsewhere and assembled in Thailand, rather than being the fruit of in-house R&D, such as Thai exports of hard disc drives, computers and aeroplane engines. Thailand is the region's biggest exporter of chemical goods: 28% of the total. At present, value-added chemical products are the main focus of private-sector investment in R&D. Clearly, there is a need to develop a business environment that encourages multinational corporations to invest in R&D, as Singapore and Malaysia have done. Thai governments have wrestled with this dilemma but, thus far, have been reticent to offer financial incentives to foreign firms, unlike Malaysia (see Chapter 26).

A major challenge will be to achieve a stable socio-economic environment that is conducive to maintaining FDI, in order to fuel investment in industrial R&D, and to developing higher education of quality. Thailand is still one of the world's largest producers of hard disc drives and light pick-up trucks but maintaining this global edge will require considerable investment in higher education to overcome the skills shortage.

The shortage of both skilled and unskilled labour has remained a chronic problem for Thai businesses (EIU, 2012). Investment in tertiary education was quite high in 2002 (1.1% of GDP) but had fallen to 0.7% of GDP by 2012. Although expenditure on higher education has been slipping as a percentage of GDP, there is a commitment to raising the proportion of students enrolling in science, technology, engineering and mathematics. A pilot programme was initiated in 2008 to establish science-based schools for gifted pupils with a creative streak and a bent for technology (Pichet, 2014). Teaching and learning are project-based, the long-term aim being to help pupils specialize in different fields of technology. Five schools have since been established within this programme:

- the Science-based Technology Vocational College (Chonburi) in central Thailand;
- Lamphun College of Agriculture and Technology in the north (agricultural biotechnology);
- Suranaree College in the northeast (science-based industrial technology);
- Singburi Vocational College (food technology); and
- Phang-nga Technical College in the south (innovation in tourism).

The number of FTE researchers and technicians per million inhabitants increased by 7% and 42% respectively between 2005 and 2009. Researcher density nevertheless remains low, with the great majority of researchers being employed by public research institutes or universities. The National Science and Technology Development Agency (NSTDA) alone employs over 7% of the country's full-time researchers in four institutions: the National Centre for Genetic Engineering and Biotechnology; the National Electronics and Computer Technology Centre; the National Metal and Materials Technology Centre; and the National Nanotechnology Centre.

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[7] see www.thaiembassy.org/permanentmission.geneva/contents/files/news-20150508-203416-400557.pdf

Ambitious policy targets

Although the *Ten-Year Action Plan for Science and Technology* (2004–2013) introduced the concept of a national innovation system, it did not clearly indicate how to integrate innovation in science and technology. This omission has been remedied by the *National Science, Technology and Innovation Policy and Plan* (2012–2021) adopted in 2012, which identifies avenues for achieving this goal, such as infrastructure development, capacity-building, regional science parks, industrial technology assistance and tax incentives for R&D. Central to the new plan is a commitment to strengthening collaboration between public research agencies and the private sector. The plan also perceives regional development as a potential remedy to the socio-economic disparities which have fuelled social unrest. It fixes a target of raising GERD to 1% of GDP by 2021, with a private-public sector ratio of 70:30.

A complex array of financial incentives target the private sector, including grants or matching grants with innovation coupons, assistance with industrial technology, low-interest loans for innovation and tax incentives to promote the upgrading of skills and technology. The 200% tax reduction for R&D introduced in 2002 to enable companies having invested in R&D to claim a double deduction for their expenses incurred during the same fiscal year has recently been increased to 300%. The statement issued by the Minister of Science and Technology in May 2015 drew attention to the Industrial Technology Assistance Programme for SMEs that includes innovation coupons, loan guarantees and access to ministry-run testing labs. Moreover, a new talent mobility programme allows researchers in universities or government laboratories to be seconded to private firms; under this latter initiative, the firm reimburses the university or research laboratory for the person's salary for the duration of the secondment but importantly, SMEs are exempt from this clause, thanks to a ministerial subsidy which reimburses the laboratory on their behalf. Recent legislative changes now allow for the transfer of ownership of intellectual property from funding agencies to grantees and a new law allows government agencies to set up funds for the commercialization of technology. Collectively, these initiatives are intended to reform the incentive system for R&D.

On the administrative side, there are plans to establish an STI Advisory Committee which will report directly to the Prime Minister. This development should coincide with the transfer of the National STI Policy Office from the Ministry of Science and Technology to the Office of the Prime Minister.

One tambon, one product

Another challenge will be to transfer the knowledge and skills currently concentrated in research institutions and science parks to productive units situated in rural areas, including farms and SMEs.

The One Tambon, One Product programme is being pursued in rural Thailand. Inspired by the One Village, One Product programme in Japan in the 1980s, which sought to combat depopulation, the Thai government introduced the One Tambon, One Product programme (a tambon being a subdistrict) between 2001 and 2006 to stimulate local entrepreneurship and innovative, quality products. A superior product is selected from each tambon for formal branding with one to five stars to indicate the standard of quality before undergoing nationwide promotion. Tambon products include garments and fashion accessories, household goods, foodstuffs and traditional handicrafts. The spread of mobile phone technology into rural areas is opening up opportunities for access to market-based information, as well as product development and modern production processes. The challenge here will be to orient product development towards higher value-added output.

TIMOR-LESTE

Oil-fuelled growth

Since gaining independence in 2002, Timor-Leste has shown healthy economic growth which is largely attributable to the extraction of natural resources: crude petroleum accounted for 92% of exports in 2014. GDP expanded by 71% between 2005 and 2013, the second-highest rate in the region (Figure 27.2). This has made the young country increasingly independent economically, with overseas development assistance falling steadily from 22.2% of gross national income in 2005 to 6.0% in 2012.

The region's third-biggest spender on higher education

The longer-term objective, set out in the country's *Strategic Development Plan 2011–2030*, is to progress from a low-income to an upper middle-income economy by 2030, like Cambodia. The *Development Plan* emphasizes higher education and training, infrastructure development and the need to reduce dependence on oil. Local capacity-building in science and technology and international scientific collaboration will be key factors in achieving the ambitious targets set out in the plan. These targets are based on the assumption that annual economic growth will maintain a cruising speed of 11.3% through to 2020 and 8.3% through to 2030, thanks largely to a burgeoning private sector. By 2030, there are plans to have at least one hospital in all 13 districts and a specialist hospital in Dili and for at least half of the nation's energy needs to be met by renewable sources.

At present, scientific capacity and R&D output are low but the government's massive investment in education is likely to change this picture over the next decade. Between 2009 and 2011, Timor-Leste invested 10.4% of GDP in education, on average, and raised the level of investment in higher education from 0.92% to 1.86% of GDP. It has become the second-biggest spender on higher education in the region, after Malaysia (Figure 27.5).

A review of science education in 2010 drew attention to the need to improve its quality and relevance. Three key sectors have been identified as priorities for future education and training: health and medicine; agriculture; and technology and engineering (Gabrielson *et al.*, 2010). Science, technology, engineering and mathematics have all been targeted as priorities for development across all levels of education, with particular emphasis on higher education.

The main research university in Timor-Leste is the Universidade Nacional de Timor-Lorosae (UNTL) but three smaller universities have opened in recent years and seven institutes also conduct research. At the start of 2011, there was a combined enrolment of 27 010 students across UNTL's 11 campuses, representing an increase of more than 100% since 2004. Enrolment of women increased by 70% from 2009 to 2011. In 2010, UNTL joined the School on Internet Asia Project, which allows under-resourced universities in the region to link up with one other and to benefit from distance learning using low-cost satellite-based internet access.

A need for greater co-ordination and inclusiveness

NGOs play a vital role in Timor-Leste's development but their presence does create problems when it comes to co-ordinating programmes across different government sectors. Whereas the Ministry of Education holds the primary responsibility for higher education, many other agencies are also involved. The *Development Plan* to 2030 cites the objective of 'developing an efficient management system to co-ordinate government interventions in higher education and set priority targets and budgets'. It also cites the establishment of a National Qualifications Framework.

Timor-Leste has one of the lowest levels of connectivity to internet in the world (1.1% in 2013) but mobile phone subscriptions have taken off in the past five years. In 2013, 57.4% of the population had a subscription, compared to 11.9% five years earlier. This suggests that the country's potential for accessing the global information system is growing.

Perhaps Timor-Leste's biggest challenge for the future will be to develop its scientific human capital, so that the country can capitalize on innovation in agriculture and industry to effect its economic transformation. In the meantime, Timor-Leste will need to overcome what has been described as 'Dili-centric' development, in reference to the capital city, and to demonstrate that it has the capacity to make use of new knowledge and information.

VIET NAM

Productivity gains needed to compensate for other losses

Viet Nam has become increasingly integrated into the world economy, particularly since its efforts to liberalize the economy enabled it to join the World Trade Organization in 2007. The manufacturing and service sectors each account for 40% of GDP. However, almost half the labour force (48%) is still employed in agriculture. One million workers a year, out of a total of 51.3 million in 2010, are projected to continue leaving agriculture for the other economic sectors in the foreseeable future (EIU, 2012).

In manufacturing, Viet Nam is expected to lose some of its current comparative advantage in low wages in the near future. It will need to compensate for this loss with productivity gains, if it is to sustain high growth rates: GDP per capita has almost doubled since 2008. High-tech exports from Viet Nam grew dramatically during 2008–2013, particularly with respect to office computers and electronic communications equipment – only Singapore and Malaysia exported more of the latter. A big challenge will be to implement strategies that increase the potential for enhancing technology and skills currently present in large multinational firms to smaller-scale domestic firms. This will require strategies to enhance technical capacity and skills among local firms that are, as yet, only weakly integrated with global production chains.

Since 1995, enrolment in higher education has grown tenfold to well over 2 million in 2012. By 2014, there were 419 institutions of higher education (Brown, 2014). A number of foreign universities operate private campuses in Viet Nam, including Harvard University (USA) and the Royal Melbourne Institute of Technology (Australia).

The government's strong commitment to education, in general, and higher education, in particular (respectively 6.3% and 1.05% of GDP in 2012), has fostered significant growth in higher education but this will need to be sustained to retain academics. Reform is under way. A law passed in 2012 gives university administrators greater autonomy, although the Ministry of Education retains responsibility for quality assurance. The large number of universities and even larger pool of research institutions in Viet Nam presents a serious challenge for governance, particularly with respect to co-ordination among ministries. To some extent, market forces are likely to eliminate the smaller and financially weaker units.

There are no recent data available on R&D expenditure but the number of Vietnamese publications in the Web of Science has increased at a rate well above the average for Southeast Asia. Publications focus mainly on life sciences

(22%), physics (13%) and engineering (13%), which is consistent with recent advances in the production of diagnostic equipment and shipbuilding. Almost 77% of all papers published between 2008 and 2014 had at least one international co-author.

Public–private partnerships key in S&T strategy

The autonomy which Vietnamese research centres have enjoyed since the mid-1990s has enabled many of them to operate as quasi-private organizations, providing services such as consulting and technology development. Some have 'spun off' from the larger institutions to form their own semi-private enterprises, fostering the transfer of public sector S&T personnel to these semi-private establishments. One comparatively new university, Ton Duc Thang (est. 1997), has already set up 13 centres for technology transfer and services that together produce 15% of university revenue. Many of these research centres serve as valuable intermediaries bridging public research institutions, universities and firms. In addition, Viet Nam's most recent Law on Higher Education, passed in June 2012, offers university administrators greater autonomy and there are reports that growing numbers of academic staff are also serving as advisors to NGOs and private firms.

The *Strategy for Science and Technology Development for 2011–2020,* adopted in 2012, builds upon this trend by promoting public–private partnerships and seeking to transform 'public S&T organisations into self-managed and accountable mechanisms as stipulated by law' (MoST, 2012). The main emphasis is on overall planning and priority-setting, with a view to enhancing innovation capability, particularly in industrial sectors. Although the *Strategy* omits to fix any targets for funding, it nevertheless sets broad policy directions and priority areas for investment, including:

- research in mathematics and physics;
- investigation of climate change and natural disasters;
- development of operating systems for computers, tablets and mobile devices;
- biotechnology applied particularly to agriculture, forestry, fisheries and medicine; and
- environmental protection.

The new *Strategy* foresees the development of a network of organizations to support consultancy services in the field of innovation and the development of intellectual property. The *Strategy* also seeks to promote greater international scientific co-operation, with a plan to establish a network of Vietnamese scientists overseas and to initiate a network of 'outstanding research centres' linking key national science institutions with partners abroad.

Viet Nam has also developed a set of national development strategies for selected sectors of the economy, many of which involve S&T. Examples are the *Sustainable Development Strategy* (April 2012) and the *Mechanical Engineering Industry Development Strategy* (2006), together with *Vision 2020* (2006). Spanning the period 2011–2020, these dual strategies call for a highly skilled human resource base, a strong R&D investment policy, fiscal policies to encourage technological upgrading in the private sector and private-sector investment and regulations to steer investment towards sustainable development.

PACIFIC ISLAND COUNTRIES

Small states with big development needs

Pacific Island economies are mostly dependent on natural resources, with a tiny manufacturing sector and no heavy industry. The trade balance is more skewed towards imports than exports, with the exception of Papua New Guinea, which has a mining industry. There is growing evidence that Fiji is becoming a re-export hub in the Pacific; between 2009 and 2013, its re-exports grew threefold, accounting for more than half of all exports by Pacific Island states. Now that it has joined the World Trade Organization (in 2012), Samoa can also expect to become more integrated in global markets.

The wider cultural and social context heavily influences science and technology in the Pacific Island countries. Furthermore, limited freedom of expression and, in some cases, religious conservatism discourage research in certain areas. This said, the experience of these countries shows that sustainable development and a green economy can benefit from the inclusion of traditional knowledge in formal science and technology, as underlined by the *Sustainable Development Brief* prepared by the Secretariat of the Pacific Community in 2013.

The *UNESCO Science Report 2010* observed that the lack of national and regional policy frameworks was a major stumbling block for developing integrated national STI agendas. Pacific Island states have since moved forward in this regard by establishing a number of regional bodies to address technological issues for sectorial development.

Examples are the:

- Secretariat of the Pacific Community for climate change, fisheries and agriculture;
- Pacific Forum Secretariat for transport and telecommunications; and
- Secretariat of the Pacific Region Environmental Programme for related issues.

Unfortunately, none of these agencies has a specific mandate for S&T policy. The recent establishment of the Pacific–Europe Network for Science, Technology and Innovation (PACE-Net Plus) goes some way towards filling this void, at least temporarily. Funded by the European Commission within its Seventh Framework Programme for Research and Innovation (2007–2013), this project spans the period 2013–2016 and thus overlaps with the European Union's Horizon 2020 programme (see Chapter 9). Its objectives are to reinforce the dialogue between the Pacific region and Europe in STI; to support biregional research and innovation through calls for research proposals and to promote scientific excellence and industrial and economic competition. Ten of its 16 members[8] come from the Pacific region.

PACE-Net Plus focuses on three societal challenges:

- Health, demographic change and well-being;
- Food security, sustainable agriculture, marine and maritime research and the bio-economy; and
- Climate action, resource efficiency and raw materials.

PACE–Net Plus has organized a series of high-level policy dialogue platforms alternately in the Pacific region and in Brussels, the headquarters of the European Commission. These platforms bring together key government and institutional stakeholders in both regions, around STI issues.

A conference held in Suva (Fiji) in 2012 under the umbrella of PACE–Net Plus produced recommendations for a strategic plan[9] on research, innovation and development in the Pacific. The conference report published in 2013 identified R&D needs in the Pacific in seven areas: health; agriculture and forestry; fisheries and aquaculture; biodiversity and ecosystem management; freshwater; natural hazards; and energy. Noting the general absence of regional and national STI policies and plans in the Pacific, the conference also established the Pacific Islands University Research Network to support intra- and inter- regional knowledge creation and sharing and to prepare succinct recommendations for the development of a regional STI policy framework. This policy framework was supposed to be informed by evidence gleaned from measuring STI capability but the absence of data presents a formidable barrier. This formal research network will complement the Fiji-based University of the South Pacific, which has campuses in other Pacific Island countries.

In 2009, Papua New Guinea articulated its *National Vision 2050*, which led to the establishment of a Research, Science and Technology Council. *Vision 2050*'s medium-term priorities include:

- emerging industrial technology for downstream processing;
- infrastructure technology for the economic corridors;
- knowledge-based technology;
- S&T education; and
- the ambitious target of investing 5% of GDP in R&D by 2050.

At its gathering in November 2014, the Research, Science and Technology Council re-emphasized the need to focus on sustainable development through science and technology. Moreover, in its *Higher Education Plan III 2014–2023*, Papua New Guinea sets out a strategy for transforming tertiary education and R&D through the introduction of a quality assurance system and a programme to overcome the limited R&D capacity.

Like Papua New Guinea, Fiji and Samoa consider education to be one of the key policy tools for driving STI and modernization. Fiji, in particular, has made a supreme effort to re-visit existing policies, rules and regulations in this sector. The Fijian government allocates a larger portion of its national budget to education than any other Pacific Island country (4% of GDP in 2011), although this is down from 6% of GDP in 2000. The proportion of the education budget allocated to higher education has fallen slightly, from 14% to 13%, but scholarship schemes like National Toppers, introduced in 2014, and the availability of student loans have made higher education attractive and rewarding in Fiji. Many Pacific Island countries take Fiji as a benchmark: the country draws education leaders from other Pacific Island countries for training and, according to the Ministry of Education, teachers from Fiji are in great demand in these countries.

According to an internal investigation into the choice of disciplines in school-leaving examinations (year 13), Fijian students have shown a greater interest in science since 2011. A similar trend can be observed in enrolment figures at all three Fijian universities. One important initiative has been the creation of the Higher Education Commission (FHEC) in 2010, the regulatory body in charge of tertiary education in Fiji. FHEC has embarked on registration and accreditation processes for tertiary-level education providers to improve the quality of higher education in Fiji. In 2014, FHEC allocated research grants to universities with a view to enhancing the research culture among faculty.

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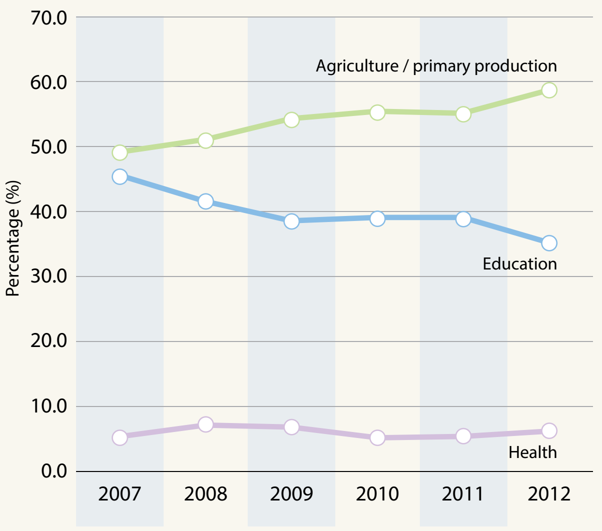
[8] **8.** The ten are the: Australian National University, Montroix Pty Ltd (Australia), University of the South Pacific, Institut Malardé in French Caledonia, National Centre for Technological Research into Nickel and its Environment in New Caledonia, South Pacific Community, Landcare Research Ltd in New Zealand, University of Papua New Guinea, Samoa National University and the Vanuatu Cultural Centre.

[9] **9.** See: http://pacenet.eu/news/pacenet-outcomes-2013

Figure 27.11: **Government expenditure on R&D in Fiji by socio-economic objective, 2007–2012**



Source: Fiji Bureau of Statistics, 2014

Fiji is the only Pacific Island country with recent data for GERD. The national Bureau of Statistics cites a GERD/GDP ratio of 0.15% in 2012. Private-sector R&D is negligible. Between 2007 and 2012, government investment in R&D tended to favour agriculture (Figure 27.11). Scientists publish much more in geosciences and medical sciences than in agricultural sciences, however (Figure 27.8).

According to the Web of Science, Papua New Guinea had the largest number of publications (110) among Pacific Island states[10] in 2014, followed by Fiji (106). These publications concerned mainly life sciences and geosciences. A noticeable feature of scientific publications from French Polynesia and New Caledonia is the emphasis on the geosciences: six to eight times the world average for this field. Conversely, nine out of ten scientific publications from Papua New Guinea concentrate on immunology, genetics, biotechnology and microbiology.

Fijian research collaboration with North American partners exceeded that with India between 2008 and 2014 – a large proportion of Fijians are of Indian origin – and was concentrated in a handful of scientific disciplines, such as medical sciences, environmental sciences and biology. International co-authorship was higher for Papua New Guinea and Fiji (90% and 83% respectively) than for New Caledonia and French Polynesia (63% and 56% respectively). Research partnerships also involved countries in Southeast Asia and Oceania, as well as the USA and Europe. Surprisingly, there was little co-authorship with authors based in France, with the notable exception of Vanuatu (Figure 27.8).

Having 100% foreign co-authors has its drawbacks

A near-100% rate of international co-authoring can be a double-edged sword. According to the Fijian Ministry of Health, research collaboration often results in an article being published in a reputed journal but gives very little back in terms of strengthening health in Fiji. A new set of guidelines are now in place in Fiji to help build endogenous capacity in health research through training and access to new technology. The new policy guidelines require that all research projects initiated in Fiji with external bodies demonstrate how the project will contribute to local capacity-building in health research. The Ministry of Health itself is seeking to develop endogenous research capacity through the *Fiji Journal of Public Health*, which it launched in 2012. In parallel, the Ministry of Agriculture revived Fiji's *Agricultural Journal* in 2013, which had been dormant for 17 years. In addition, two regional journals were launched in 2009 as a focus for Pacific scientific research, the *Samoan Medical Journal* and the *Papua New Guinea Journal of Research, Science and Technology.*

Fiji leading growth in ICTs

Access to the internet and mobile phone technologies has increased considerably across the Pacific Island countries in the past few years. Fiji shows substantial growth in this field, supported by its geographical location, service culture, pro-business policies, English-speaking population and well-connected e-society. Relative to many other South Pacific Islands, Fiji has a fairly reliable and efficient telecommunications system with access to the Southern Cross submarine cable linking New Zealand, Australia and North America. A recent move to establish the University of the South Pacific Stathan ICT Park, the Kalabo ICT economic zone and the ATH technology park in Fiji should boost the ICT support service sector in the Pacific region.

Tokelau first to generate all electricity from renewable sources

On average, 10% of the GDP of Pacific Island countries funds imports of petroleum products but in some cases this figure can exceed 30%. In addition to high fuel transport costs, this reliance on fossil fuels leaves Pacific economies vulnerable to volatile global fuel prices and potential spills[11] by oil tankers. Consequently, many Pacific Island countries are convinced that renewable energy will play a role in their countries' socio-economic development. In Fiji, Papua New Guinea, Samoa and Vanuatu, renewable energy sources already represent significant shares of the total electricity supply: 60%, 66%, 37% and 15% respectively. Tokelau has even become the first country in the world to generate 100% of its electricity using renewable sources.

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[10] They are not covered in the present chapter but the French territories of New Caledonia and French Polynesia had 116 and 58 publications catalogued in the Web of Science in 2013.

[11] See: www.pacificenergysummit2013.com/about/energy-needs-in-the-pacific

Targets for developing sustainable energy

New targets for many Pacific Island countries were established between 2010 and 2012 (Tables 27.3 and 27.4) and efforts are under way to improve countries' capacity to produce, conserve and use renewable energy. For example, the EU has funded the Renewable Energy in Pacific Island Countries Developing Skills and Capacity programme (EPIC). Since its inception in 2013, EPIC has developed two master's programmes in renewable energy management and helped to establish two Centres of Renewable Energy, one at the University of Papua New Guinea and the other at the University of Fiji. Both centres became operational in 2014 and aim to create a regional knowledge hub for the development of renewable energy. In February 2014, the EU and the Pacific Islands Forum Secretariat signed an agreement for a programme on Adapting to Climate Change and Sustainable Energy worth € 37.26 million which will benefit 15 Pacific Island[12] states.

Climate change a common concern

In the Pacific region, climate change mostly concerns marine issues, such as rising sea levels and the increased salinity of soils and groundwater, whereas, in Southeast Asia, carbon reduction strategies are a major focus. Disaster resilience, on the other hand, resonates with both regions.

Climate change seems to be the most pressing environmental issue for Pacific Island countries, as it is already affecting almost all socio-economic sectors. The consequences of climate change can be seen in agriculture, food security, forestry and even in the spread of communicable diseases. The Secretariat of the Pacific Community has initiated several activities to tackle problems associated with climate change. These cover a great variety of areas, such as fisheries, freshwater, agriculture, coastal zone management, disaster management, energy, traditional knowledge, education, forestry, communication, tourism, culture, health, weather,

Table 27.3: **National renewable energy targets for selected Pacific Island states, 2013–2020**

Country	Energy Target	Timeframe
Cook Islands	50% of energy demand provided by renewable energy by 2015 and 100% by 2020	2015 and 2020
Fiji	90% renewable	2015
Nauru	50% renewable	2015
Palau	20% renewable and a 30% reduction in energy consumption	2020
Samoa	10% renewable	2016
Tonga	50% renewable and the overall energy cost reduced by 50%	2015
Vanuatu	33% renewable, target fixed by UNELCO (a private company)	2013

Source: Secretariat of the Pacific Community (2013) *Sustainable Development Brief*

Table 27.4: **Fiji's Green Growth Framework, 2014**

Focus area	Strategy
Support research and innovation in green technologies and services	■ support existing green industries by subsidizing firms that use green technologies throughout the production value chain; ■ increase public research funding for refining and improving existing technologies, such as the Ocean Centre for Sustainable Transport; ■ develop a national framework for promoting innovation and research into environmentally sustainable technologies by the end of 2017.
Promote the use of green technologies	■ increase public awareness of green technologies; ■ measure the success of public school environmental education; ■ examine the potential for tariffs on non-green technology imports; ■ reduce import duties on low carbon technologies; ■ introduce incentives for large-scale FDI in industries that develop environmentally sustainable technology in areas such as transport, energy, manufacturing and agriculture.
Develop national innovative capabilities	■ develop a strategy for science and technology, innovation and R&D that is integrated in an overall sustainable development strategy across all thematic areas by the end of 2017; ■ ensure that at least 50% of secondary school teachers are trained to implement the revised Fiji National Curriculum Framework by 2020.

Source: Ministry of Strategic Planning and National Development and Statistics (2014) *A Green Growth Framework for Fiji: Restoring the Balance in Development that is Sustainable for our Future.* Suva

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[12] Cook Islands, Fiji, Kiribati , Marshall Islands, Federated States of Micronesia, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor-Leste, Tonga, Tuvalu and Vanuatu

gender implications and biodiversity. Almost all Pacific Island countries are involved in one or more of these activities.

Several projects related to climate change are also being co-ordinated by UNEP, within the Secretariat of the Pacific Region Environmental Programme (SPREP). The aim of SPREP is to help all members improve their 'capacity to respond to climate change through policy improvement, implementation of practical adaptation measures, enhancing ecosystem resilience to the impacts of climate change and implementing initiatives aimed at achieving low-carbon development'.

The first major scheme focusing on adaptation to climate change and climate variability dates back to 2009. Pacific Adaptation to Climate Change involves 13 Pacific Island nations, with international funding from the Global Environment Facility, as well as from the US and Australian governments.

Using S&T to foster value-added production in Fiji

The desire to ensure that fisheries remain sustainable is fuelling the drive to use S&T to make the transition to value-added production. The fisheries sector in Fiji is currently dominated by the catch of tuna for the Japanese market. The Fijian government plans to diversify this sector through aquaculture, inshore fisheries and offshore fish products such as sunfish and deep-water snapper. Accordingly, many incentives and concessions are being offered to encourage the private sector to invest in these areas.

Another priority area in the Pacific is agriculture and food security. The *Fiji 2020–Agriculture Sector Policy Agenda* (MoAF, 2014) draws attention to the need to build a sustainable community and gives high priority in the development agenda to ensuring food security. Strategies outlined in *Fiji 2020* include:

- modernizing agriculture in Fiji;
- developing integrated systems for agriculture;
- improving delivery of agricultural support systems;
- enhancing innovative agricultural business models; and
- strengthening the capacity for policy formulation.

Fiji has taken the initiative of shifting away from subsistence agriculture towards commercial agriculture and agro-processing of root crops, tropical fruits, vegetables, spices, horticulture and livestock.

Little use of technology in forestry

Forestry is an important economic resource for Fiji and Papua New Guinea. However, forestry in both countries uses low- and semi-intensive technological inputs. As a result, product ranges are limited to sawed timber, veneer, plywood, block board, moulding, poles and posts and wood chips. Only a few limited finished products are exported. Lack of automated machinery, coupled with inadequately trained local technical personnel, are some of the obstacles to introducing automated machinery and design. Policy-makers need to turn their attention to eliminating these barriers, in order for forestry to make a more efficient and sustainable contribution to national economic development.

The blueprint for the subregion's sustainable development over the coming decade is the *Samoa Pathway*, the action plan adopted by countries at the third United Nations Conference on Small Island Developing States in Apia (Samoa) in September 2014. The *Samoa Pathway* focuses on, *inter alia*, sustainable consumption and production; sustainable energy, tourism and transportation; climate change; disaster risk reduction; forests; water and sanitation, food security and nutrition; chemical and waste management; oceans and seas; biodiversity; desertification, land degradation and drought; and health and non-communicable diseases.

CONCLUSION

A need to find a balance between local and global engagement in problem-solving

Leaving aside for the moment the region's four leaders for R&D intensity – Australia, Malaysia, New Zealand and Singapore – most countries covered in the present chapter are small both economically and in terms of their scientific production. It is thus not surprising to find an extremely high proportion of researchers in these countries who collaborate more or less systematically with the more scientifically prolific countries in the region and with scientists from knowledge hubs in North America, Europe and elsewhere in Asia. For the less developed economies in the Southeast Pacific and Oceania, co-authorship is in the range of 90–100% and such collaboration appears to be growing. This trend can be of benefit not only for the low income countries but also for global science when it comes to tackling regional problems associated with food production, health, medicine and geo-technical issues. However, the issue for the smaller economies is whether output dominated by international scientific collaboration is steering research in the direction envisaged by national S&T policies or whether research in these less developed countries is being driven by the particular interests of foreign scientists.

We have seen that multinational corporations have gravitated towards Cambodia and Viet Nam in recent years. Despite this, the number of patents granted for these two countries is negligible: four and 47 patents respectively over the period from 2002–2013. Even though 11% of the region's high-tech exports came from Viet Nam in 2013, according to the

Comtrade database, the majority of high-tech exports from Viet Nam (and no doubt Cambodia, too, but data are lacking) were designed elsewhere and simply assembled in the host country. Even if foreign firms *do* intensify their in-house R&D in the low income country that hosts them, this will not necessarily boost capacity for science and technology in the host country. Unless there is a sufficient number of trained personnel and strong institutional capabilities, R&D will continue to take place elsewhere. The rapid growth of FDI in R&D in India and China, where there has been parallel growth in the availability of local skills, is the outcome of strategic business decisions. The alternative for developing economies such as Viet Nam and Cambodia is to draw on the knowledge and skills embedded in the activities of large foreign firms, in order to develop the same level of professionalism among local suppliers and firms. By encouraging foreign high-tech manufacturers to run training programmes in the host country, governments will also be drawing manufacturers into national training strategies, with positive spin-offs for both producers and suppliers. A more technically advanced supply chain that is capable of absorbing new skills and knowledge should, in turn, encourage foreign firms to invest in R&D, with a flow-on benefit to local firms.

Regional blocs are playing an important role in science and technology across the region. We have seen that ASEAN is monitoring and co-ordinating developments in science and moving towards the free flow of skilled personnel across its member states. APEC has recently completed a study of skills shortages in the region with a view to setting up a monitoring system to address training needs before shortages become critical. Pacific Island countries have initiated a number of networks to foster research collaboration and solutions to deal with climate change.

The end of the commodities boom since 2013 has led resource-rich economies to devise S&T policies that can reinvigorate economic alternatives in areas in which countries show strengths, such as life sciences for Australia and New Zealand or engineering for some Asian countries. There is a growing tendency for policy to integrate innovation into S&T policies and STI strategies into longer-term development plans.

To some extent, this trend has created a dilemma for science and, in particular, for scientists. On the one hand, there is a strong imperative to produce quality scientific research and the metric for measuring quality is essentially scientific output in peer-reviewed journals. The careers of academic researchers and those in public research institutions depend upon it, yet many national development plans are also seeking research relevance. Clearly, both imperatives are important for fostering development and international competitiveness. The richer countries have the economic opportunity to pursue advances in basic research and to build a deeper and broader science base. Lower-income economies, however, face accrued pressure to favour relevance. Maintaining career paths for scientists that allow them to pursue both quality and relevance will remain a challenge.

Today, most policies across Southeast Asia and Oceania are oriented towards sustainable development and managing the consequences of climate change. The most notable exception is Australia. To some extent, the focus on sustainable development is probably driven by global concerns and the imminent adoption of the United Nations' Sustainable Development Goals in September 2015. Global engagement is far from the only motivation, however. Rising sea levels and increasingly frequent and virulent hurricanes are threatening agricultural production and freshwater quality and are thus of direct concern to most countries in the region. In turn, global collaboration will remain an important strategy for resolving these local issues.

KEY TARGETS FOR SOUTHEAST ASIA AND OCEANIA

- Attain economic growth of 12.7% on average in Indonesia from 2010 to 2025, in order to become one of the world's ten largest economies by 2025;
- Raise GERD to 1% of GDP in Thailand by 2021, with the private sector contributing 70% of GERD;
- Raise GERD to 3.5% of GDP in Singapore by 2015 (2.1% in 2012);
- By 2030, ensure that all 13 districts in Timor-Leste have at least one hospital and that there is a specialist hospital in Dili, with at least half of the nation's energy needs to be met by renewable energy sources;
- Raise the share of renewable energy by 2015–2016 in the following Pacific Island nations to: Cook Islands, Nauru and Tonga (50%), Fiji (90%) and Samoa (10%).

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