Global overview

Many dilemmas appear increasingly common to a wide range of countries, such as that of trying to find a balance between local and international engagement in research, or between basic and applied science, the generation of new knowledge and marketable knowledge, or public good science versus science to drive commerce.

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1 · A world in search of an effective growth strategy

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INTRODUCTION

For two decades now, the *UNESCO Science Report* series has been mapping science, technology and innovation (STI) around the world on a regular basis. Since STI do not evolve in a vacuum, this latest edition summarizes the evolution since 2010 against the backdrop of socio-economic, geopolitical and environmental trends that have helped to shape contemporary STI policy and governance.

More than 50 experts have contributed to the present report, each of them covering the region or country from which they hail. A quinquennial report has the advantage of being able to focus on longer-term trends, rather than becoming entrenched in descriptions of short-term annual fluctuations which, with respect to policy and science and technology indicators, rarely add much value.

KEY INFLUENCES ON STI POLICY AND GOVERNANCE

Geopolitical events have reshaped science in many regions

The past five years have witnessed major geopolitical changes with significant implications for science and technology. To name just a few: the Arab Spring in 2011; the nuclear deal with Iran in 2015; and the creation of the Association of Southeast Asian Nations (ASEAN) Economic Community in 2015.

At first sight, many of these developments have little to do with science and technology but their indirect impact has often been significant. In Egypt, for instance, there has been a radical change in STI policy since the Arab Spring. The new government considers the pursuit of a knowledge economy as being the best way to harness an effective growth engine. The Constitution adopted in 2014 mandates the state to allocate 1% of GDP to research and development (R&D) and stipulates that the 'state guarantees the freedom of scientific research and encourages its institutions as a means towards achieving national sovereignty and building a knowledge economy that supports researchers and inventors' (Chapter 17).

In Tunisia, there has been greater academic freedom in the past year and scientists have been developing closer international ties; Libya, on the other hand, is confronted with a militant insurgency, offering little hope of a rapid revival of science and technology. Syria is in the throes of a civil war. Porous political borders resulting from the political upheaval of the Arab Spring have, meanwhile, allowed opportunistic terrorist groups to prosper. These hyper-violent militias not only pose a threat to political stability; they also undermine national aspirations towards a knowledge economy, for they are inherently hostile to enlightenment, in general, and the education of girls and women, in particular. The tentacles of this obscurantism now stretch as far south as Nigeria and Kenya (Chapters 18 and 19).

Meanwhile, countries emerging from armed conflict are modernizing infrastructure (railways, ports, etc) and fostering industrial development, environmental sustainability and education to facilitate national reconciliation and revive the economy, as in Côte d'Ivoire and Sri Lanka (Chapters 18 and 21).

The nuclear deal concluded in 2015 could be a turning point for science in Iran but, as Chapter 15 observes, international sanctions have already incited the regime to accelerate the transition to a knowledge economy, in order to compensate for lost oil revenue and international isolation by developing local products and processes. The flow of revenue from the lifting of sanctions should give the government an opportunity to boost investment in R&D, which accounted for just 0.31% of GDP in 2010.

Meanwhile, the Association of South East Asian Nations (ASEAN) intends to transform this vast 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 and thereby reinforce the emerging Asia–Pacific knowledge hub. The greater mobility of skilled personnel should be a boon for the region and enhance the role of the ASEAN University Network, which already counts 30 members. As part of the negotiating process for the ASEAN Economic Community, each member state may express its preference for a specific research focus. The Laotian government, for instance, hopes to prioritize agriculture and renewable energy (Chapter 27).

In sub-Saharan Africa, too, regional economic communities are playing a growing role in the region's scientific integration, as the continent prepares the groundwork for its own African Economic Community by 2028. Both the Economic Community of West African States and the Southern African Development Community (SADC) have adopted regional strategies for STI in recent years that complement the continent's decadal plans.[1] The East African Community (EAC) has entrusted the Inter-University Council for East Africa with the mission of developing a Common Higher Education Area. The ongoing development of networks of centres of excellence across the continent should foster greater scientific mobility and information-sharing, as long as obstacles to the mobility of scientists can be removed. The decision by Kenya, Rwanda and Uganda in 2014 to adopt a single tourist visa is a step in the right direction.

It will be interesting to see the extent to which the new Union of South American Nations (UNASUR) fosters regional scientific integration in the years to come. Modelled on the European Union (EU), UNASUR plans to establish a common parliament and currency for its 12 members and to foster the free movement of goods, services, capital and people around the subcontinent (Chapter 7).

Environmental crises raising expectations of science

Environmental crises, be they natural or human-made, have also influenced STI policy and governance in the past five years. The shockwaves from the Fukushima nuclear disaster in March 2011 carried far beyond Japan's shores. The disaster prompted Germany to commit to phasing out nuclear energy by 2020 and fostered debate in other countries on the risks of nuclear energy. In Japan itself, the triple catastrophe[2] made a tremendous impact on Japanese society. Official statistics show that the tragedy of 2011 has shaken the public's trust not only in nuclear technology but in science and technology more broadly (Chapter 24).

It doesn't tend to make the headlines but growing concern over recurrent drought, flooding and other natural phenomena have led governments to adopt coping strategies in the past five years. Cambodia, for instance, has adopted a *Climate Change Strategy* (2014–2023) with the assistance of European development partners to protect its agriculture. In 2013, the Philippines was hit by possibly the strongest tropical cyclone ever to make landfall. The country has been investing heavily in tools to mitigate disaster risk, such as 3D disaster-simulation models, and building local capability to apply, replicate and produce many of these technologies (Chapter 27). The biggest single US economy, the State of California, has been experiencing drought for years; in April 2015, the state governor announced a 40% carbon emissions reduction target by 2030 over 1990 levels (Chapter 5).

1. Namely, *Africa's Science and Technology Consolidated Plan of Action* (2005–2014) and its successor, the *Science, Technology and Innovation Strategy for Africa* (STISA–2024)

2. A subterranean earthquake generated a tsunami that swamped the Fukushima nuclear plant, cutting off the power supply to its cooling system, causing the nuclear rods to overheat and sparking multiple explosions which released radioactive particles into the air and water.

Angola, Malawi and Namibia have all experienced below-normal rainfall in recent years that has affected food security. In 2013, ministers from the SADC approved the development of a Regional Climate Change programme. In addition, the Common Market for Eastern and Southern Africa (COMESA), EAC and SADC have been implementing a joint five-year initiative since 2010 known as the Tripartite Programme on Climate Change Adaptation and Mitigation (Chapter 20).

In Africa, agriculture continues to suffer from poor land management and low investment. Despite the continent's commitment, in the *Maputo Declaration* (2003), to devoting at least 10% of GDP to agriculture, only a handful of countries have since reached this target (see Table 19.2). Agricultural R&D suffers as a consequence. There have been moves, however, to reinforce R&D. For instance, Botswana established an innovative hub in 2008 to foster the commercialization and diversification of agriculture and Zimbabwe is planning to establish two new universities of agricultural science and technology (Chapter 20).

Energy has become a major preoccupation

The EU, USA, China, Japan, the Republic of Korea and others have all toughened national legislation in recent years to reduce their own carbon emissions, develop alternative energy sources and promote greater energy efficiency. Energy has become a major preoccupation of governments everywhere, including oil-rent economies like Algeria and Saudi Arabia that are now investing in solar energy to diversify their energy mix.

This trend was evident even before Brent crude oil prices began their downward spiral in mid-2014. Algeria's Renewable Energy and Energy Efficiency Programme was adopted in March 2011, for instance, and has since approved more than 60 wind and solar energy projects. Gabon's *Strategic Plan* to 2025 (2012) states that setting the country on the path to sustainable development 'is at the heart of the new executive's policy'. The plan identifies the need to diversify an economy dominated by oil (84% of exports in 2012), foresees a national climate plan and fixes the target of raising the share of hydropower in Gabon's electricity matrix from 40% in 2010 to 80% by 2020 (Chapter 19).

A number of countries are developing futuristic, hyper-connected 'smart' cities (such as China) or 'green' cities which use the latest technology to improve efficiency in water and energy use, construction, transportation and so on, examples being Gabon, Morocco and the United Arab Emirates (Chapter 17).

If sustainability is a primary concern for most governments, some are swimming against the tide. The Australian government, for instance, has shelved the country's carbon tax and announced plans to abolish institutions instigated by the previous government[3] to stimulate technological development in the renewable energy sector (Chapter 27).

The quest for a growth strategy that works

Overall, the years 2009–2014 have been a difficult transition period. Ushered in by the global financial crisis of 2008, this transition has been marked by a severe debt crisis in the wealthier countries, uncertainty over the strength of the ensuing recovery and the quest for an effective growth strategy. Many high-income countries are faced with similar challenges, such as an ageing society (USA, EU, Japan, etc.) and chronic low growth (Table 1.1); all are confronted with tough international competition. Even those countries that are doing well, such as Israel and the Republic of Korea, fret over how to maintain their edge in a rapidly evolving world.

In the USA, the Obama administration has made investment in climate change research, energy and health a priority but much of its growth strategy has been contraried by the congressional priority of reducing the federal budget deficit. Most federal research budgets have remained flat or declined in inflation-adjusted dollars over the past five years (Chapter 5).

In 2010, the EU adopted its own growth strategy, *Europe 2020*, to help the region emerge from the crisis by embracing smart, sustainable and inclusive growth. The strategy observed that 'the crisis has wiped out years of economic and social progress and exposed structural weaknesses in Europe's economy'. These structural weaknesses include low R&D spending, market barriers and insufficient use of information and communication technologies (ICTs). *Horizon 2020*, the EU's current seven-year framework programme for research and innovation, has received the biggest budget ever in order to drive this agenda between 2014 and 2020. The *2020 Strategy* adopted by Southeast Europe mirrors that of its EU namesake but, in this case, the primary aim of this growth strategy is to prepare countries for their future accession to the EU.

Japan is one of the world's big spenders on R&D (Figure 1.1) but its self-confidence has been shaken in recent years, not only by the triple catastrophe in 2011 but also by the failure to shake off the deflation that has stifled the economy for the past 20 years. Japan's current growth strategy, Abenomics, dates from 2013 and has not yet delivered on its promise of faster growth. The effects of a low-growth equilibrium on investor confidence are visible in the reluctance of Japanese firms to raise R&D spending or staff salaries and in their aversion to the necessary risk-taking to launch a new growth cycle.

The Republic of Korea is seeking its own growth strategy. Although it came through the global financial crisis remarkably unscathed, it has outgrown its 'catch-up model.' Competition with China and Japan is intense, exports are slipping and global demand is evolving towards green growth. Like Japan, it is faced with a rapidly ageing population and declining birthrates that challenge its long-term economic development prospects. The Park Geun-hye administration is pursuing her predecessor's goal of 'low carbon, green growth' but also emphasizing the 'creative economy,' in an effort to revitalize the manufacturing sector through the emergence of new creative industries. Up until now, the Republic of Korea has relied on large conglomerates such as Hyundai (vehicles) and Samsung (electronics) to drive growth and export earnings. Now, it is striving to become more entrepreneurial and creative, a process that will entail changing the very structure of the economy – and the very bases of science education.

Among the BRICS (Brazil, Russian Federation, India, China and South Africa), China has managed to dodge the fallout from the 2008 global financial and economic crisis but its economy was showing signs of strain[4] in mid-2015. Up until now, China has relied upon public expenditure to drive growth but, with investor confidence faltering in August 2015, China's desired switch from export-orientation to more consumption-driven growth has been thrown into doubt. There is also some concern among the political leadership that the massive investment in R&D over the past decade is not being matched by scientific output. China, too, is in search of an effective growth strategy.

By maintaining a strong demand for commodities to fuel its rapid growth, China has buffeted resource-exporting economies since 2008 from the drop in demand from North America and the EU. Ultimately, however, the cyclical boom in commodities has come to an end, revealing structural weaknesses in Brazil and the Russian Federation, in particular.

In the past year, Brazil has entered into recession. Although the country has expanded access to higher education in recent years and raised social spending, labour productivity remains low. This suggests that Brazil has, so far, not managed to harness innovation to economic growth, a problem shared by the Russian Federation.

The Russian Federation is searching for its own growth strategy. In May 2014, President Putin called for a widening of Russian import substitution programmes to reduce the country's dependence on technological imports. Action plans have since been launched in various industrial sectors to produce cutting-edge technologies. However, the government's plans to stimulate business innovation may be

3. namely the Australian Renewable Energy Agency and the Clean Energy Finance Corporation

4. The Chinese economy grew by 7.4% in 2014 and is projected to grow by 6.8% in 2015 but there is growing uncertainty as to whether it will achieve this target.

contraried by the current recession, following the downturn in Brent crude oil prices, the imposition of sanctions and a deteriorating business climate.

Meanwhile, in India, growth has remained at the respectable level of about 5% in the past few years but there are concerns that economic growth is not creating enough jobs. Today, India's economy is dominated by the services sector (57% of GDP). The Modi government elected in 2014 has argued for a new economic model based on export-oriented manufacturing to foster job creation. India is already becoming a hub for frugal innovation, thanks to the large domestic market for pro-poor products and services such as low-cost medical devices and cheap cars.

With the end of the commodities boom, Latin America is, itself, in search of a new growth strategy. Over the past decade, the region has reduced its exceptionally high levels of economic inequality but, as global demand for raw materials has fallen, Latin America's own growth rates have begun stagnating or even contracting in some cases. Latin American countries are not lacking in policy initiatives or in the sophistication of institutional structures to promote science and research (Chapter 7). Countries have made great strides in terms of access to higher education, scientific mobility and output. Few, however, appear to have used the commodities boom to embrace technology-driven competitiveness. Looking ahead, the region may be well placed to develop the type of scientific excellence that can underpin green growth by combining its natural advantages in biological diversity and its strengths with regard to indigenous (traditional) knowledge systems.

The long-term planning documents to 2020 or 2030 of many low- and middle-income countries also reflect the quest for a growth strategy able to carry them into a higher income bracket. These 'vision' documents tend to have a triple focus: better governance, in order to improve the business environment and attract foreign investment to develop a dynamic private sector; more inclusive growth, to reduce poverty levels and inequality; and environmental sustainability, to protect the natural resources on which most of these economies depend for foreign exchange.

GLOBAL TRENDS IN R&D EXPENDITURE

How has the crisis affected R&D investment?

The *UNESCO Science Report 2010* was written in the immediate aftermath of the global financial crisis. Its coverage encompassed a period of historically unmatched global economic growth between 2002 and 2007. It was also forward-looking. One question it addressed was the extent to which the global crisis might be bad for global knowledge creation. The conclusion that global investment in R&D would not be that strongly affected by the crisis appears, with hindsight, to have been spot on.

In 2013, world GERD amounted to PPP$ 1 478 billion, compared to only PPP$ 1 132 billion in 2007[5]. This was less than the 47% increase recorded over the previous period (2002–2007) but a significant increase nevertheless. Moreover, this rise took place during a time of crisis. As GERD progressed much faster than global GDP, this caused global R&D intensity to climb from 1.57% (2007) to 1.70% (2013) of GDP (Tables 1.1 and 1.2).

As argued in the *UNESCO Science Report 2010*, Asia, in general, and China, in particular, were the first to recover from the crisis, pulling global R&D investment relatively quickly to higher levels.[6] In other emerging economies such as Brazil and India, the rise in R&D intensity took longer to kick in.

Similarly, the prediction that both the USA and EU would be able to maintain their own R&D intensity at pre-crisis levels was not only correct but even too conservative a prediction. The Triad (EU, Japan and USA) have all seen GERD rise over the past five years to levels well above those of 2007, unlike Canada.

Public research budgets: a converging, yet contrasting picture

The past five years have seen a converging trend: disengagement in R&D by the public sector in many high-income countries (Australia, Canada, USA, etc.) and a growing investment in R&D on the part of lower income countries. In Africa, for instance, Ethiopia has used some of the fastest growth rates on the continent to raise GERD from 0.24% (2009) to 0.61% (2013) of GDP. Malawi has raised its own ratio to 1.06% and Uganda to 0.48% (2010), up from 0.33% in 2008. There is a growing recognition in Africa and beyond that the development of modern infrastructure (hospitals, roads, railways, etc.) and the achievement of economic diversification and industrialization will necessitate greater investment in STI, including the constitution of a critical mass of skilled workers.

Spending on R&D is on the rise in many East and Central African countries with innovation hubs (Cameroon, Kenya, Rwanda, Uganda, etc.), driven by greater investment by both the public and private sectors (Chapter 19). The sources of Africa's heightened interest in STI are multiple but the global financial crisis of 2008–2009 certainly played a role. It boosted commodity prices and focused attention on beneficiation policies in Africa.

5. PPP stands for purchasing power parity.

6. China's R&D intensity more than doubled between 2007 and 2013 to 2.08. This is above the EU average and means that China is on track to achieve its target of a 2.5% GERD/GDP ratio by 2020.

Table 1.1: **World trends in population and GDP**

	Population (in millions)		Share of global population (%)		GDP in constant 2005 PPP$ billions				Share of global GDP (%)			
	2007	2013	2007	2013	2007	2009	2011	2013	2007	2009	2011	2013
World	**6 673.1**	**7 162.1**	**100.0**	**100.0**	**72 198.1**	**74 176.0**	**81 166.9**	**86 674.3**	**100.0**	**100.0**	**100.0**	**100.0**
High-income economies	1 264.1	1 309.2	18.9	18.3	41 684.3	40 622.2	42 868.1	44 234.6	57.7	54.8	52.8	51.0
Upper-middle-income economies	2 322.0	2 442.1	34.8	34.1	19 929.7	21 904.3	25 098.5	27 792.6	27.6	29.5	30.9	32.1
Lower-middle-income economies	2 340.7	2 560.4	35.1	35.7	9 564.7	10 524.5	11 926.1	13 206.4	13.2	14.2	14.7	15.2
Low-income economies	746.3	850.3	11.2	11.9	1 019.4	1 125.0	1 274.2	1 440.7	1.4	1.5	1.6	1.7
Americas	**913.0**	**971.9**	**13.7**	**13.6**	**21 381.6**	**21 110.0**	**22 416.8**	**23 501.5**	**29.6**	**28.5**	**27.6**	**27.1**
North America	336.8	355.3	5.0	5.0	14 901.4	14 464.1	15 088.7	15 770.5	20.6	19.5	18.6	18.2
Latin America	535.4	574.1	8.0	8.0	6 011.0	6 170.4	6 838.5	7 224.7	8.3	8.3	8.4	8.3
Caribbean	40.8	42.5	0.6	0.6	469.2	475.5	489.6	506.4	0.6	0.6	0.6	0.6
Europe	**806.5**	**818.6**	**12.1**	**11.4**	**18 747.3**	**18 075.1**	**19 024.5**	**19 177.9**	**26.0**	**24.4**	**23.4**	**22.1**
European Union	500.8	509.5	7.5	7.1	14 700.7	14 156.7	14 703.8	14 659.5	20.4	19.1	18.1	16.9
Southeast Europe	19.6	19.2	0.3	0.3	145.7	151.0	155.9	158.8	0.2	0.2	0.2	0.2
European Free Trade Association	12.6	13.5	0.2	0.2	558.8	555.0	574.3	593.2	0.8	0.7	0.7	0.7
Other Europe	273.6	276.4	4.1	3.9	3 342.0	3 212.3	3 590.5	3 766.4	4.6	4.3	4.4	4.3
Africa	**957.3**	**1 110.6**	**14.3**	**15.5**	**3 555.7**	**3 861.4**	**4 109.8**	**4 458.4**	**4.9**	**5.2**	**5.1**	**5.1**
Sub-Saharan Africa	764.7	897.3	11.5	12.5	2 020.0	2 194.3	2 441.8	2 678.5	2.8	3.0	3.0	3.1
Arab States in Africa	192.6	213.3	2.9	3.0	1 535.8	1 667.1	1 668.0	1 779.9	2.1	2.2	2.1	2.1
Asia	**3 961.5**	**4 222.6**	**59.4**	**59.0**	**27 672.8**	**30 248.0**	**34 695.7**	**38 558.5**	**38.3**	**40.8**	**42.7**	**44.5**
Central Asia	61.8	67.2	0.9	0.9	408.9	446.5	521.2	595.4	0.6	0.6	0.6	0.7
Arab States in Asia	122.0	145.2	1.8	2.0	2 450.0	2 664.0	3 005.2	3 308.3	3.4	3.6	3.7	3.8
West Asia	94.9	101.9	1.4	1.4	1 274.2	1 347.0	1 467.0	1 464.1	1.8	1.8	1.8	1.7
South Asia	1 543.1	1 671.6	23.1	23.3	5 016.1	5 599.2	6 476.8	7 251.4	6.9	7.5	8.0	8.4
Southeast Asia	2 139.7	2 236.8	32.1	31.2	18 523.6	20 191.3	23 225.4	25 939.3	25.7	27.2	28.6	29.9
Oceania	**34.8**	**38.3**	**0.5**	**0.5**	**840.7**	**881.5**	**920.2**	**978.0**	**1.2**	**1.2**	**1.1**	**1.1**
Other groupings												
Least developed countries	783.4	898.2	11.7	12.5	1 327.2	1 474.1	1 617.9	1 783.6	1.8	2.0	2.0	2.1
Arab States all	314.6	358.5	4.7	5.0	3 985.7	4 331.1	4 673.2	5 088.2	5.5	5.8	5.8	5.9
OECD	1 216.3	1 265.2	18.2	17.7	38 521.2	37 306.1	39 155.4	40 245.7	53.4	50.3	48.2	46.4
G20	4 389.5	4 615.5	65.8	64.4	57 908.7	59 135.1	64 714.6	68 896.8	80.2	79.7	79.7	79.5
Selected countries												
Argentina	39.3	41.4	0.6	0.6	631.8	651.7	772.1	802.2	0.9	0.9	1.0	0.9
Brazil	190.0	200.4	2.8	2.8	2 165.3	2 269.8	2 507.5	2 596.5	3.0	3.1	3.1	3.0
Canada	33.0	35.2	0.5	0.5	1 216.8	1 197.7	1 269.4	1 317.2	1.7	1.6	1.6	1.5
China	1 334.3	1 385.6	20.0	19.3	8 313.0	9 953.6	12 015.9	13 927.7	11.5	13.4	14.8	16.1
Egypt	74.2	82.1	1.1	1.1	626.0	702.1	751.3	784.2	0.9	0.9	0.9	0.9
France	62.2	64.3	0.9	0.9	2 011.1	1 955.7	2 035.6	2 048.3	2.8	2.6	2.5	2.4
Germany	83.6	82.7	1.3	1.2	2 838.9	2 707.0	2 918.9	2 933.0	3.9	3.6	3.6	3.4
India	1 159.1	1 252.1	17.4	17.5	3 927.4	4 426.2	5 204.3	5 846.1	5.4	6.0	6.4	6.7
Iran	71.8	77.4	1.1	1.1	940.5	983.3	1 072.4	1 040.5	1.3	1.3	1.3	1.2
Israel	6.9	7.7	0.1	0.1	191.7	202.2	222.7	236.9	0.3	0.3	0.3	0.3
Japan	127.2	127.1	1.9	1.8	4 042.1	3 779.0	3 936.8	4 070.5	5.6	5.1	4.9	4.7
Malaysia	26.8	29.7	0.4	0.4	463.0	478.0	540.2	597.7	0.6	0.6	0.7	0.7
Mexico	113.5	122.3	1.7	1.7	1 434.8	1 386.5	1 516.3	1 593.6	2.0	1.9	1.9	1.8
Republic of Korea	47.6	49.3	0.7	0.7	1 293.2	1 339.2	1 478.8	1 557.6	1.8	1.8	1.8	1.8
Russian Federation	143.7	142.8	2.2	2.0	1 991.7	1 932.3	2 105.4	2 206.5	2.8	2.6	2.6	2.5
South Africa	49.6	52.8	0.7	0.7	522.1	530.5	564.2	589.4	0.7	0.7	0.7	0.7
Turkey	69.5	74.9	1.0	1.0	874.1	837.4	994.3	1 057.3	1.2	1.1	1.2	1.2
United Kingdom	61.0	63.1	0.9	0.9	2 203.7	2 101.7	2 177.1	2 229.4	3.1	2.8	2.7	2.6
United States of America	303.8	320.1	4.6	4.5	13 681.1	13 263.0	13 816.1	14 450.3	18.9	17.9	17.0	16.7

Source: World Bank's World Development Indicators, April 2015; and estimations by UNESCO Institute for Statistics; United Nations Department of Economic and Social Affairs, Population Division (2013) *World Population Prospects: the 2012 Revision*

Table 1.2: **World shares of expenditure on R&D, 2007, 2009, 2011 and 2013**

	GERD (in PPP$ billions)				Share of world GERD (%)			
	2007	2009	2011	2013	2007	2009	2011	2013
World	**1 132.3**	**1 225.5**	**1 340.2**	**1 477.7**	**100.0**	**100.0**	**100.0**	**100.0**
High-income economies	902.4	926.7	972.8	1 024.0	79.7	75.6	72.6	69.3
Upper middle-income economies	181.8	243.9	303.9	381.8	16.1	19.9	22.7	25.8
Lower middle-income economies	46.2	52.5	60.2	68.0	4.1	4.3	4.5	4.6
Low-income economies	1.9	2.5	3.2	3.9	0.2	0.2	0.2	0.3
Americas	**419.8**	**438.3**	**451.6**	**478.8**	**37.1**	**35.8**	**33.7**	**32.4**
North America	382.7	396.5	404.8	427.0	33.8	32.4	30.2	28.9
Latin America	35.5	39.8	45.6	50.1	3.1	3.3	3.4	3.4
Caribbean	1.6	2.0	1.3	1.7	0.1	0.2	0.1	0.1
Europe	**297.1**	**311.6**	**327.5**	**335.7**	**26.2**	**25.4**	**24.4**	**22.7**
European Union	251.3	262.8	278.0	282.0	22.2	21.4	20.7	19.1
Southeast Europe	0.5	0.8	0.7	0.8	0.0	0.1	0.1	0.1
European Free Trade Association	12.6	13.1	13.7	14.5	1.1	1.1	1.0	1.0
Other Europe	32.7	34.8	35.0	38.5	2.9	2.8	2.6	2.6
Africa	**12.9**	**15.5**	**17.1**	**19.9**	**1.1**	**1.3**	**1.3**	**1.3**
Sub-Saharan Africa	8.4	9.2	10.0	11.1	0.7	0.7	0.7	0.8
Arab States in Africa	4.5	6.4	7.1	8.8	0.4	0.5	0.5	0.6
Asia	**384.9**	**440.7**	**524.8**	**622.9**	**34.0**	**36.0**	**39.2**	**42.2**
Central Asia	0.8	1.1	1.0	1.4	0.1	0.1	0.1	0.1
Arab States in Asia	4.3	5.0	5.6	6.7	0.4	0.4	0.4	0.5
West Asia	15.5	16.1	17.5	18.1	1.4	1.3	1.3	1.2
South Asia	35.4	39.6	45.7	50.9	3.1	3.2	3.4	3.4
Southeast Asia	328.8	378.8	455.1	545.8	29.0	30.9	34.0	36.9
Oceania	**17.6**	**19.4**	**19.1**	**20.3**	**1.6**	**1.6**	**1.4**	**1.4**
Other groupings								
Least developed countries	2.7	3.1	3.7	4.4	0.2	0.3	0.3	0.3
Arab States all	8.8	11.4	12.7	15.4	0.8	0.9	0.9	1.0
OECD	860.8	882.2	926.1	975.6	76.0	72.0	69.1	66.0
G20	1 042.6	1 127.0	1 231.1	1 358.5	92.1	92.0	91.9	91.9
Selected countries								
Argentina	2.5	3.1	4.0	4.6^{-1}	0.2	0.3	0.3	0.3^{-1}
Brazil	23.9	26.1	30.2	31.3^{-1}	2.1	2.1	2.3	2.2^{-1}
Canada	23.3	23.0	22.7	21.5	2.1	1.9	1.7	1.5
China	116.0	169.4^{b}	220.6	290.1	10.2	13.8^{b}	16.5	19.6
Egypt	1.6	3.0^{b}	4.0	5.3	0.1	0.2^{b}	0.3	0.4
France	40.6	43.2	44.6^{b}	45.7	3.6	3.5	3.3^{b}	3.1
Germany	69.5	73.8	81.7	83.7	6.1	6.0	6.1	5.7
India	31.1	36.2	42.8	–	2.7	3.0	3.2	–
Iran	7.1^{+1}	3.1^{b}	3.2^{-1}	–	0.6^{+1}	0.3^{b}	0.3^{-1}	–
Israel	8.6	8.4	9.1	10.0	0.8	0.7	0.7	0.7
Japan	139.9	126.9^{b}	133.2	141.4	12.4	10.4^{b}	9.9	9.6
Malaysia	2.7^{-1}	4.8^{b}	5.7	6.4^{-1}	0.3^{+1}	0.4^{b}	0.4	0.5^{-1}
Mexico	5.3	6.0	6.4	7.9	0.5	0.5	0.5	0.5
Republic of Korea	38.8	44.1	55.4	64.7	3.4	3.6	4.1	4.4
Russian Federation	22.2	24.2	23.0	24.8	2.0	2.0	1.7	1.7
South Africa	4.6	4.4	4.1	4.2^{-1}	0.4	0.4	0.3	0.3^{-1}
Turkey	6.3	7.1	8.5	10.0	0.6	0.6	0.6	0.7
United Kingdom	37.2	36.7	36.8	36.2	3.3	3.0	2.7	2.5
United States of America	359.4	373.5	382.1	396.7^{-1}	31.7	30.5	28.5	28.1^{-1}

-n/+n = data are for n years before or after reference year

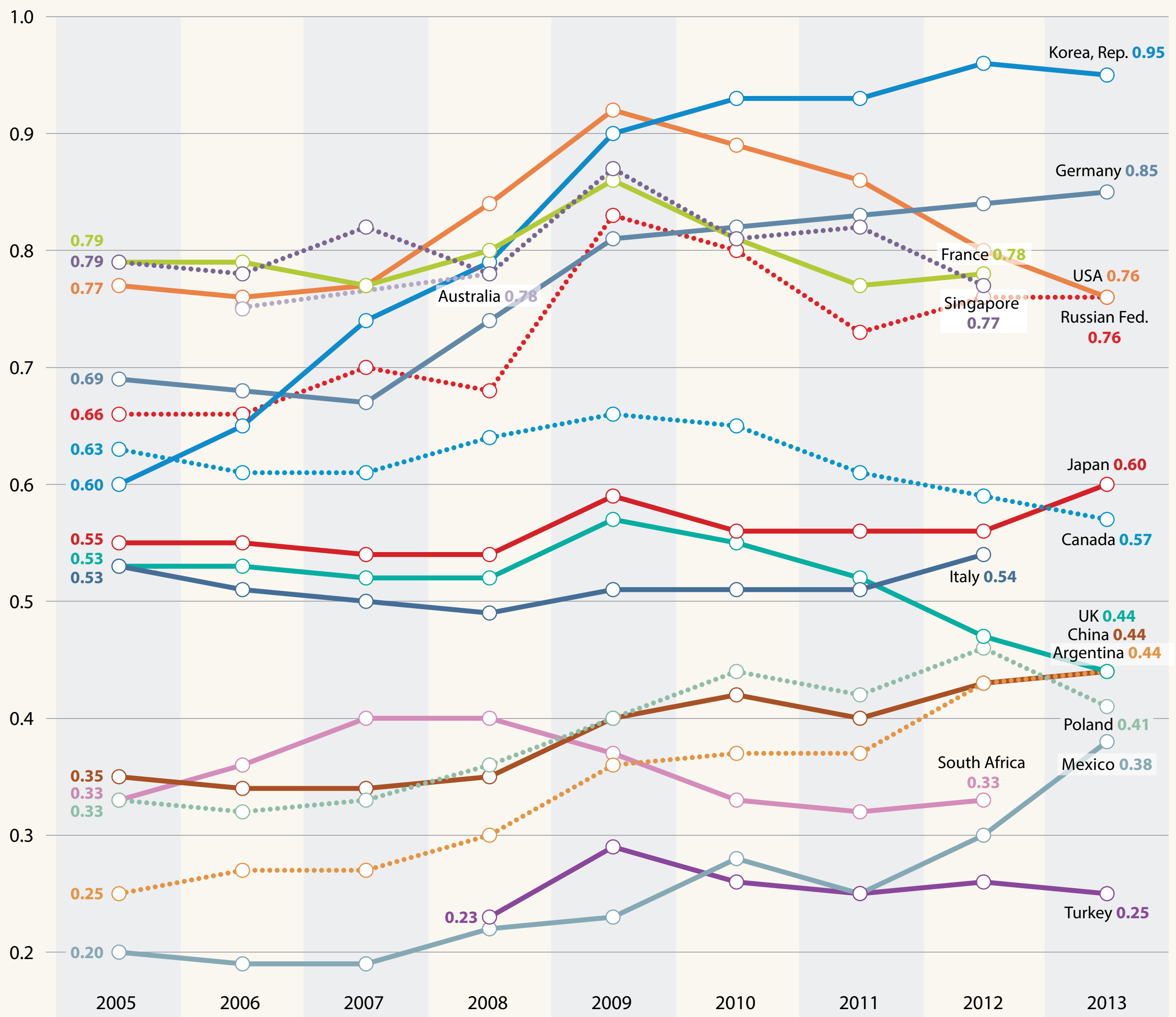
b: break in series with previous year for which data are shown

Note: GERD figures are in PPP$ (constant prices – 2005). Many of the underlying data are estimated by the UNESCO Institute for Statistics for developing countries, in particular. Furthermore in a substantial number of developing countries data do not cover all sectors of the economy.

	GERD as share of GDP (%)				GERD per capita (in PPP$)				GERD per researcher (PPP$ thousands)			
	2007	2009	2011	2013	2007	2009	2011	2013	2007	2009	2011	2013
	1.57	**1.65**	**1.65**	**1.70**	**169.7**	**179.3**	**191.5**	**206.3**	**176.9**	**177.6**	**182.3**	**190.4**
	2.16	2.28	2.27	2.31	713.8	723.2	750.4	782.1	203.0	199.1	201.7	205.1
	0.91	1.11	1.21	1.37	78.3	103.3	126.6	156.4	126.1	142.7	155.7	176.1
	0.48	0.50	0.50	0.51	19.7	21.8	24.2	26.6	105.0	115.9	126.0	137.7
	0.19	0.22	0.25	0.27	2.6	3.1	3.9	4.5	26.2	28.7	32.9	37.6
	1.96	**2.08**	**2.01**	**2.04**	**459.8**	**469.9**	**474.2**	**492.7**	**276.8**	**264.6**	**266.3**	**278.1**
	2.57	2.74	2.68	2.71	1 136.2	1 154.9	1 158.3	1 201.8	297.9	283.0	285.9	297.9
	0.59	0.65	0.67	0.69	66.3	72.7	81.2	87.2	159.5	162.1	168.2	178.9
	0.33	0.41	0.26	0.34	38.5	47.6	30.5	40.8	172.9	202.0	138.4	203.1
	1.58	**1.72**	**1.72**	**1.75**	**368.3**	**384.0**	**401.6**	**410.1**	**139.8**	**141.3**	**142.6**	**139.4**
	1.71	1.86	1.89	1.92	501.9	521.3	548.2	553.5	172.4	169.1	171.2	163.4
	0.31	0.56	0.47	0.51	23.0	43.5	38.2	42.4	40.0	65.9	52.0	54.9
	2.25	2.36	2.39	2.44	995.1	1 014.4	1 038.8	1 072.0	242.0	231.0	218.4	215.2
	0.98	1.08	0.98	1.02	119.5	126.6	127.0	139.2	54.1	59.8	58.8	64.1
	0.36	**0.40**	**0.42**	**0.45**	**13.5**	**15.5**	**16.2**	**17.9**	**86.2**	**101.8**	**98.6**	**106.1**
	0.42	0.42	0.41	0.41	11.0	11.4	11.7	12.4	143.5	132.2	129.4	135.6
	0.29	0.38	0.43	0.49	23.4	32.0	34.5	41.2	49.3	76.5	73.8	83.3
	1.39	**1.46**	**1.51**	**1.62**	**97.2**	**108.8**	**126.9**	**147.5**	**154.1**	**159.0**	**171.3**	**187.7**
	0.20	0.24	0.20	0.23	13.4	16.9	15.7	20.7	38.2	42.7	39.2	41.5
	0.18	0.19	0.18	0.20	35.5	38.5	40.2	45.9	137.2	141.3	136.4	151.3
	1.22	1.20	1.19	1.24	163.3	166.2	176.1	178.1	133.4	135.4	141.0	132.6
	0.71	0.71	0.70	0.70	23.0	25.0	28.0	30.5	171.8	177.3	195.9	210.0
	1.78	1.88	1.96	2.10	153.7	174.4	206.5	244.0	154.9	160.0	172.4	190.8
	2.09	**2.20**	**2.07**	**2.07**	**505.7**	**537.5**	**512.0**	**528.7**	**159.3**	**166.1**	**158.7**	**164.3**
	0.20	0.21	0.23	0.24	3.4	3.8	4.3	4.8	59.0	61.4	66.4	74.1
	0.22	0.26	0.27	0.30	28.1	34.6	36.8	43.1	71.9	95.9	92.4	103.3
	2.23	2.36	2.37	2.42	707.7	715.1	740.8	771.2	220.8	213.7	215.7	217.7
	1.80	1.91	1.90	1.97	237.5	252.3	271.1	294.3	186.0	186.5	192.5	201.5
	0.40	0.48	0.52	0.58[-1]	64.5	78.6	98.1	110.7[-1]	65.6	72.0	79.4	88.2[-1]
	1.11	1.15	1.20	1.15[-1]	126.0	135.0	153.3	157.5[-1]	205.8	202.4	210.5[-1]	–
	1.92	1.92	1.79	1.63	707.5	682.3	658.5	612.0	154.2	153.3	139.2	141.9[-1]
	1.40	1.70[b]	1.84	2.08	87.0	125.4[b]	161.2	209.3	–[*]	147.0[b]	167.4	195.4
	0.26	0.43[b]	0.53	0.68	21.5	39.6[b]	50.3	64.8	32.4	86.5[b]	96.1	111.6
	2.02	2.21	2.19[b]	2.23	653.0	687.0	701.4	710.8	183.1	184.3	178.9[b]	172.3
	2.45	2.73	2.80	2.85	832.0	887.7	985.0	1 011.7	239.1	232.7	241.1	232.3
	0.79	0.82	0.82	–	26.8	30.5	35.0	–	171.4[-2]	–	201.8[-1]	–
	0.75[+1]	0.31[b]	0.31[-1]	–	97.5[+1]	41.8[b]	43.0	–	130.5[+1]	58.9[b]	58.4[-1]	–
	4.48	4.15	4.10	4.21	1 238.9	1 154.1	1 211.4	1 290.5	–	–	165.6	152.9[-1]
	3.46	3.36[b]	3.38	3.47	1 099.5	996.2[b]	1 046.1	1 112.2	204.5	193.5[b]	202.8	214.1
	0.61[-1]	1.01[b]	1.06	1.13[-1]	101.1[1]	173.7[b]	199.9	219.9[-1]	274.6[-1]	163.1[b]	121.7	123.5[-1]
	0.37	0.43	0.42	0.50	46.6	51.3	54.0	65.0	139.3	138.9	139.7	–
	3.00	3.29	3.74	4.15	815.6	915.7	1 136.0	1 312.7	174.8	180.7	191.6	200.9
	1.12	1.25	1.09	1.12	154.7	168.4	160.1	173.5	47.4	54.7	51.3	56.3
	0.88	0.84	0.73	0.73[-1]	92.9	87.1	79.7	80.5[-1]	238.6	224.0	205.9	197.3[-1]
	0.72	0.85	0.86	0.95	90.9	99.8	117.0	133.5	127.1	123.1	118.5	112.3
	1.69	1.75	1.69	1.63	610.1	594.4	590.3	573.8	147.2	143.2	146.6	139.7
	2.63	2.82	2.77	2.81[-1]	1 183.0	1 206.7	1 213.3	1 249.3[-1]	317.0	298.5	304.9	313.6[-1]

Source: estimations by UNESCO Institute for Statistics, July 2015; for Brazilian GERD/GDP ratio in 2012: Brazilian Ministry of Science, Technology and Innovation

Figure 1.1: **GERD financed by government as a share of GDP, 2005–2013 (%)**



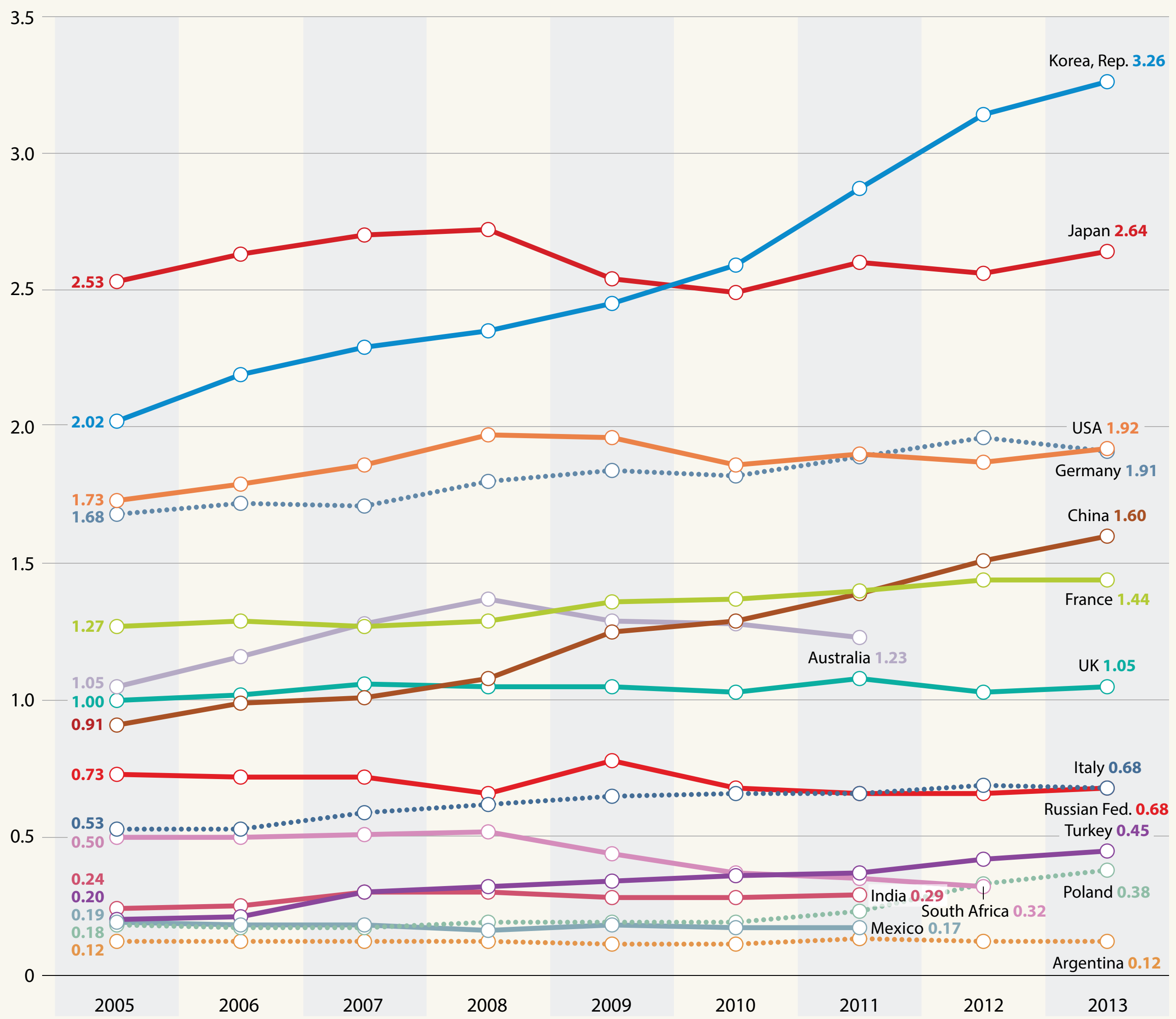
Source: OECD's Main Science and Technology Indicators, September 2015

The global crisis also provoked a reversal in brain drain in some parts of Africa, as visions of Europe and North America struggling with low growth rates and high unemployment discouraged emigration and encouraged some to return home. Returnees are today playing a key role in STI policy formulation, economic development and innovation. Even those who remain abroad are contributing: remittances are now overtaking FDI inflows to Africa (Chapter 19).

The heightened interest in STI is clearly visible in the *Vision 2020* or *2030* planning documents adopted by African countries in recent years. In Kenya, for instance, the Science, Technology and Innovation Act passed in 2013 contributes to the realization of *Kenya Vision 2030*, which foresees the country's transformation into an upper middle-income economy with a skilled labour force by 2030. The act may be a 'game-changer' for Kenya, which has not only created a National Research Fund but also, critically, made provisions for the fund to receive 2% of Kenya's GDP each financial year. This substantial commitment of funds should help Kenya raise its GERD/GDP ratio well above 0.79% (2010).

The BRICS countries present a contrasting picture. In China, public and business funding of R&D have risen in tandem. In India, business R&D has progressed faster than government commitment to R&D. In Brazil, public commitment to R&D has remained more or less stable since 2008, whereas the business enterprise sector has slightly augmented its own effort. Since all firms surveyed in 2013 reported a drop in innovation activity since 2008, this trend will most likely affect spending if the Brazilian economic

Figure 1.2: **GERD performed by business enterprises as a share of GDP, 2005–2013 (%)**



Source: OECD's Main Science and Technology Indicators, September 2015

slowdown persists. In South Africa, there has been a sharp drop in private-sector R&D since the global financial crisis, in spite of rising public spending on R&D. This partly explains why the GERD/GDP ratio shrank from a high of 0.89% in 2008 to 0.73% in 2012.

The high-income countries have been particularly hard hit by the crisis which swept the world in 2008 and 2009. Whereas the US economy is back on an even keel, Japan and the EU are finding recovery an uphill struggle. In Europe, slow economic growth since the financial crisis of 2008 and the ensuing pressures of fiscal consolidation within Eurozone countries have put pressure on public investment in knowledge (Chapter 9), despite the hike in the Horizon 2020 budget. Among EU countries, only Germany was actually in a position to increase its commitment to public R&D over the past five years. France and the UK saw it decline. As in Canada, budgetary pressures on national research budgets have led to significant reductions in government-funded R&D intensity (Figure 1.1). With the notable exception of Canada, this trend is not perceptible in overall R&D expenditure, since the private sector has maintained its own level of spending throughout the crisis (Figures 1.1 and 1.2 and Table 1.2).

In search of an optimal balance between basic and applied science

The great majority of countries now acknowledge the importance of STI for sustaining growth over the longer term. Low and lower-middle income countries hope to use it to raise income levels, wealthier countries to hold their own in an increasingly competitive global marketplace.

The danger is that, in the race to improve national competitiveness, countries may lose sight of the old adage that 'without basic science, there would be no science to apply'. Basic research generates the new knowledge that gives rise to applications, commercial or otherwise. As the author of the chapter on Canada puts it (Chapter 4), 'science powers commerce – but not only.' The question is: what is the optimal balance between basic and applied research?

The Chinese leadership has become dissatisfied with the return on its wider investment in R&D. At the same time, China has opted to devote just 4–6% of research expenditure to basic research over the past decade. In India, universities perform just 4% of GERD. Although India has created an impressive number of universities in recent years, industry has complained about the 'employability' of science and engineering graduates. Basic research not only generates new knowledge; it also contributes to the quality of university education.

In the USA, the federal government specializes in supporting basic research, leaving industry to take the lead in applied research and technological development. There is a risk that the current austerity drive, combined with changing priorities, may affect the USA's long-term capacity to generate new knowledge.

Meanwhile, the USA's northern neighbour is cutting back on federal funding of government science but investing in venture capital, in order to develop business innovation and woo new trading partners. In January 2013, the Canadian government announced its *Venture Capital Action Plan*, a strategy for deploying CAN$ 400 million in new capital over the next 7–10 years to leverage private sector-led investment in the form of venture capital funds.

The Russian Federation has traditionally devoted a large share of GERD to basic research (like South Africa: 24% in 2010). Since the government adopted an innovation-led growth strategy in 2012, a greater share of its appropriation for R&D has been oriented towards the needs of industry. Since funding is finite, this readjustment has occurred to the detriment of basic research, which dropped from 26% to 17% of the total between 2008 and 2013.

The EU has made the opposite calculation. Despite the chronic debt crisis, the European Commission has maintained its commitment to basic research. The European Research Council (est. 2007), the first pan-European funding body for frontier research in basic sciences, has been endowed with € 13.1 billion for the period 2014–2020, equivalent to 17% of Horizon 2020's overall budget.

The Republic of Korea increased its own commitment to basic research from 13% to 18% of GERD between 2001 and 2011 and Malaysia has followed a similar path (from 11% in 2006 to 17% in 2011). These two countries now devote a comparable share to that of the USA: 16.5% in 2012. In the Republic of Korea, the government is investing heavily in basic research to correct the impression that the country made the transition from a poor agricultural country to an industrial giant through imitation alone, without developing an endogenous capacity in basic sciences. The government also plans to foster linkages between basic sciences and the business world: in 2011, the National Institute for Basic Science opened on the site of the future International Science Business Belt in Daejeon.

The gap in R&D expenditure is narrowing

Geographically, the distribution of investment in knowledge remains unequal (Table 1.2). The USA still dominates, with 28% of global investment in R&D. China has moved into second place (20%), ahead of the EU (19%) and Japan (10%). The rest of the world represents 67% of the global population but just 23% of global investment in R&D.

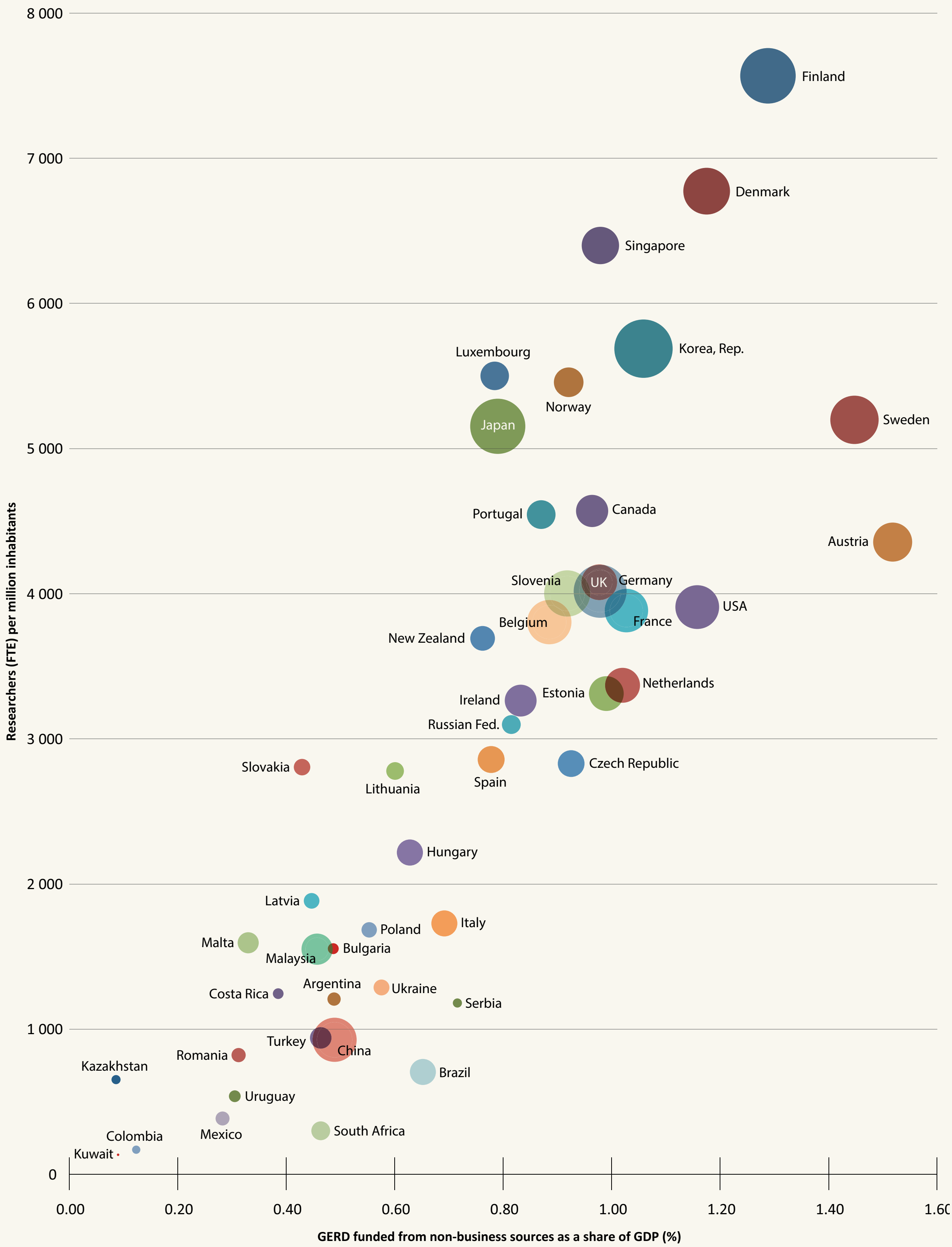
GERD encompasses both public and private investment in R&D. The share of GERD performed by the business enterprise sector (BERD) tends to be higher in economies with a greater focus on technology-based competitiveness in manufacturing, as reflected in their higher BERD/GDP ratio (Chapter 2). Among the larger economies for which adequate data are available, the BERD/GDP intensity has risen appreciably in only a few countries such as the Republic of Korea and China and, to a lesser extent, in Germany, the USA, Turkey and Poland (Figure 1.2). At best, it has remained stable in Japan and the UK and receded in Canada and South Africa.

Given the fact that almost one in five human beings is Chinese, the rapid progression in BERD in China has had a knock-on effect of massive proportions: between 2001 and 2011, China and India's combined global share of BERD quadrupled from 5% to 20%, largely to the detriment of Western Europe and North America (see Figure 2.1).

Figure 1.3 highlights the continuing concentration of R&D resources in a handful of highly developed or dynamic economies. Several of these advanced economies fall in the middle of the figure (Canada and UK), reflecting their similar density of researchers with the leaders (such as Germany or the USA), yet lower levels of R&D intensity. The R&D or human capital intensities of Brazil, China, India and Turkey might still be low but their contribution to the global stock of knowledge is rapidly rising, thanks to the sheer size of their financial investment in R&D.

Figure 1.3: **Mutually reinforcing effect of strong government investment in R&D and researchers, 2010–2011**

The size of the bubbles is proportionate to GERD funded by business as a share of GDP (%)



Source: UNESCO Institute for Statistics, August 2015

Table 1.3: **World shares of researchers, 2007, 2009, 2011 and 2013**

	Researchers ('000s)				Share of global researchers (%)			
	2007	2009	2011	2013	2007	2009	2011	2013
World	**6 400.9**	**6 901.9**	**7 350.4**	**7 758.9**	**100.0**	**100.0**	**100.0**	**100.0**
High-income economies	4 445.9	4 653.9	4 823.1	4 993.6	69.5	67.4	65.6	64.4
Upper middle-income economies	1 441.8	1 709.4	1 952.3	2 168.8	22.5	24.8	26.6	28.0
Lower middle-income economies	439.6	453.2	478.0	493.8	6.9	6.6	6.5	6.4
Low-income economies	73.6	85.4	96.9	102.6	1.2	1.2	1.3	1.3
Americas	**1 516.6**	**1 656.7**	**1 696.1**	**1 721.9**	**23.7**	**24.0**	**23.1**	**22.2**
North America	1 284.9	1 401.2	1 416.1	1 433.3	20.1	20.3	19.3	18.5
Latin America	222.6	245.7	270.8	280.0	3.5	3.6	3.7	3.6
Caribbean	9.1	9.7	9.2	8.5	0.1	0.1	0.1	0.1
Europe	**2 125.6**	**2 205.0**	**2 296.8**	**2 408.1**	**33.2**	**31.9**	**31.2**	**31.0**
European Union	1 458.1	1 554.0	1 623.9	1 726.3	22.8	22.5	22.1	22.2
Southeast Europe	11.3	12.8	14.2	14.9	0.2	0.2	0.2	0.2
European Free Trade Association	51.9	56.8	62.9	67.2	0.8	0.8	0.9	0.9
Other Europe	604.3	581.4	595.8	599.9	9.4	8.4	8.1	7.7
Africa	**150.1**	**152.7**	**173.4**	**187.5**	**2.3**	**2.2**	**2.4**	**2.4**
Sub-Saharan Africa	58.8	69.4	77.1	82.0	0.9	1.0	1.0	1.1
Arab States in Africa	91.3	83.3	96.3	105.5	1.4	1.2	1.3	1.4
Asia	**2 498.1**	**2 770.8**	**3 063.9**	**3 318.0**	**39.0**	**40.1**	**41.7**	**42.8**
Central Asia	21.7	25.1	26.1	33.6	0.3	0.4	0.4	0.4
Arab States in Asia	31.6	35.6	40.7	44.0	0.5	0.5	0.6	0.6
West Asia	116.2	119.2	124.3	136.9	1.8	1.7	1.7	1.8
South Asia	206.2	223.6	233.0	242.4	3.2	3.2	3.2	3.1
Southeast Asia	2 122.4	2 367.4	2 639.8	2 861.1	33.2	34.3	35.9	36.9
Oceania	**110.5**	**116.7**	**120.1**	**123.3**	**1.7**	**1.7**	**1.6**	**1.6**
Other groupings								
Least developed countries	45.2	51.0	55.8	58.8	0.7	0.7	0.8	0.8
Arab States all	122.9	118.9	137.0	149.5	1.9	1.7	1.9	1.9
OECD	3 899.2	4 128.9	4 292.5	4 481.6	60.9	59.8	58.4	57.8
G20	5 605.1	6 044.0	6 395.0	6 742.1	87.6	87.6	87.0	86.9
Selected countries								
Argentina	38.7	43.7	50.3	51.6^{-1}	0.6	0.6	0.7	0.7^{-1}
Brazil	116.3	129.1	138.7^{-1}	–	1.8	1.9	2.0^{-1}	–
Canada	151.3	150.2	163.1	156.6^{-1}	2.4	2.2	2.2	2.1^{-1}
China	–*	$1\,152.3^{b}$	1 318.1	1 484.0	–*	16.7^{b}	17.9	19.1
Egypt	49.4	35.2	41.6	47.7	0.8	0.5	0.6	0.6
France	221.9	234.4	249.2^{b}	265.2	3.5	3.4	3.4^{b}	3.4
Germany	290.9	317.3	338.7	360.3	4.5	4.6	4.6	4.6
India	154.8^{-2}	–	192.8^{-1}	–	2.6^{-2}	–	2.7^{-1}	–
Iran	54.3^{+1}	52.3^{b}	54.8^{-1}	–	0.8^{+1}	0.8^{b}	0.8^{-1}	–
Israel	–	–	55.2	63.7^{-1}	–	–	0.8	0.8^{-1}
Japan	684.3	655.5^{b}	656.7	660.5	10.7	9.5^{b}	8.9	8.5
Malaysia	9.7^{-1}	29.6^{b}	47.2	52.1^{-1}	0.2^{-1}	0.4^{b}	0.6	0.7^{-1}
Mexico	37.9	43.0	46.1	–	0.6	0.6	0.6	–
Republic of Korea	221.9	244.1	288.9	321.8	3.5	3.5	3.9	4.1
Russian Federation	469.1	442.3	447.6	440.6	7.3	6.4	6.1	5.7
South Africa	19.3	19.8	20.1	21.4^{-1}	0.3	0.3	0.3	0.3^{-1}
Turkey	49.7	57.8	72.1	89.1	0.8	0.8	1.0	1.1
United Kingdom	252.7	256.1	251.4	259.3	3.9	3.7	3.4	3.3
United States of America	1 133.6	1 251.0	1 252.9	$1\,265.1^{-1}$	17.7	18.1	17.0	16.7^{-1}

-n/+n = data are for n years before or after reference year

b: break in series with previous year for which data are shown

	Researchers per million inhabitants			
	2007	2009	2011	2013
	959.2	**1 009.8**	**1 050.4**	**1 083.3**
	3 517.0	3 632.3	3 720.4	3 814.1
	620.9	723.9	813.0	888.1
	187.8	187.8	192.2	192.9
	98.7	109.6	119.1	120.7
	1 661.2	**1 776.1**	**1 780.8**	**1 771.6**
	3 814.6	4 081.5	4 052.0	4 034.1
	415.8	448.3	482.7	487.7
	223.0	235.4	220.2	200.8
	2 635.4	**2 717.4**	**2 816.4**	**2 941.9**
	2 911.8	3 081.9	3 202.0	3 388.3
	575.4	659.9	734.8	772.0
	4 112.4	4 390.4	4 757.0	4 980.8
	2 208.8	2 115.3	2 160.2	2 170.4
	156.8	**151.8**	**164.1**	**168.8**
	77.0	86.0	90.6	91.4
	474.0	418.1	467.2	494.5
	630.6	**684.4**	**740.8**	**785.8**
	351.6	395.0	399.7	500.0
	259.2	272.5	294.4	303.1
	1 224.1	1 226.9	1 249.1	1 343.2
	133.7	141.0	143.1	145.0
	991.9	1 090.1	1 197.6	1 279.1
	3 173.8	**3 235.7**	**3 226.8**	**3 218.9**
	57.7	62.2	65.0	65.5
	390.7	360.5	397.8	417.0
	3 205.9	3 346.7	3 433.7	3 542.3
	1 276.9	1 353.2	1 408.0	1 460.7
	983.5	1 092.3	1 236.0	1 255.8[-1]
	612.0	667.2	710.3[-1]	–
	4 587.7	4 450.6	4 729.0	4 493.7[-1]
	–[*]	852.8[b]	963.2	1 071.1
	665.0	457.9	523.6	580.7
	3 566.1	3 726.7	3 920.1[b]	4 124.6
	3 480.0	3 814.6	4 085.9	4 355.4
	137.4[-2]	–	159.9[-1]	–
	746.9[+1]	710.6[b]	736.1[-1]	–
	–	–	7 316.6	8 337.1[-1]
	5 377.7	5 147.4[b]	5 157.5	5 194.8
	368.2[-1]	1 065.4[b]	1 642.7	1 780.2[-1]
	334.1	369.1	386.4	–
	4 665.0	5 067.5	5 928.3	6 533.2
	3 265.4	3 077.9	3 120.4	3 084.6
	389.5	388.9	387.2	408.2[-1]
	714.7	810.7	987.0	1 188.7
	4 143.8	4 151.1	4 026.4	4 107.7
	3 731.4	4 042.1	3 978.7	3 984.4[-1]

Note: Researchers are in full-time equivalents.

Source: estimations by UNESCO Institute for Statistics, July 2015

GLOBAL TRENDS IN HUMAN CAPITAL

Widespread growth in researchers, little change in the global balance

Today, there are some 7.8 million researchers worldwide (Table 1.3). Since 2007, the number of researchers has risen by 21%. This remarkable growth is also reflected in the explosion of scientific publications.

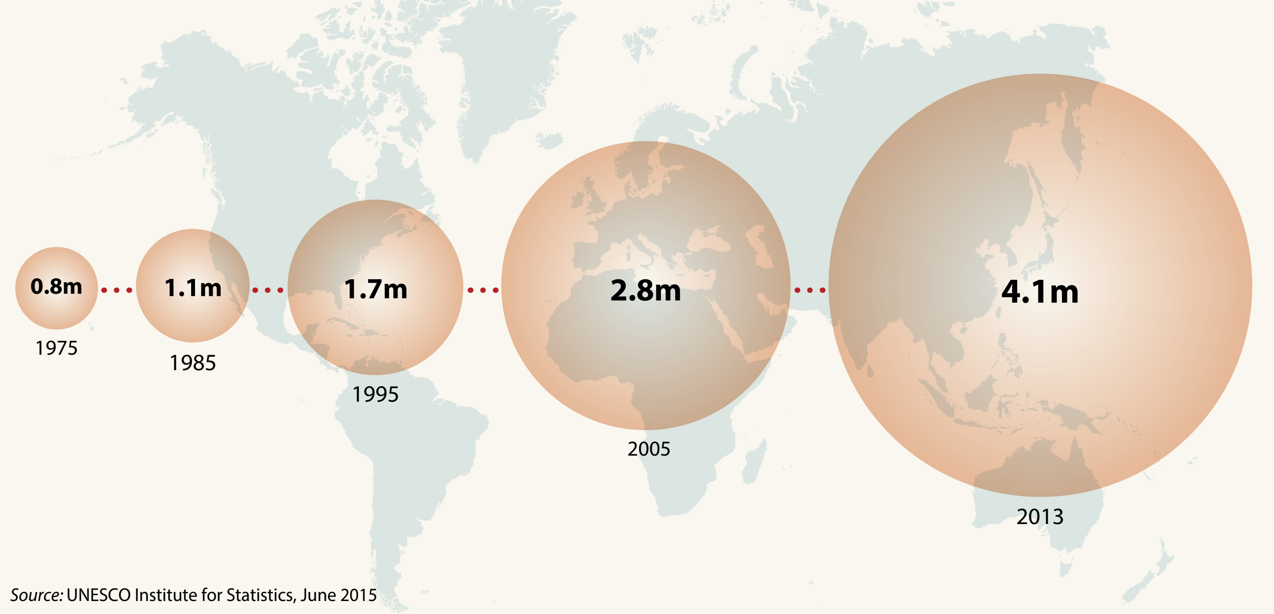
The EU remains the world leader for the number of researchers, with a 22.2% share. Since 2011, China (19.1%) has overtaken the USA (16.7%), as predicted by the *UNESCO Science Report 2010*, despite a downward readjustment of the Chinese figures since this publication's release. Japan's world share has shrunk from 10.7% (2007) to 8.5% (2013) and the Russian Federation's share from 7.3% to 5.7%.

The Big Five thus still account for 72% of all researchers, even if there has been a reshuffle in their respective shares. Of note is that the high-income countries have ceded some ground to the upper middle-income countries, including China; the latter accounted for 22.5% of researchers in 2007 but 28.0% in 2013 (Table 1.3).

As Figure 1.3 highlights, once countries are prepared to invest more in research personnel and in publicly funded research, the propensity of businesses to invest in R&D also increases (the size of the bubbles). Public and privately funded research have different aims, of course, but their contribution to national growth and welfare depends on how well they complement one another. This holds for countries of all income levels but it is clear that the relationship becomes powerful above a certain threshold in researcher density and publicly funded R&D intensity. Whereas one can find a few countries with a relatively high intensity of business-funded R&D in the lower left-hand quadrant of the graphic, none in the upper right-hand quadrant have a low intensity of business R&D.

Researchers from lower income countries are still pursuing career opportunities abroad but their destination of choice is widening. This may be partly because the 2008 crisis has somewhat tarnished the image of Europe and North America as an Eldorado. Even countries suffering from brain drain are also attracting researchers. For instance, Sudan lost more than 3 000 junior and senior researchers to migration between 2002 and 2014, according to the National Research Centre. Researchers were drawn to neighbouring countries such as Eritrea and Ethiopia by the better pay, which is more than double that offered to university staff in Sudan. In turn, Sudan has become a refuge for students from the Arab world, particularly since the turmoil of the Arab Spring. Sudan is also attracting a growing number of students from Africa (Chapter 19).

Figure 1.4: **Long-term growth of tertiary-level international students worldwide, 1975–2013**



Source: UNESCO Institute for Statistics, June 2015

In the coming years, competition for skilled workers from the global pool will most likely intensify (Chapter 2). This trend will depend in part on levels of investment in science and technology around the world and demographic trends, such as low birth rates and ageing populations in some countries (Japan, EU, etc). Countries are already formulating broader policies to attract and retain highly skilled migrants and international students, in order to establish an innovative environment or maintain it, as in Malaysia (Chapter 26).

The number of international students is growing rapidly (Figure 1.4). Chapter 2 highlights the increasing mobility at doctoral level, which, in turn, is driving the mobility of scientists. This is perhaps one of the most important trends of recent times. A study conducted recently by the UNESCO Institute for Statistics found that students from the Arab States, Central Asia, sub-Saharan African and Western Europe were more likely to study abroad than their peers from other regions. Central Asia has even overtaken Africa for the share of tertiary students studying abroad (see Figure 2.10).

National and regional schemes in Europe and Asia are actively encouraging doctoral students to study abroad. The Vietnamese government, for instance, sponsors the doctoral training of its citizens overseas, in order to add 20 000 doctorate-holders to the faculty of Vietnamese universities by 2020. Saudi Arabia is taking a similar approach. Malaysia, meanwhile, plans to become the sixth-largest global destination for international university students by 2020. Between 2007 and 2012, the number of international students in Malaysia almost doubled to more than 56 000 (Chapter 26). South Africa hosted about 61 000 international students in 2009, two-thirds of whom came from other SADC nations (Chapter 20). Cuba is a popular destination for Latin American students (Chapter 7).

The other half of human capital still a minority

As countries grapple with the need to establish a pool of scientists or researchers that is commensurate with their ambitions for development, their attitudes to gender issues are changing. Some Arab States now have more women than men studying natural sciences, health and agriculture at university (Chapter 17). Saudi Arabia plans to create 500 vocational training schools to reduce its dependence on foreign workers, half of which will train teenage girls (Chapter 17). Some 37% of researchers in the Arab world are women, more than in the EU (33%).

On the whole, women constitute a minority in the research world. They also tend to have more limited access to funding than men and to be less represented in prestigious universities and among senior faculty, which puts them at a further disadvantage in high-impact publishing (Chapter 3). The regions with the highest shares of women researchers are Southeast Europe (49%), the Caribbean, Central Asia and Latin America (44%). Sub-Saharan Africa counts 30% women and South Asia 17%. Southeast Asia presents a contrasting picture, with women representing 52% of researchers in the Philippines and Thailand, for instance, but only 14% in Japan and 18% in the Republic of Korea (Chapter 3).

Globally, women have achieved parity (45–55%) at the bachelor's and master's levels, where they represent 53% of graduates. At the PhD level, they slip beneath parity to 43%.

The gap widens at the researcher level, where they now only account for 28.4% of researchers, before becoming a gulf at the higher echelons of decision-making (Chapter 3).

A number of countries have put policies in place to foster gender equality. Three examples are Germany, where the coalition agreement of 2013 introduced a 30% quota for women on company boards of directors, Japan, where the selection criteria for most large university grants now take into account the proportion of women among teaching staff and researchers, and the Republic of Congo, which established a Ministry for the Promotion of Women and Integration of Women in National Development in 2012.

TRENDS IN KNOWLEDGE GENERATION

The EU still leads the world for publications

The EU still leads the world for publications (34%), followed by the USA on 25% (Table 1.4). Despite these impressive figures, the world shares of both the EU and the USA have fallen over the past five years, as China has pursued its meteoric rise: Chinese publications have nearly doubled over the past five years to 20% of the world total. Ten years ago, China accounted for just 5% of global publications. This rapid growth reflects the coming of age of the Chinese research system, be it in terms of investment, the number of researchers or publications.

In terms of the relative specializations of countries in scientific disciplines, Figure 1.5 points to the large differences in specialization among countries. The traditionally dominant scientific countries seem to be relatively strong in astronomy and relatively weak in agricultural sciences. This is particularly the case for the UK, which is strong in social sciences. France's scientific strength still seems to lie in mathematics. The USA and UK focus more on life sciences and medicine and Japan on chemistry.

Among the BRICS countries, there are some striking differences. The Russian Federation shows a strong specialization in physics, astronomy, geosciences, mathematics and chemistry. By contrast, China's scientific output shows a fairly well-balanced pattern, with the exception of psychology, social and life sciences, where China's scientific output is well below the average. Brazil's relative strengths lie in agriculture and life sciences. Malaysia, not surprisingly, specializes in engineering and computer sciences.

Over the past five years, several new trends have emerged in terms of national research priorities. Some of the data on scientific publications reflect these priorities but often the classification across disciplines is not detailed enough. For instance, energy has become an overriding preoccupation but related research is spread across several disciplines.

Innovation occurring in countries of all income levels

As Chapter 2 highlights, and contrary to some received wisdom, innovative behaviour is occurring in countries spanning all income levels. The significant differences in innovation rate and typologies observed among developing countries that otherwise have comparable levels of income are of distinct policy interest. According to a survey of innovation conducted by the UNESCO Institute for Statistics (Chapter 2), firms' innovative behaviour tends to be clustered in research hotspots, such as in coastal regions of China or in the Brazilian State of São Paolo. The survey suggests that, over time, FDI flows related to R&D are spreading innovation more evenly around the world.

Whereas much high-level policy focuses on fostering investment in R&D, the innovation survey underscores the potential importance for firms of acquiring external knowledge or pursuing non-technological innovation (Chapter 2). The survey confirms the weakness of interaction between firms, on the one hand, and universities and public laboratories, on the other. This worrying trend is highlighted in many chapters of the present report, including those on Brazil (Chapter 8), the Black Sea basin (Chapter 12), Russian Federation (Chapter 13), Arab States (Chapter 17) and India (Chapter 22).

Patenting behaviour provides insights into the impact of innovation. Triadic patents – a term referring to the same invention being patented by the same inventor with the patenting offices of the USA, EU and Japan – provide an indicator of a country's propensity to pursue technology-based competitiveness at the global level. The overall dominance of high-income economies in this regard is striking (Table 1.5 and Figure 1.6). The Republic of Korea and China are the only countries that have made a significant dent in the dominance of the Triad for this indicator. Although the global share of the non-G20 countries tripled in the ten years to 2012, it remains a trifling 1.2%. Table 1.5 likewise illustrates the extreme concentration of patent applications in North America, Asia and Europe: the rest of the world barely counts for 2% of the world stock.

The United Nations is currently discussing how to operationalize the proposed technology bank for least developed countries.[7] The purpose of the technology bank will be to enhance the ability of these countries to access technologies developed elsewhere and to increase their capacity to patent. In September 2015, the United Nations adopted a Technology Facilitation Mechanism for clean and environmentally sound technologies at a Summit on Sustainable Development in New York (USA); this mechanism will contribute to the implementation of the Sustainable Development Goals (*Agenda 2030*) adopted the same month.

7. See: http://unohrlls.org/technologybank

Table 1.4: **World shares of scientific publications, 2008 and 2014**

	Total publications		Change (%) 2008–2014	World share of publications (%)		Publications per million inhabitants		Publications with international co-authors (%)	
	2008	2014		2008	2014	2008	2014	2008	2014
World	**1 029 471**	**1 270 425**	**23.4**	**100.0**	**100.0**	**153**	**176**	**20.9**	**24.9**
High-income economies	812 863	908 960	11.8	79.0	71.5	653	707	26.0	33.8
Upper middle-income economies	212 814	413 779	94.4	20.7	32.6	91	168	28.0	28.4
Lower middle-income economies	58 843	86 139	46.4	5.7	6.8	25	33	29.2	37.6
Low-income economies	4 574	7 660	67.5	0.4	0.6	6	9	80.1	85.8
Americas	**369 414**	**417 372**	**13.0**	**35.9**	**32.9**	**403**	**428**	**29.7**	**38.2**
North America	325 942	362 806	11.3	31.7	28.6	959	1 013	30.5	39.6
Latin America	50 182	65 239	30.0	4.9	5.1	93	112	34.5	41.1
Caribbean	1 289	1 375	6.7	0.1	0.1	36	36	64.6	82.4
Europe	**438 450**	**498 817**	**13.8**	**42.6**	**39.3**	**542**	**609**	**34.8**	**42.1**
European Union	379 154	432 195	14.0	36.8	34.0	754	847	37.7	45.5
Southeast Europe	3 314	5 505	66.1	0.3	0.4	170	287	37.7	43.3
European Free Trade Association	26 958	35 559	31.9	2.6	2.8	2 110	2 611	62.5	70.1
Other Europe	51 485	57 208	11.1	5.0	4.5	188	207	27.2	30.3
Africa	**20 786**	**33 282**	**60.1**	**2.0**	**2.6**	**21**	**29**	**52.3**	**64.6**
Sub-Saharan Africa	11 933	18 014	51.0	1.2	1.4	15	20	57.4	68.7
Arab States in Africa	8 956	15 579	74.0	0.9	1.2	46	72	46.0	60.5
Asia	**292 230**	**501 798**	**71.7**	**28.4**	**39.5**	**73**	**118**	**23.7**	**26.1**
Central Asia	744	1 249	67.9	0.1	0.1	12	18	64.0	71.3
Arab States in Asia	5 842	17 461	198.9	0.6	1.4	46	118	50.3	76.8
West Asia	22 981	37 946	65.1	2.2	3.0	239	368	33.0	33.3
South Asia	41 646	62 468	50.0	4.0	4.9	27	37	21.2	27.8
Southeast Asia	224 875	395 897	76.1	21.8	31.2	105	178	23.7	25.2
Oceania	**35 882**	**52 782**	**47.1**	**3.5**	**4.2**	**1 036**	**1 389**	**46.8**	**55.7**
Other groupings									
Least developed countries	4 191	7 447	77.7	0.4	0.6	5	8	79.7	86.8
Arab States all	14 288	29 944	109.6	1.4	2.4	44	82	45.8	65.9
OECD	801 151	899 810	12.3	77.8	70.8	654	707	25.8	33.3
G20	949 949	1 189 605	25.2	92.3	93.6	215	256	22.4	26.2
Selected countries									
Argentina	6 406	7 885	23.1	0.6	0.6	161	189	44.9	49.3
Brazil	28 244	37 228	31.8	2.7	2.9	147	184	25.6	33.5
Canada	46 829	54 631	16.7	4.5	4.3	1 403	1 538	46.6	54.5
China	102 368	256 834	150.9	9.9	20.2	76	184	23.4	23.6
Egypt	4 147	8 428	103.2	0.4	0.7	55	101	38.0	60.1
France	59 304	65 086	9.7	5.8	5.1	948	1 007	49.3	59.1
Germany	79 402	91 631	15.4	7.7	7.2	952	1 109	48.6	56.1
India	37 228	53 733	44.3	3.6	4.2	32	42	18.5	23.3
Iran	11 244	25 588	127.6	1.1	2.0	155	326	20.5	23.5
Israel	10 576	11 196	5.9	1.0	0.9	1 488	1 431	44.6	53.1
Japan	76 244	73 128	-4.1	7.4	5.8	599	576	24.5	29.8
Malaysia	2 852	9 998	250.6	0.3	0.8	104	331	42.3	51.6
Mexico	8 559	11 147	30.2	0.8	0.9	74	90	44.7	45.9
Republic of Korea	33 431	50 258	50.3	3.2	4.0	698	1 015	26.6	28.8
Russian Federation	27 418	29 099	6.1	2.7	2.3	191	204	32.5	35.7
South Africa	5 611	9 309	65.9	0.5	0.7	112	175	51.9	60.5
Turkey	18 493	23 596	27.6	1.8	1.9	263	311	16.3	21.6
United Kingdom	77 116	87 948	14.0	7.5	6.9	1 257	1 385	50.4	62.0
United States of America	289 769	321 846	11.1	28.1	25.3	945	998	30.5	39.6

Note: The sum of the numbers for the various regions exceeds the total number because papers with multiple authors from different regions contribute fully to each of these regions.

Source: Data from Thomson Reuters' Web of Science Science Citation Index Expanded compiled for UNESCO by Science-Metrix, May 2015

Figure 1.5: **Trends in scientific publications worldwide, 2008 and 2014**

13.8%
Growth in publications with authors from Europe between 2008 and 2014

60.1%
Growth in publications with authors from Africa between 2008 and 2014

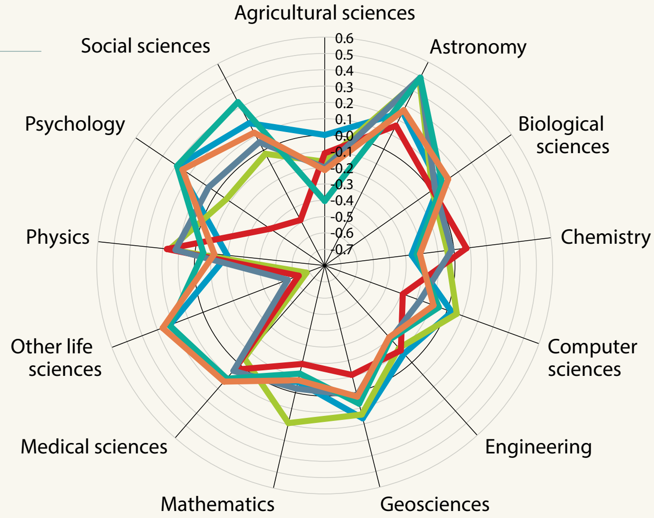
109.6%
Growth in publications with authors from Arab states between 2008 and 2014

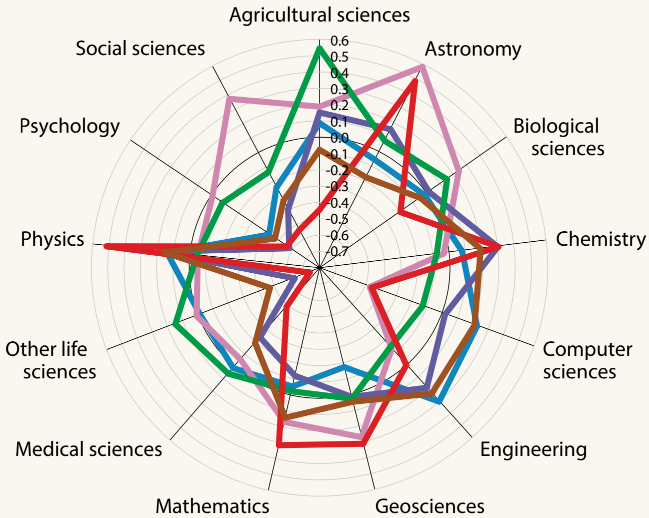
Scientific specialization in large advanced economies

France tops G7 counties for its specialization in mathematics

G7 countries diverge the most in their specialization in psychology and social sciences

USA, UK, Germany, France, Canada, Japan





Scientific specialization in large emerging economies

The Russian Federation tops large emerging economies in geosciences, physics and mathematics but trails them in life sciences

The Republic of Korea, China and India dominate engineering and chemistry

Brazil specializes in agricultural sciences, South Africa in astronomy

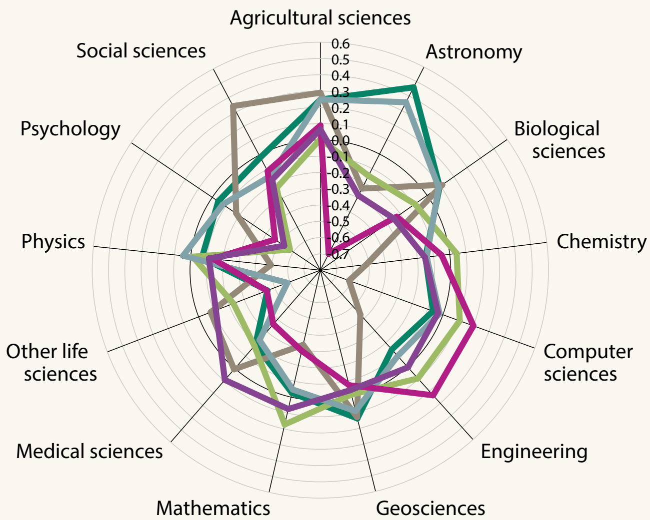
China, India, Brazil, Korea, Rep., Russian Fed., South Africa

Scientific specialization in other emerging national and regional economies

Sub-Saharan Africa and Latin America have a similar concentration in agriculture and geosciences

The Arab States focus most on mathematics and least on psychology

Turkey, Arab States, Malaysia, Latin America (minus Brazil), Mexico, Sub-Saharan Africa (minus S. Africa)



Source: UNU-MERIT, based on the Web of Science (Thomson Reuters); data treatment by Science–Metrix

Table 1.5: **Patents submitted to USPTO, 2008 and 2013**

By region or country of inventor

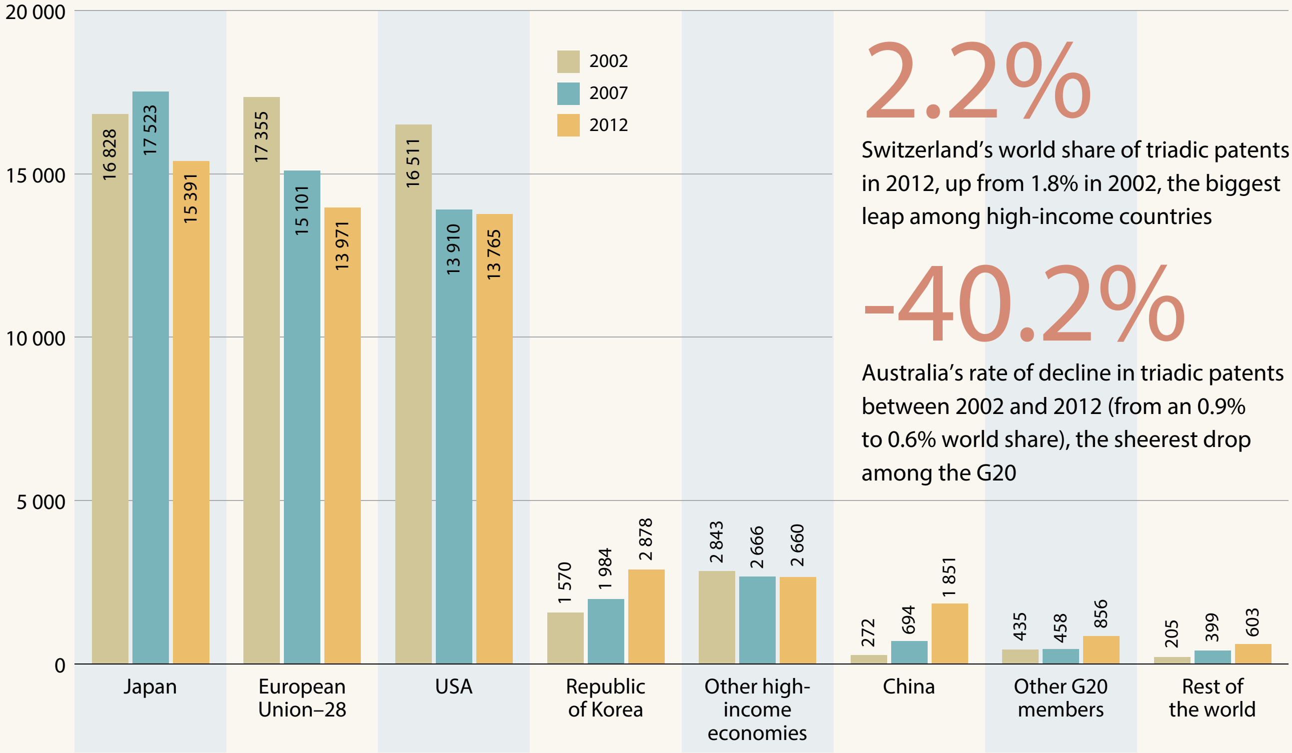
	USPTO patents			
	Total		World share (%)	
	2008	2013	2008	2013
World	**157 768**	**277 832**	**100.0**	**100.0**
High-income economies	149 290	258 411	94.6	93.0
Upper middle-income economies	2 640	9 529	1.7	3.4
Lower middle-income economies	973	3 586	0.6	1.3
Low-income economies	15	59	0.0	0.0
Americas	83 339	145 741	52.8	52.5
North America	83 097	145 114	52.7	52.2
Latin America	342	829	0.2	0.3
Caribbean	21	61	0.0	0.0
Europe	**25 780**	**48 737**	**16.3**	**17.5**
European Union	24 121	45 401	15.3	16.3
Southeast Europe	4	21	0.0	0.0
European Free Trade Association	1 831	3 772	1.2	1.4
Other Europe	362	773	0.2	0.3
Africa	**137**	**303**	**0.1**	**0.1**
Sub-Saharan Africa	119	233	0.1	0.1
Arab States in Africa	18	70	0.0	0.0
Asia	**46 773**	**83 904**	**29.6**	**30.2**
Central Asia	3	8	0.0	0.0
Arab States in Asia	81	426	0.1	0.2
West Asia	1 350	3 464	0.9	1.2
South Asia	855	3 350	0.5	1.2
Southeast Asia	44 515	76 796	28.2	27.6
Oceania	**1 565**	**2 245**	**1.0**	**0.8**
Other groupings				
Least developed countries	7	23	0.0	0.0
Arab States all	99	492	0.1	0.2
OECD	148 658	257 066	94.2	92.5
G20	148 608	260 904	94.2	93.9
Selected countries				
Argentina	45	114	0.0	0.0
Brazil	142	341	0.1	0.1
Canada	3 936	7 761	2.5	2.8
China	1 757	7 568	1.1	2.7
Egypt	10	52	0.0	0.0
France	3 683	7 287	2.3	2.6
Germany	9 901	17 586	6.3	6.3
India	848	3 317	0.5	1.2
Iran	3	43	0.0	0.0
Israel	1 337	3 405	0.8	1.2
Japan	34 198	52 835	21.7	19.0
Malaysia	200	288	0.1	0.1
Mexico	90	217	0.1	0.1
Republic of Korea	7 677	14 839	4.9	5.3
Russian Federation	281	591	0.2	0.2
South Africa	102	190	0.1	0.1
Turkey	35	113	0.0	0.0
United Kingdom	3 828	7 476	2.4	2.7
United States of America	79 968	139 139	50.7	50.1

Note: The sum of the numbers and percentages for the various regions exceeds the total because patents with multiple inventors from different regions contribute fully to each of these regions.

Source: Data from United States Patents and Trademark Office (USPTO) PATSTAT, database compiled for UNESCO by Science-Metrix, June 2015

Figure 1.6: **Trends in triadic patents worldwide, 2002, 2007 and 2012**

Number of triadic patents, 2002, 2007 and 2012



2.2%

Switzerland's world share of triadic patents in 2012, up from 1.8% in 2002, the biggest leap among high-income countries

-40.2%

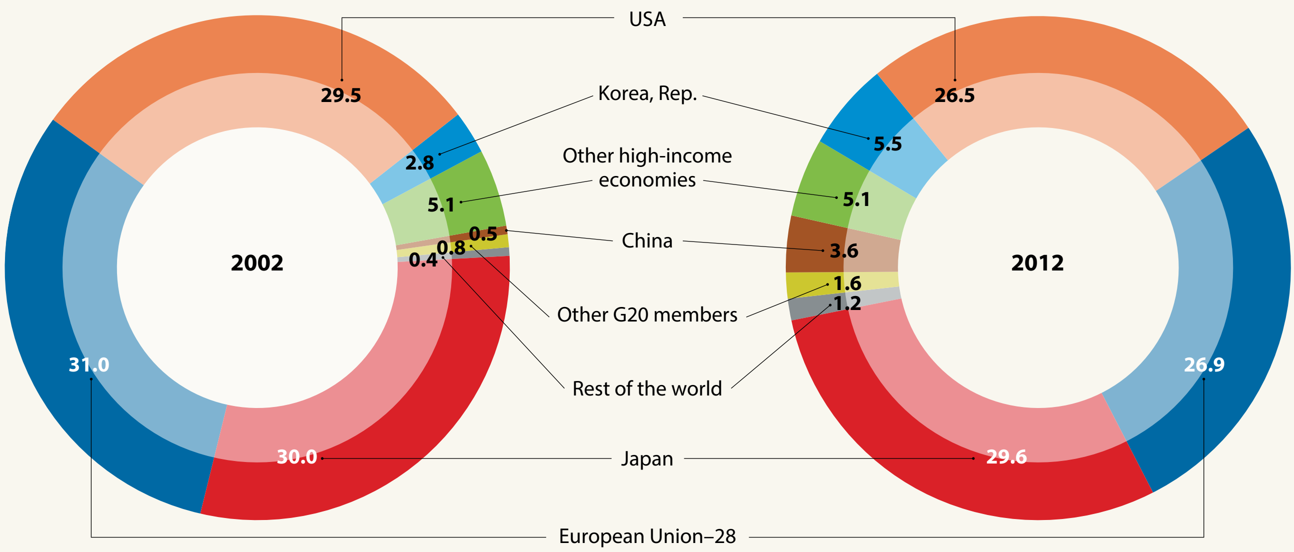
Australia's rate of decline in triadic patents between 2002 and 2012 (from an 0.9% to 0.6% world share), the sheerest drop among the G20

Among the Triad, the European Union and USA showed the greatest contraction in their world share of triadic patents between 2002 and 2012

The Republic of Korea's share of triadic patents almost doubled to 5.5% between 2002 and 2012

China's share of triadic patents grew from 0.5% to 3.6% and the other G20 members doubled their world share to 1.6%, on average

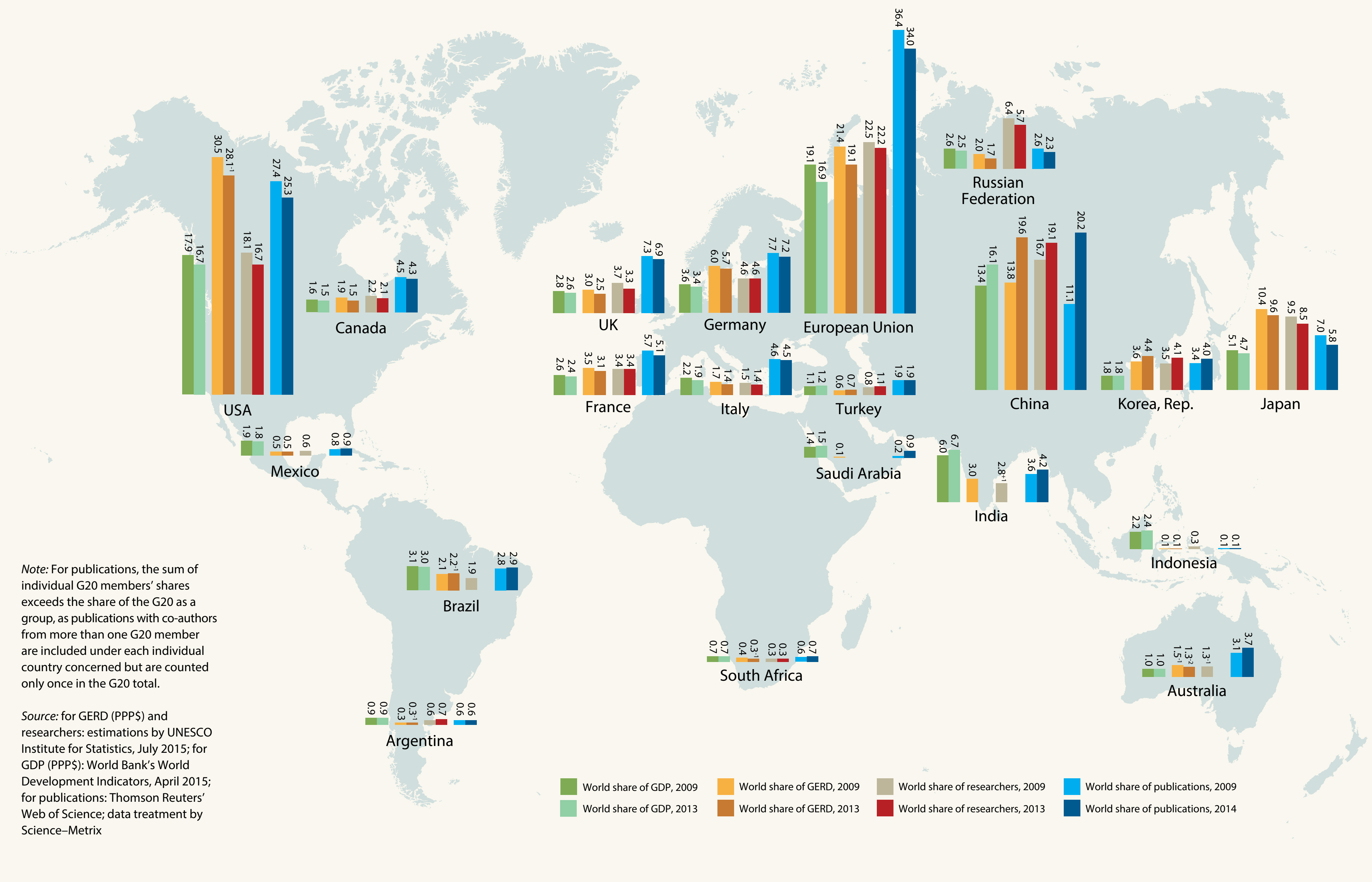
Global shares of triadic patents, 2002 and 2012 (%)



Note: Nowcasting triadic patents of countries in the USPTO database, 2002, 2007 and 2012; triadic patents are a series of corresponding patents filed at the European Patent Office (EPO), the United States Patent and Trademark Office (USPTO) and the Japan Patent Office (JPO) for the same invention, by the same applicant or inventor.

Source: UNESCO Institute for Statistics based on OECD online database (OECD.Stat), August 2015

Figure 1.7: World shares of GDP, GERD, researchers and publications for the G20, 2009 and 2013 (%)



Note: For publications, the sum of individual G20 members' shares exceeds the share of the G20 as a group, as publications with co-authors from more than one G20 member are included under each individual country concerned but are counted only once in the G20 total.

Source: for GERD (PPP$) and researchers: estimations by UNESCO Institute for Statistics, July 2015; for GDP (PPP$): World Bank's World Development Indicators, April 2015; for publications: Thomson Reuters' Web of Science; data treatment by Science–Metrix

A CLOSER LOOK AT COUNTRIES AND REGIONS

More countries are covered by the *UNESCO Science Report* this time than ever before. This reflects the growing acceptance worldwide of STI as a driver of development. The following section summarizes the most insightful trends and developments emerging from Chapters 4 to 27.

Canada (Chapter 4) has managed to dodge the worst shockwaves from the US financial crisis of 2008, thanks to a robust banking industry and strong energy and natural resource sectors, but this is now changing with the decline in global oil prices since 2014.

Two important weaknesses highlighted by the *UNESCO Science Report 2010* persist: a tepid private-sector commitment to innovation and the lack of a strong national agenda for talent and training in scientific and engineering fields. Academic research remains relatively strong, overall, with publications outperforming the OECD average in terms of average citation rate, but Canada is slipping in higher education rankings. An additional vulnerability has emerged: a policy agenda focused almost exclusively on using science to power commerce, often to the detriment of critical 'public good' science, alongside the downsizing of government science agencies and departments.

A recent government review has identified a possible disconnect between Canada's strengths in science and technology, on the one hand, and industrial R&D and economic competitiveness, on the other. Although overall industrial R&D remains weak, four industries display considerable strength: aerospace products and parts manufacturing; ICTs; oil and gas extraction; and pharmaceutical manufacturing.

Between 2010 and 2013, Canada's GERD/GDP fell to its lowest level in a decade (1.63%). In parallel, the share of business funding of R&D receded from 51.2% (2006) to 46.4%. The pharmaceutical, chemical, primary and fabricated metals industries have all experienced an erosion in R&D spending. Consequently, the number of personnel employed in industrial R&D shrank by 23.5% between 2008 and 2012.

Notable developments since 2010 include a renewed focus on polar research and knowledge, enhanced support for universities, growing applications of genomics through Genome Canada, a *Venture Capital Action Plan* (2013), a Canadian partnership with the EU's Eureka programme and an *International Education Strategy* to attract more foreign students to Canada's shores and maximize opportunities for global partnerships.

In the **United States of America** (Chapter 5), GDP has been on the upswing since 2010. However, the recovery from the 2008–2009 recession remains fragile. Despite the decline in unemployment levels, wages have stagnated. There is evidence that the economic stimulus package of 2009, formally known as the American Recovery and Reinvestment Act, may have buffered immediate job losses for those working in science and technology, since a significant portion of this stimulus package went to R&D.

Since 2010, federal investment in R&D has stagnated in the wake of the recession. Despite this, industry has largely maintained its commitment to R&D, particularly in growing, high-opportunity sectors. As a result, total R&D spending has dipped only slightly and the balance of spending has shifted further towards industrial sources since 2010. GERD is now rising and the business sector's investment in innovation appears to be accelerating.

Most of the 11 agencies that conduct the bulk of federally funded R&D have seen flat R&D budgets for the past five years. The Department of Defense has even experienced a steep decline, reflecting the winding down of the intervention in Afghanistan and Iraq and the lesser need for related technologies. The decline in non-defence R&D appears to be due to a combination of decreasing federal budgets for specific research and the budget sequester instigated by Congress in 2013, which has enacted US$1 trillion in automatic cuts to the federal budget to reduce the deficit.

This trend is having the greatest impact on basic research and public-interest science in such areas as life sciences, energy and climate, which happen to be priority areas for the executive branch of government. In order to take up the 'grand challenges' in priority areas announced by the president in 2013, the executive is fostering tripartite industry–non–profit–government partnerships. Some milestones built on this collaborative model are the BRAIN Initiative, the Advanced Manufacturing Partnership and the American Business Act on Climate Pledge that received a US$140 billion commitment from its industrial partners in 2015.

While business R&D has been thriving, budget restrictions have resulted in deep cuts to universities' research budgets. Universities have responded by seeking new sources of funding from industry and relying heavily on temporary contract or adjunct workers. This is affecting the morale of both young and established scientists and inciting some to change career course or emigrate. In parallel, the rate of return migration among foreign students based in the USA is rising as levels of development in their country of origin improve.

The countries of the Caribbean Common Market (CARICOM) (Chapter 6) have been hit by the post-2008 economic slowdown in developed countries, on which they are highly dependent for trade. After meeting their debt obligations, there is little left over for the state to spend on socio-economic development. Many countries also rely heavily on volatile earnings from tourism and remittances.

The region is vulnerable to natural disasters. A costly and ageing fossil-fuel-based energy infrastructure and acute vulnerability to climate change make renewable energy an obvious focus for future research. The *Caribbean Community Climate Change Centre Plan* (2011–2021) for climate change mitigation and resilient development is a key step in this direction.

Health is another key priority, the region boasting several centres of excellence in this field. One of these, St George's University, produces 94% of Grenada's refereed publications. Thanks to the impressive growth in output from this university in recent years, Grenada is now only surpassed by the larger Jamaica and Trinidad and Tobago for the volume of internationally catalogued publications.

One of the region's greatest challenges will be to develop a more vibrant research culture. Even the more affluent Trinidad and Tobago spends just 0.05% of GDP (2012) on R&D. Poor data hamper evidence-based STI policy-making in most countries. Existing pockets of research excellence in academia and business tend to owe more to dynamic individuals than to any particular policy framework.

The *Strategic Plan for the Caribbean Community* (2015–2019) is a first for the region. This planning document advocates nurturing innovation and creativity, entrepreneurship, digital literacy and inclusiveness. CARICOM countries stand to gain a lot from a genuinely regional approach to STI by reducing duplication and promoting synergies in research. There are already some bases to build upon, including the regional University of the West Indies and the Caribbean Science Foundation.

Socio-economic development in **Latin America** (Chapter 7) has slowed after a buoyant decade, especially for the region's commodity exporters, but high-tech production and exports remain marginal for most Latin American countries.

There is, however, a growing public policy focus on research and innovation. Several countries now have sophisticated STI policy instruments in place. The region is also leading efforts to understand and promote the role of indigenous knowledge systems for development.

However, with the exception of Brazil (Chapter 8), no Latin American country has an R&D intensity comparable to that of dynamic emerging market economies. To narrow this gap, countries need to start by augmenting the number of researchers. It is, thus, encouraging that investment in higher education is on the rise; so, too, are scientific production and international scientific collaboration.

Latin America's modest performance in patenting reveals a lack of zeal for technology-driven competitiveness. There is a trend towards greater patenting in natural resource-related sectors such as mining and agriculture, however, largely through public research institutions.

In order to harness STI to development more effectively, some Latin American countries have adopted measures to support strategic sectors such as agriculture, energy and ICTs, including a focus on biotechnologies and nanotechnologies. Examples are Argentina, Brazil, Chile, Mexico and Uruguay. Other countries are targeting science and research funding to expand endogenous innovation, such as Panama, Paraguay and Peru, or promoting broad-based strategies to foster competitiveness, as in the Dominican Republic and El Salvador.

Technologies fostering sustainable development are an emerging priority throughout Latin America, especially in the area of renewable energy, but the region needs to do much more to close the gap with dynamic emerging markets in technology-focused manufacturing. A first step will be to instil greater stability in long-term STI policy-making and to prevent a proliferation of strategies and initiatives.

Brazil (Chapter 8) has faced an economic slowdown since 2011 that has affected its capacity to push on with socially inclusive growth. The slowdown has been triggered by weaker international commodities markets, coupled with the perverse effects of economic policies designed to fuel consumption. In early 2015, Brazil entered into recession for the first time in six years.

Labour productivity has stagnated, despite a range of policies to revive it. Since productivity levels are an indication of the rate of absorption and generation of innovation, this trend suggests that Brazil has not managed to harness innovation to economic growth. The Brazilian experience is akin to that of the Russian Federation and South Africa, where labour productivity has stagnated since 1980, unlike in China and India.

Brazil's R&D intensity in both the government and business enterprise sectors has grown but the GERD/GDP ratio failed to reach the government target of 1.50% by 2010 (1.15% in 2012) and business stands no chance of contributing the

Table 1.6: **Internet users per 100 population, 2008 and 2013**

	2008	2013
World	**23.13**	**37.97**
High-income economies	64.22	78.20
Upper middle-income economies	23.27	44.80
Lower middle-income economies	7.84	21.20
Low-income economies	2.39	7.13
Americas	**44.15**	**60.45**
North America	74.26	84.36
Latin America	27.09	47.59
Caribbean	16.14	30.65
Europe	**50.82**	**67.95**
European Union	64.19	75.50
Southeast Europe	34.55	57.42
European Free Trade Association	83.71	90.08
Other Europe	25.90	53.67
Africa	**8.18**	**20.78**
Sub-Saharan Africa	5.88	16.71
Arab States in Africa	17.33	37.65
Asia	**15.99**	**31.18**
Central Asia	9.53	35.04
Arab States in Asia	19.38	38.59
West Asia	14.37	37.84
South Asia	4.42	13.74
Southeast Asia	24.63	43.58
Oceania	**54.50**	**64.38**
Other groupings		
Least developed countries	2.51	7.00
Arab States all	18.14	38.03
OECD	63.91	75.39
G20	28.82	44.75
Selected countries		
Argentina	28.11	59.90
Brazil	33.83	51.60
Canada	76.70	85.80
China	22.60	45.80
Egypt	18.01	49.56
France	70.68	81.92
Germany	78.00	83.96
India	4.38	15.10
Iran	10.24	31.40
Israel	59.39	70.80
Japan	75.40	86.25
Malaysia	55.80	66.97
Mexico	21.71	43.46
Republic of Korea	81.00	84.77
Russian Federation	26.83	61.40
South Africa	8.43	48.90
Turkey	34.37	46.25
United Kingdom	78.39	89.84
United States of America	74.00	84.20

Source: for data on internet users: International Telecommunications Union/ ICT Indicators database, June 2015, and estimations by UNESCO Institute for Statistics; for population, United Nations Department of Economic and Social Affairs, Population Division (2013) *World Population Prospects: the 2012 Revision*

desired 0.90% of GDP by 2014 (0.52% in 2012). Public and private firms have actually reported a drop in innovation activity since 2008. Among the targets set by the four-year plan *Brasil Maior* (Larger Brazil), only that for expanding access to fixed broadband internet has seen tangible progress. Brazil's share of world exports has actually receded (see also Table 1.6).

The government's efforts to overcome rigidities in the public research system by instituting a category of autonomous research bodies ('social organizations') to pave the way for research institutions to apply modern management methods and develop closer ties with industry has produced some success stories in fields such as applied mathematics or sustainable development. Research excellence nevertheless remains concentrated in a handful of institutions situated mainly in the south.

The volume of Brazilian publications has swelled in recent years but patenting by Brazilians in key global markets remains low. Technology transfer from public research institutions to the private sector remains a major component of innovation in fields ranging from medicine to ceramics, agriculture and deep-sea oil drilling. Two national laboratories have been set up since 2008 to foster the development of nanotechnology. Universities now have the capacity to develop nanoscale materials for drug delivery but, since domestic pharmaceutical companies don't have internal R&D capabilities, universities have to work with them to push new products and processes out to market.

Since 2008, the **European Union** (Chapter 9) has been in a protracted debt crisis. Unemployment rates have soared, especially for the young. As it strives to shore up its macro-economic governance, the world's most advanced project for economic and political union between sovereign states is searching for a growth strategy that works.

Europe 2020, the ten-year strategy adopted in 2010 for smart, sustainable and inclusive growth, is striving to reposition the EU to reach the unfulfilled goals of its earlier Lisbon Strategy by raising investment in R&D (1.92% of GDP in 2013), completing the internal market (especially in services) and promoting the use of ICTs. Additional programmes have been launched since 2010, including the ambitious *Innovation Union*. In July 2015, the Juncker Commission added a European Fund for Strategic Investment to the EU's growth policy arsenal, a small public budget (€ 21 billion) being used to leverage 14 times more (€ 294 billion) in private investment.

Europe remains a pole of excellence and international co-operation in basic research. The first pan-European funding body for frontier research was set up in 2008: the European

Research Council (ERC). Between 2008 and 2013, one-third of all ERC grantees co-authored articles listed among the top 1% most highly cited publications worldwide. The Horizon 2020 programme for research and innovation, which has been endowed with by far the biggest budget yet of any EU framework programme (nearly € 80 billion), is expected to boost EU scientific output further.

Although the R&D intensity of the ten countries which joined the EU in 2004 remains lower than that of the older members, the gap is narrowing. The same cannot be said of Bulgaria, Croatia and Romania, which contributed less to EU GERD in 2013 than in 2007.

Several member states are promoting technology-intensive manufacturing, including France and Germany, or seeking ways to give SMEs greater access to finance. Of some concern is the fact that the innovation performance of 13 countries out of 28 has slipped, owing to a declining share of innovative companies, fewer public–private scientific partnerships and a lesser availability of risk capital.

Southeast European (Chapter 10) economies are at different stages of EU integration, which remains a common goal: whereas Slovenia has been part of the Eurozone since 2007, Bosnia and Herzegovina's Stabilisation and Association Agreement with the EU only entered into force in June 2015. In July 2014, all non-EU countries in the region announced their decision to join the EU's Horizon 2020 programme.

Slovenia is often considered a leader in the region. Its GERD/GDP ratio rose from 1.63% to 2.59% between 2008 and 2013, albeit within a contracting GDP. Slovenia is also the only country in Southeast Europe where business enterprises fund and perform the majority of R&D. Although business R&D has stagnated in most other countries, R&D intensity has risen in Bosnia and Herzegovina, the Former Yugoslav Republic of Macedonia and Serbia; as of 2012, it was close to 1% in Serbia (0.91), which was also performing better in innovation surveys. However, even the more industrialized countries of Croatia and Serbia suffer from weak university–industry linkages. Strong growth in the number of doctorate-holders has enabled researcher density to grow in most countries.

In 2013, governments adopted the *SEE 2020 Strategy* mirroring its EU namesake, in which they commit to raising their R&D intensity and boosting the size of their highly skilled labour force. This strategy is complemented by the *Western Balkans Regional Research and Development Strategy for Innovation* (2013) promoting technology transfer from public research organizations to the private sector and greater collaboration with industry; it advocates smart specialization in high-opportunity areas, such as 'green' innovation and energy, and includes a component promoted by the UNESCO Institute for Statistics of bringing the region's statistics up to EU standards by 2018.

The **European Free Trade Association** (Chapter 11) encompasses four wealthy countries which remain strongly integrated with the EU, yet distinct from it. The European Economic Area agreement signed two decades ago gives Iceland, Liechtenstein and Norway fully associated partner status in EU research programmes. Switzerland's involvement in the latter, while traditionally strong, has recently been confined to temporary arrangements limiting participation in key programmes like Excellent Science, pending the resolution of a dispute with the EU over the implications of the February 2014 Swiss referendum for the free movement of EU researchers in Switzerland.

Switzerland figures in the top three OECD countries for innovation. It has a research-intensive private sector, even though the share of Swiss firms investing in innovation has recently fallen. Switzerland owes its success partly to its ability to attract international talent to private industry and the university sector.

At 1.7 (2013), Norway's GERD/GDP ratio remains below the EU28 average and the level of Iceland (1.9 in 2013) and Switzerland (3.0 in 2012). Norway's share of the adult population with tertiary qualifications and/or engaged in the STI sector is one of the highest in Europe. Unlike Switzerland, Norway struggles to attract international talent and to transform scientific knowledge into innovative products; it also counts a small proportion of high-tech companies conducting R&D. These trends may reflect weak incentives to compete in an oil-rich welfare state.

Iceland was severely hit by the global financial crisis of 2008. Its R&D intensity declined from 2.6 to 1.9 between 2007 and 2013. Despite being confronted with brain drain, Iceland has an excellent publication record, largely due to a highly mobile younger generation of scientists. Most spend at least part of their career abroad and half of all doctorates are awarded in the USA.

Despite Liechtenstein's tiny size, some of its internationally competitive companies in machinery, construction and medical technology conduct a high level of R&D.

Seldom viewed as a region, the countries of the **Black Sea basin** (Chapter 12) are middle-income economies that face similar challenges with regard to STI. Although they have followed different trajectories, most Black Sea countries appear to be converging in terms of educational attainment and, for the larger ones (such as Turkey and Ukraine), in terms of their level of industrialization. Most are feeling the gravitational pull of the EU in international scientific collaboration.

In their strategic documents, all seven Black Sea countries acknowledge the importance of science-based innovation for long-term productivity growth, including Azerbaijan where R&D intensity had struggled to keep up with oil-driven growth in the 2000s. In the historically more industrialized post-Soviet states of Belarus and Ukraine, GERD is no longer as high as in the heady days of the 1980s but remains on a par (0.7–0.8% of GDP) with less ambitious middle-income economies.

In the other, less populous post-Soviet states (Armenia, Georgia and Moldova), post-transition instability and long-term policy and funding neglect have rendered much of the Soviet-era research infrastructure obsolete and severed modern industry–science linkages. These countries do have exploitable assets, though. Armenia, for instance, can boast of scientific excellence in ICTs.

All six post-Soviet states suffer from severe lacunae when it comes to the availability or comparability of data on R&D and personnel, partly because this aspect of their transition to advanced economies remains incomplete.

Coming from a lower starting point, Turkey has been surpassing the other Black Sea countries for many quantitative measures of STI input. Its equally impressive socio-economic transformation over the past decade appears to have been mostly driven by medium-tech production. Turkey could still learn from the other shores of the Black Sea why an early emphasis on strong educational attainment is so important for building technological excellence. In turn, its neighbours could learn from Turkey that a highly educated labour force and R&D alone do not lead to innovation; you also need a business-friendly economic environment and contestable markets.

Economic growth has slowed in the **Russian Federation** (Chapter 13) since the global financial crisis (2008) and the country has been in recession since the third-quarter of 2014, following the sharp drop in global oil prices and the imposition of sanctions by the EU and USA in reaction to the events in Ukraine.

Reforms implemented since 2012 as part of an innovation-led growth strategy have failed to overcome the structural weaknesses which hamper growth in the Russian Federation, including limited market competition and persistent barriers to entrepreneurship. These reforms include an attempt to attract researchers to 'research deserts' by raising their salaries and providing incentives for state-owned enterprises to innovate. Government appropriations for R&D in 2013 reflected a greater orientation towards the needs of industry than five years earlier, to the detriment of basic research, which was down from 26% to 17% of the total.

Despite government efforts, the financial contribution of industry to GERD in the Russian Federation fell from 33% to 28% between 2000 and 2013, even though industry performs 60% of GERD. Generally speaking, a low proportion of industrial investment goes towards acquiring new technologies and technology-based start-ups remain uncommon. The modest investment so far in sustainable technologies can largely be explained by the business sector's tepid interest in green growth. Only one in four (26%) innovative enterprises are producing inventions in the environmental field. The government has high hopes for the Skolkovo Innovation Centre, a high-tech business complex being built near Moscow to attract innovative companies and nurture start-ups in five priority areas: energy efficiency and energy saving; nuclear technologies; space technologies; biomedicine; and strategic computer technologies and software. A law adopted in 2010 provides residents with generous tax benefits for 10 years and makes provision for the establishment of the Skolkovo Fund to support development of a university on site. One of the centre's biggest partners is the Massachusetts Institute of Technology (USA).

Low business patenting illustrates the weak synergies between a relatively determined government effort to promote economically relevant research and a business sector unfocused on innovation. For example, since the government made nanotechnology a priority growth area in 2007, production and exports have grown but the patenting intensity of related research has been very low.

Scientific production has shown modest growth but is making a relatively low impact. A recent government initiative has shaken up university research by establishing a Federal Agency for Research Organizations to take over the role of financing and managing the property of research institutes from the Russian Academy of Sciences. In 2013, the government set up the Russian Science Foundation to expand the spectrum of competitive funding mechanisms for research.

The countries of **Central Asia** (Chapter 14) are gradually moving from a state-controlled to a market economy. Although both exports and imports grew impressively during the commodities boom of the past decade, these countries remain vulnerable to economic shocks, owing to their reliance on exports of raw materials, a restricted circle of trading partners and a negligible manufacturing capacity.

All but Uzbekistan halved the number of its national research institutions between 2009 and 2013. These centres established during the Soviet period have since become obsolete with the development of new technologies and changing national priorities. As part of a drive modernize infrastructure, Kazakhstan and Turkmenistan are both building technology parks and grouping existing institutions to create research hubs. Bolstered by strong economic growth in all but Kyrgyzstan, national development strategies are fostering new high-tech industries, pooling resources and orienting the economy towards export markets.

Three universities have been set up in Central Asia in recent years to foster competence in strategic economic areas: Nazarbayev University in Kazakhstan, Inha University in Uzbekistan, specializing in ICTs, and the International Oil and Gas University in Turkmenistan. Countries are not only bent on augmenting the efficiency of traditional extractive sectors but also wish to make greater use of ICTs and other modern technologies to develop the business sector, education and research.

This ambition is hampered by chronic low investment in R&D. Over the past decade, the region's GERD/GDP ratio has hovered around 0.2–0.3%. Uzbekistan broke with this trend in 2013 by raising its own R&D intensity to 0.41%. Kazakhstan is the only country where the business enterprise and private non-profit sectors make any significant contribution to R&D – but R&D intensity overall is very low in Kazakhstan: just 0.17 in 2013. Nevertheless, spending on scientific and technological services has risen strongly in this country, suggesting a growing demand for R&D products. This trend is also revealing of enterprises' preference for purchasing embodied technological solutions in imported machinery and equipment. The government has adopted a strategy for modernizing enterprises through technology transfer and the development of business acumen; the focus is on developing project finance, including through joint ventures.

Between 2005 and 2014, Kazakhstan's share of scientific papers from the region grew from 35% to 56%. Although two-thirds of papers from the region have a foreign co-author, the main partners tend to come from beyond Central Asia.

In **Iran** (Chapter 15), international sanctions have slowed industrial and economic growth, limited foreign investment and oil and gas exports and triggered national currency devaluation and hyperinflation. The sanctions also appear to have accelerated the shift from a resource-based economy to a knowledge economy by challenging policy-makers to look beyond extractive industries to the country's human capital for wealth creation, including a large pool of young university graduates. Between 2006 and 2011, the number of firms declaring R&D activities more than doubled. However, even though one-third of GERD came from the business sector in 2008, this contribution (0.08% of GDP) remains too small to nurture innovation effectively. GERD amounted to just 0.31% of GDP in 2010. The easing of sanctions following the conclusion of the nuclear deal in July 2015 may help the government to reach its target of raising GERD to 3% of GDP.

As economic sanctions have tightened their grip, the government has sought to boost endogenous innovation. The Innovation and Prosperity Fund was established by law in 2010 to support investment in R&D by knowledge-based firms and the commercialization of research results, as well as to help SMEs acquire technology. Between 2012 and late 2014, it planned to allocate 4 600 billion Iranian rials (*circa* US$ 171.4 million) to 100 knowledge-based companies.

Although sanctions have caused a shift in Iran's trading partners from West to East, scientific collaboration has remained largely oriented towards the West. Between 2008 and 2014, the top foreign partners for scientific co-authorship were the USA, Canada, the UK, Germany and Malaysia. Ties with Malaysia are growing: one in seven foreign students in Malaysia is now of Iranian origin (see Chapter 26).

Over the past decade, several research centres and 143 companies have been established in nanotechnology. By 2014, Iran ranked seventh worldwide for the volume of papers related to nanotechnology, even if few patents are being granted to inventors, as yet.

Israel (Chapter 16) has the world's most R&D-intensive business sector, in addition to being the world's most venture capital-intensive economy. The country has achieved a qualitative edge in a range of technologies in electronics, avionics and related systems, initially propelled by spin-offs from the defence industry. The development of these systems has given Israeli high-tech industries a qualitative edge in civilian spin-offs in the software, communications and internet sectors. In 2012, the high-tech sector accounted for an exceptional 46% of Israel's exports.

Such success, combined with an acute sense of vulnerability in a country largely isolated from its immediate neighbourhood, has given rise to introspection. There is debate, for instance, on how Israel should promote its technological edge in the largely non-defence-driven disciplines that are considered to be tomorrow's drivers of growth, including biotechnology and pharmaceuticals, nanotechnology and material sciences. Since excellence in these areas tends to be rooted in the basic research laboratories of universities, Israel's decentralized university research system will need to manage the necessary transition to these growth areas – but is it equipped to do so? In the absence of a national policy for universities, it is not clear how they will manage to supply the knowledge, skills and human resources needed for these new science-based industries.

There is a visible ageing of scientists and engineers in some fields, including physical sciences and practical engineering. The shortage of professional staff will be a major handicap for the national innovation system, as the growing demand for engineers and technical professionals begins to outpace supply. The *Sixth Higher Education Plan* (2011–2015) foresees the recruitment of 1 600 senior faculty, about half of whom will occupy new positions (a net increase of more than 15%). It also foresees an investment of NIS 300 million (*circa* US$ 76 million) over six years in upgrading and renovating academic infrastructure and research facilities. Some argue that the plan pays insufficient attention to the funding of university research, which in the past relied heavily on Jewish philanthropic contributions from abroad.

Israel's broader problem of a binary economic structure persists, with a small high-tech sector serving as the locomotive of the economy co-existing with much larger but less efficient traditional industrial and services sectors with lower productivity levels. This binary economic structure has led to a well-paid labour force living at the 'core' of the country and a poorly paid labour force living primarily on the periphery. Israeli decision-makers need to reflect on how to address such systemic issues in the absence of an umbrella organization for STI policy, without sacrificing the flexibility of the decentralized education and research systems that has served the country so well, so far.

Most **Arab States** (Chapter 17) devote more than 1% of GDP to higher education and many have high gross tertiary enrolment rates for both sexes. Generally speaking, though, they have failed to create economic opportunities on a sufficient scale to absorb the growing pool of youth.

With the exception of the capital-surplus oil-exporting countries, Arab economies have not experienced rapid, sustained expansion. Low economic participation rates (especially among women) and high unemployment rates (especially among youth) have been exacerbated in most countries since 2008. Events that have erupted since 2011 (the so-called Arab Spring) were as much a reaction to economic frustration as poor public governance. Military spending was already high in the Middle East but political turmoil in recent years and the concomitant rise of opportunist terrorist groups have led many governments to divert additional resources towards military spending.

The democratic transition in Tunisia is one of the Arab Spring's success stories. It has brought greater academic freedom that will be a boon for Tunisian research and should make it easier for universities to develop ties with industry. Tunisia already counts several technoparks.

R&D intensity has remained low in most Arab states, especially in the oil-rent economies where high GDP makes it hard to increase intensity. The GERD/GDP ratio in Morocco and Tunisia (around 0.7%) is close to the average for upper middle-income economies. Moreover, this ratio has risen in the most populous Arab country, Egypt: from 0.43% (2009) to 0.68% of GDP (2013); the government has opted to engage Egypt on the path to a knowledge economy, with the prospect of more diversified sources of income.

Governments dependent on both oil exports (Gulf States and Algeria) and oil imports (Morocco and Tunisia) are also fostering the development of knowledge economies. A wide range of recent initiatives harness STI to socio-economic development, often in the field of energy. Examples are the revival of the Zewail City of Science and Technology project in Egypt and the establishment of the Emirates Institution for Advanced Science and Technology to operate Earth observation satellites. Morocco inaugurated Africa's biggest wind farm in 2014 and is developing what may turn out to be Africa's biggest solar farm. In 2015, Saudi Arabia announced a programme to develop solar energy.

Both Qatar and Saudi Arabia have seen phenomenal growth in the volume of scientific publications over the past decade. Saudi Arabia now counts two universities among the world's top 500. It plans to reduce its dependence on foreign workers by developing technical and vocational education, including for girls.

West Africa (Chapter 18) has experienced strong economic growth in recent years, despite the Ebola epidemic and other crises. However, this growth masks structural weaknesses: the members of the Economic Community of West African States (ECOWAS) remain dependent on revenue from commodities and have, so far, failed to diversify their economies. The main obstacle is the shortage of skilled personnel, including technicians. Only three West African countries devote more than 1% of GDP to higher education (Ghana, Mali and Senegal) and illiteracy remains a major hurdle to expanding vocational training.

Africa's Science and Technology Consolidated Plan of Action (2005–2014) called for the establishment of regional networks of centres of excellence and for a greater mobility of scientists across the continent. In 2012, the West African Economic and Monetary Union designated 14 centres of excellence, a label which earned them funding for the next two years. The World Bank launched a similar project in 2014 but in the form of loans.

ECOWAS' *Vision 2020* (2011) provides a road map for improving governance, accelerating economic and monetary integration and fostering public–private partnerships. The *ECOWAS Policy on Science and Technology* (2011) is an integral part of *Vision 2020* and espouses the ambitions of the continental plan of action for STI.

So far, the research sector has had little impact in West Africa, owing to a lack of national research and innovation strategies, low investment in R&D, little private-sector involvement and little intraregional collaboration among West African researchers. The government remains by far the biggest source of GERD. West African output remains low, with only Gambia and Cabo Verde publishing 50 scientific articles or more per million inhabitants.

In **East and Central Africa** (Chapter 19), there has been a considerable gain in interest in STI since 2009. Most countries have based their long-term planning ('vision') documents on harnessing STI to development. These planning documents tend to reflect the common vision for the future that they share with West and Southern Africa: a prosperous middle-income country (or higher) characterized by good governance, inclusive growth and sustainable development.

Governments are increasingly looking for investors rather than donors and devising schemes to support local businesses: a fund developed by Rwanda to foster a green economy provides competitive funds to successful public and private applicants; in Kenya, the Nairobi Industrial and Technology Park is being developed within a joint venture with a public university. The first technology incubators in Kenya have been incredibly successful in helping start-ups capture markets in information technology (IT), in particular. Many governments are now investing in this dynamic sector, including those of Cameroon, Rwanda and Uganda.

Spending on R&D is on the rise in most countries with innovation hubs. Kenya now has one of Africa's highest R&D intensities (0.79% of GDP in 2010), followed by Ethiopia (0.61% in 2013), Gabon (0.58% of GDP in 2009) and Uganda (0.48% in 2010). The government tends to be the main source of R&D spending but business contributes 29% in Gabon (2009) and 14% in Uganda (2010). Foreign sources account for at least 40% of R&D in Kenya, Uganda and Tanzania.

East and Central African countries participated in *Africa's Science and Technology Consolidated Plan of Action* (CPA, 2005–2014) and have embraced its successor, the *Science, Technology and Innovation Strategy for Africa* (STISA-2024). Implementation of the CPA suffered from the failure to set up the African Science and Technology Fund to ensure sustainable funding but several networks of centres of excellence in biosciences were nevertheless established, including a research hub for East Africa in Kenya and two complementary networks, Bio-Innovate and the African Biosafety Network of Expertise. Five African Institutes of Mathematical Sciences have been established in Cameroon, Ghana, Senegal, South Africa and Tanzania. Since 2011, the African Observatory of Science, Technology and Innovation – another product of the CPA – has been helping to improve African data.

The East African Community (EAC) and Common Market for Southern and Eastern Africa consider STI to be a key component of economic integration. For instance, the EAC *Common Market Protocol* (2010) makes provisions for market-led research, technological development and the adaptation of technologies in the community, in order to support the sustainable production of goods and services and enhance international competitiveness. The EAC has entrusted the Inter-University Council for East Africa with the mission of developing a Common Higher Education Area by 2015.

Southern Africa (Chapter 20) is characterized by a common desire to harness STI to sustainable development. As elsewhere in the subcontinent, the economies of the Southern African Development Community (SADC) are highly dependent on natural resources. The drop in government funding for agricultural R&D by SADC countries is, thus, a cause for concern.

There is a wide disparity in R&D intensity, from a low of 0.01% in Lesotho to a high of 1.06% in Malawi, which is trying to attract FDI to develop its private sector. South Africa attracted about 45% of the FDI flowing to the SADC in 2013 and is establishing itself as a leading investor in the region: between 2008 and 2013, its outward flows of FDI almost doubled to US$ 5.6 billion, powered by investment in telecommunications, mining and retail in mostly neighbouring countries.

The contraction in South Africa's GERD/GDP ratio between 2008 and 2012 from 0.89% to 0.73% is mostly due to a drop in private-sector funding that could not be offset by the concomitant rise in public spending on R&D. South Africa generates about one-quarter of African GDP and has a fairly solid innovation system: it filed 96% of SADC patents between 2008 and 2013.

In most SADC countries, STI policies remain firmly linked to the state apparatus, with little participation by the private sector. STI policy documents are rarely accompanied by implementation plans and allocated budgets. A lack of human and financial resources has also hampered progress towards regional STI policy targets. Other obstacles to the development of national innovation systems include a poorly developed manufacturing sector, few incentives for private-sector investment in R&D, a serious shortage of scientific and technological skills at all levels, ongoing brain drain, poor science education at school for want of qualified teachers and an appropriate curricula, poor legal protection of intellectual property rights, and lack of co-operation in science and technology.

Intra-African trade remains dismally low, at approximately 12% of total African trade. Regional integration is high on the list of the African Union, the New Partnership for Africa's

Development and regional economic communities like the SADC, COMESA and EAC, which formally launched a Free Trade Area in June 2015. The development of regional STI programmes is also high on their list of priorities. The most formidable obstacle of all to regional integration is probably the resistance of individual governments to relinquishing any national sovereignty.

In **South Asia** (Chapter 21), political instability has been a barrier to development but the resolution of crises in the region, including the return to peace in Sri Lanka and the democratic transition in Afghanistan offer hope for the future. Sri Lanka is investing heavily in infrastructure development and Afghanistan in education at all levels.

All economies have grown in the past decade, with GDP per capita progressing fastest in Sri Lanka (excluding India, see Chapter 22). South Asia nevertheless remains one of the world's least economically integrated regions, intraregional trade accounting for just 5% of the total.

Although South Asian countries have made a strong drive to achieve universal primary education by 2015, this effort has eaten into investment in higher education (just 0.2–0.8% of GDP). Most countries have formulated policies and programmes to foster the use of ICTs in schools, research and economic sectors but these efforts are hampered by an unreliable electricity supply in rural areas, in particular, and the lack of broadband internet infrastructure. Mobile phone technology is widely used in the region but still underutilized for information- and knowledge-sharing, as well as for the development of commercial and financial services.

Pakistan's R&D effort slid from 0.63% to 0.29% of GDP between 2007 and 2013, whereas Sri Lanka maintained a low 0.16% of GDP. Pakistan plans to hoist its investment in R&D to 1% of GDP by 2018 and Sri Lanka to 1.5% by 2016. The challenge will be to put effective mechanisms in place to achieve these targets. Afghanistan has surpassed its own target by doubling university enrolment between 2011 and 2014.

The country to watch may be Nepal, which has improved several indicators in just a few years: its R&D effort has risen from 0.05% (2008) to 0.30% (2010) of GDP, it now has more technicians per million inhabitants than either Pakistan or Sri Lanka and is just a whisker behind Sri Lanka for researcher intensity. Reconstruction needs after the tragic earthquake of 2015 may oblige the government to review some of its investment priorities.

To realize their ambition of becoming knowledge economies, many South Asian countries will need to boost the uptake into secondary education and adopt credible funding and prioritization mechanisms. Tax incentives for innovation and a more business-friendly economic environment could help to make public–private partnerships a driver of economic development.

In **India** (Chapter 22), economic growth has slowed to about 5% per year since the 2008 crisis; there is concern that this respectable growth rate is not creating sufficient jobs. This has led Prime Minister Modi to argue for a new economic model based on export-oriented manufacturing, as opposed to the current model weighted towards services (57% of GDP).

Despite slower economic growth, all indicators of R&D output have progressed rapidly in recent years, be they for the share of high-tech exports among Indian exports or the number of scientific publications. The business enterprise sector has become increasingly dynamic: it performed nearly 36% of all R&D in 2011, compared to 29% in 2005. The only key indicator which has stagnated is the measure of India's R&D effort: 0.82% of GDP in 2011. The government had planned to raise GERD to 2% of GDP by 2007 but has since had to set back the target date to 2018.

Innovation is concentrated in nine industrial sectors, with more than half of business R&D expenditure concerning just three industries: pharmaceuticals, automotive and computer software. Innovative firms are also largely circumscribed to just six of India's 29 states. Despite India having one of the most generous tax regimes for R&D in the world, this regime has failed to spread an innovation culture across firms and industries.

There has been strong growth in patents, six out of ten of which were in IT and one out of ten in pharmaceuticals in 2012. The majority of pharmaceutical patents are held by domestic firms, whereas foreign firms tend to hold most IT patents. This is because Indian companies have traditionally had less success in manufacturing products which require engineering skills than in science-based industries like pharmaceuticals.

The majority of patents granted to Indians are for high-tech inventions. In order to sustain this capacity, the government is investing in new areas such as aircraft design, nanotechnology and green energy sources. It is also using India's capabilities in ICTs to narrow the urban–rural divide and setting up centres of excellence in agricultural sciences to reverse the worrying drop in yields of some staple food crops. India is also evolving into a hub for 'frugal innovation,' with a growing local market for pro-poor inventions, such as low-cost medical devices or Tata's latest micro-car, the Nano Twist.

The employability of scientists and engineers has been a nagging worry for policy-makers for years and, indeed, for prospective employers. The government has introduced a number of remedial measures to improve the quality of higher education and academic research. Researcher density in the private sector is now rising, underpinned by spectacular growth in the number of engineering students. Nevertheless, the government still needs to invest more heavily in university research, which performs just 4% of R&D, to enable universities to fulfil their role better as generators of new knowledge and providers of quality education.

In **China** (Chapter 23), scientists and engineers have clocked up some remarkable achievements since 2011. These span a wide range of areas from fundamental discoveries in condensed matter physics to landing a probe on the moon in 2013 and China's first large passenger aircraft. China is on track to become the world's largest scientific publisher by 2016. Meanwhile, at home, seven out of ten (69%) of the patents granted by China's State Intellectual Property Office in 2013 went to domestic inventors.

There is nevertheless some dissatisfaction among the political leadership with the return so far on the government's investment in R&D. Despite a massive injection of funds (2.09% of GDP in 2014), better trained researchers and sophisticated equipment, Chinese scientists have yet to produce cutting-edge breakthroughs. Few research results have been turned into innovative and competitive products and China faces a US$ 10 billion deficit (2009) in its intellectual property balance of payments. Many Chinese enterprises still depend on foreign sources for core technologies. Just 4.7% of GERD goes on basic research, compared to 84.6% on experimental development (up from 73.7% in 2004).

These problems have forced China to put its ambition on hold of embarking on a truly innovation-driven development trajectory while the leadership pushes ahead with a comprehensive reform agenda to address perceived weaknesses. The Chinese Academy of Sciences, for instance, has come under pressure to raise the quality of academic research and collaborate more with other innovation actors. To foster technology transfer, an expert group has been set up under Vice-Premier Ma Kai to identify industrial champions capable of concluding strategic partnerships with foreign multinationals. This resulted in Intel acquiring 20% of the shares in Tsinghua Unigroup, a state company, in September 2014.

The 'new normal' of slower economic growth highlights the urgency for China to transform its economic development model from one that is labour-, investment-, energy- and resource-intensive to one that is increasingly dependent upon technology and innovation. A number of policies are moving in this direction. For instance, the *Twelfth Five-Year Plan* (2011–2015) specifically calls for the development of smart city technologies.

China has already managed to reach many of the quantitative targets set by its *Medium and Long-term Plan for the Development of Science and Technology* (2006–2020) and is on track to reach that of a 2.5% GERD/GDP ratio by 2020. This plan is currently undergoing a mid-term review. The findings may determine the extent to which the country preserves elements of the open, bottom-up development strategy that has served it so well for the past three decades. One risk is that a more politicized, interventionist strategy might deter foreign capital and slow down China's brain gain, which has recently accelerated: nearly half of the 1.4 million students who have returned home since the early 1990s have done so since 2010.

Japan (Chapter 24) has been pursuing extraordinarily active fiscal and economic policies to shake itself out of the economic lethargy that has plagued it since the 1990s. This policy reform package has come to be known as Abenomics, in reference to the prime minister. The third 'arrow' of this package in the area of pro-growth policies is yet to show results, however.

Japan nevertheless remains one of the most R&D-intensive economies in the world (3.5% of GDP in 2013). The most remarkable trend in industrial spending on R&D in recent years has been the substantial cutback in ICTs. Most other industries maintained more or less the same level of R&D expenditure between 2008 and 2013.The challenge for Japanese industry will be to combine its traditional strengths with a future-oriented vision.

Japan faces a number of challenges. Its ageing population, coupled with a waning interest among the young for an academic career and the drop in scientific publications, reflect a need for a far-reaching reform of the national innovation system.

For the academic sector, university reform has been a challenge for years. Regular funding of national universities has declined consistently for more than a decade by roughly 1% a year. In parallel, the amount of competitive grants and project funding have increased. In particular, there has been a proliferation recently of multipurpose, large-scale grants that do not target individual researchers but rather the universities themselves; these grants do not purely fund university research and/or education *per se;* they also mandate universities to conduct systemic reforms, such as the revision of curricula, promotion of female researchers and internationalization of education and research. The drop in regular funding has been accompanied by increasing demands on academics, who now have less time for research. This has translated into a drop in scientific publications, a trend almost unique to Japan.

The Fukushima disaster in March 2011 has had a profound impact on science. The disaster has not only shaken the public's confidence in nuclear technology but also in science and technology more broadly. The government has reacted by trying to restore public confidence. Debates have been organized and, for the first time, the importance of scientific advice in decision-making has come to the fore. Since the Fukushima disaster, the government has decided to reinvigorate the development and use of renewable energy.

Published just months after the Fukushima disaster, the *Fourth Basic Plan for Science and Technology* (2011) was a radical departure from its predecessors. It no longer identified priority areas for R&D but rather put forward three key areas to be addressed: recovery and reconstruction from the Fukushima disaster, 'green innovation' and 'life innovation.'

The **Republic of Korea** (Chapter 25) is the only nation to have transformed itself from a major recipient of foreign aid into a major donor – and in just two generations. Today, it is in search of a new development model. The government recognizes that the remarkable growth of the past is no longer sustainable. Competition with China and Japan is intense, exports are slipping and global demand for green growth has altered the balance. In addition, a rapidly ageing population and declining birthrates threaten Korea's long-term economic prospects.

The Park government is pursuing the low carbon, green growth policy adopted by its predecessor but has added the creative economy to this mix. Seed money has been allocated to fostering the emergence of a creative economy over the five years to 2018.

The government has come to realize that developing national capabilities for innovation will require nurturing creativity among the young. Ministries have jointly introduced measures to attenuate the focus on academic backgrounds and promote a new culture whereby people encourage and respect the creativity of individuals. One example of these measures is the Da Vinci Project being experimented in selected primary and secondary schools to develop a new type of class which encourages students to exercise their imagination and revitalizes hands-on research and experience-based education.

The process of making the country more entrepreneurial and creative will entail changing the very structure of the economy. Up until now, it has relied on large conglomerates to drive growth and export earnings. These still represented three-quarters of private investment in R&D in 2012. The challenge will be for the country to produce its own high-tech start-ups and to foster a creative culture in SMEs. Another challenge will be to turn the regions into hubs for creative industries by providing the right financial infrastructure and management to improve their autonomy. The new Innovation Center for the Creative Economy in Daejeon serves as a business incubator.

In parallel, the government is building the International Science Business Belt in Daejeon. The aim is to correct the impression that the Republic of Korea made the transition from a poor agricultural country to an industrial giant through imitation alone, without developing an endogenous capacity in basic sciences. A National Institute for Basic Science opened on the site in 2011 and a heavy ion accelerator is currently under construction to support basic research and provide linkages to the business world.

Malaysia (Chapter 26) has recovered from the global financial crisis to register healthy average annual GDP growth of 5.8% over 2010–2014. This, coupled with strong high-tech exports, has helped sustain government efforts to finance innovation, such as through the provision of R&D grants to universities and firms. This has helped to raise the GERD/GDP ratio from 1.06% in 2011 to 1.13% in 2012. The rise in R&D funding has translated into more patents, scientific publications and foreign students.

It was in 2005 that Malaysia adopted the target of becoming the sixth-largest global destination for international university students by 2020. Between 2007 and 2012, the number of international students almost doubled to more than 56 000, the target being to attract 200 000 by 2020. Malaysia is attracting a lot of students from the region but was also one of the top ten destinations for Arab students by 2012.

A number of bodies have helped to strengthen the participation of business in R&D in strategic sectors. One example is the Malaysian Palm Oil Board. In 2012, a group of multinational corporations created their own platform for Collaborative Research in Engineering, Science and Technology (CREST). This trilateral partnership involving industry, academia and the government strives to satisfy the research needs of electrical and electronics industries in Malaysia that employ nearly 5 000 research scientists and engineers.

While the government has done remarkably well in supporting R&D, a number of issues have undermined Malaysia's capacity to support frontier technologies. Firstly, collaboration between the principal actors of innovation still needs strengthening. Secondly, science and mathematics teaching needs upgrading, as 15 year-old Malaysian students have been performing less well in the triennial assessments conducted by the OECD's Programme for International Student Assessment. Thirdly, the share of full-time equivalent researchers per million inhabitants has grown steadily but remains fairly low for a dynamic Asian economy like Malaysia: 1 780 in 2012. Malaysia is also still a net technology importer, as its royalties from technological licensing and services have remained negative.

Southeast Asia and Oceania (Chapter 27) has successfully navigated through the global financial crisis of 2008, with many countries managing to avoid recession. The creation of the Association of Southeast Asian Nations (ASEAN) Economic Community in late 2015 is likely to boost economic growth in the region and spur both the cross-border movement of researchers and greater specialization. Meanwhile, democratic reforms in Myanmar have led to the easing of international sanctions, offering prospects for growth, particularly since the government is fostering export-oriented industries.

The Asia–Pacific Economic Cooperation completed a study in 2014 of skills shortages in the region, with a view to setting up a monitoring system to address training needs. For its part, the *ASEAN Plan of Action on Science, Technology and Innovation* (2016–2020) emphasizes social inclusion and sustainable development, including in such areas as green technology, energy, water resources and innovation for life. Government priorities in Australia, on the other hand, are shifting away from renewable energy and low carbon strategies.

Countries from the region are increasingly collaborating with one another, as reflected by trends in international scientific co-authorship. For the less developed economies, co-authorship even accounts for 90–100% of output; the challenge for them will be to steer international scientific collaboration in the direction envisaged by national S&T policies.

A comparatively high share of R&D is performed by the business sector in four countries: Singapore, Australia, the Philippines and Malaysia. In the case of the latter two, this is most likely a product of the strong presence of multinational companies in these countries. Innovation performance is generally weak in the region, which produces 6.5% of the world's scientific publications (2013) but only 1.4% of global patents (2012); moreover, four countries accounted for 95% of those patents: Australia, Singapore, Malaysia and New Zealand. The challenge for economies such as Viet Nam and Cambodia will be to draw on the knowledge and skills embedded in the large foreign firms that they host, in order to develop the same level of professionalism among local suppliers and firms.

Since 2008, many countries have boosted their R&D effort, including in the business enterprise sector. In some cases, though, 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, especially since the onset of a cycle of declining prices for raw materials adds a sense of urgency to the task of developing innovation-driven growth policies.

CONCLUSION

An evolving public commitment to science and research

This latest edition of the *UNESCO Science Report* covers more countries and regions than ever before. This reflects the growing acceptance worldwide and, in particular, in the non-OECD world, of STI as a driver of development. At the same time, the statistical data on basic STI indicators remain patchy, especially in non-OECD countries. Nevertheless, there is a growing awareness of the need for reliable data to enable monitoring of national science and innovation systems and inform policy. This realization has given rise to the African Science and Technology Indicators Initiative, which has spawned an observatory based in Equatorial Guinea. A number of Arab economies are also establishing observatories of STI, including Egypt, Jordan, Lebanon, Palestine and Tunisia.

Another striking trend observed in the *UNESCO Science Report* is the decline in public commitment to R&D observed in many developed countries (Canada, UK, USA, etc), as opposed to a growing belief in the importance of public investment in R&D for knowledge creation and technology adoption in emerging and lower income countries. STI has, of course, been mainstreamed in many emerging economies for some time, including Brazil, China and the Republic of Korea. What we are seeing now is the adhesion of many middle- and low-income countries to this philosophy, with many incorporating STI in their 'vision' or other planning documents. Of course, these countries have benefited from much higher economic growth rates than OECD countries in recent years, so the jury is still out, to some extent, as to whether they will be able to pursue this public commitment in years of lower or even negative growth. Brazil and the Russian Federation will be test cases, as both have now entered recession following the end of a cyclical boom in raw materials.

However, as Chapter 2 highlights, it is not just the diverging public commitment to investment in R&D between the highly developed and emerging and middle-income world that is narrowing. While most R&D (and patenting) is taking place in high-income countries, innovation is occurring in countries across the full spectrum of income levels. Much innovation is occurring without any R&D activity at all; in the majority of countries surveyed by the UNESCO Institute for Statistics in 2013, innovation unrelated to R&D implicated more than 50% of firms. Policy-makers should take note of this phenomenon and, accordingly, focus not just on designing incentives for firms to engage in R&D. They also need to facilitate non-research-related innovation, particularly in relation to technology transfer, since the acquisition of machinery, equipment and software is generally the most important activity tied to innovation.

Innovation spreading but policy hard to get right

Formulating a successful national science and innovation policy remains a very difficult task. Reaping the full benefit from science- and innovation-driven economic development requires moving in the right direction in a number of different policy fields simultaneously, including those affecting education, basic science, technological development and its corollary of mainstreaming sustainable ('green') technologies, business R&D and economic framework conditions.

Many dilemmas appear increasingly common to a wide range of countries, such as that of trying to find a balance between local and international engagement in research, or between basic and applied science, the generation of new knowledge and marketable knowledge, or public good science versus science to drive commerce.

The current trend towards a greater orientation of STI policy towards industrial and commercial development is also having international ramifications. The *UNESCO Science Report 2010* anticipated that international diplomacy would increasingly take the form of science diplomacy. This prophecy has come true, as illustrated by the case studies from New Zealand (Box 27.1) and Switzerland (Box 11.3). However, in some cases, things have taken an unexpected turn. Some governments are showing a tendency to tie research partnerships and science diplomacy to trade and commercial opportunities. It is revealing that Canada's innovation network is now managed by the Trade Commissioner Service at the Department of Foreign Affairs, Trade and Development, for instance, rather than being placed in the foreign service; this megadepartment was created in 2013 by amalgamating the Canadian International Development Agency and the Department of Foreign Affairs and International Trade. Australia has taken a similar step by subsuming AusAID into the Department of Foreign Affairs and Trade and giving foreign aid an increasingly commercial focus.

The global economic boom between 2002 and 2007 seemed to have 'lifted all boats' on the wave of prosperity and focused policy attention and resource allocation on innovation in many emerging and developing countries. This period witnessed a proliferation of STI policies, long-term planning ('vision') documents and ambitious targets around the world. Since the crisis of 2008–2009, slow economic growth and the tightening of public budgets appear to have made the art of crafting and implementing successful science and innovation policies much more difficult. The pressure being exerted on public interest science in Australia, Canada and the USA illustrates one of the consequences of the tightening of public R&D budgets. The challenge for low- and middle-income countries, on the other hand, will be to ensure that policies are well-funded, that their implementation is monitored and evaluated and that the bodies responsible for implementing the policy co-ordinate their efforts and are held accountable.

Some countries have either been historically equipped with relatively strong higher education systems and a wide pool of scientists and engineers or have been making important strides in these directions recently. Despite this, they are not yet seeing a strong focus on R&D and innovation in the business sector for reasons ranging from the sectorial specialization of their economies to a poor or deteriorating business environment. To varying degrees, a diverse range of countries are experiencing this phenomenon, including Canada, Brazil, India, Iran, the Russian Federation, South Africa and Ukraine.

Other countries have made great strides in economic reform, industrial modernization and international competitiveness but still need to complement their push for public-sector driven R&D with significant qualitative improvements in the spheres of higher education and basic research, in order to take their business R&D beyond experimental development towards more genuine innovation. Again, a wide range of countries find themselves confronted with this challenge, including China, Malaysia and Turkey. For some, the challenge will be to orient an FDI-driven industrial competitiveness more towards endogenous research, as in the case of Malaysia. For others, the challenge will be to foster healthy collaboration between the different components of the public research system. The current reform of academies of sciences in China, the Russian Federation and Turkey illustrates the tensions that can arise when the autonomy of these institutions is called into question.

Open science and open education within 'closed' borders?

Another trend worth noting is the steep rise in the number of researchers, who now number 7.8 million worldwide. This represents an increase of 21% since 2007 (Table 1.3). This growth is also reflected in the explosion of scientific publications. The competition to publish in a limited number of high-impact journals has increased dramatically, as has the competition among scientists to secure jobs in the most reputed research institutions and universities. Moreover, these institutions are themselves increasingly competing with one another to attract the world's best talent.

The Internet has brought with it 'open science', paving the way to online international research collaboration, as well as open access to publications and underlying data. At the same time, there has been a global move in the direction of 'open education' with the widespread development and availability of online university courses (MOOCS) provided by new global university consortia (see p. 4). In short, the academic research and higher education system is internationalizing rapidly, with major implications for its traditional national organization and funding. The same is happening in the private sector, which 'potentially has a much bigger role to play than universities in spreading the "resource balance" in science and technology around the world' (Chapter 2). Increasingly, it is considered a must to have an international composition of research staff in both research and innovation. As the saying goes, Silicon Valley was built on IC, a reference not to integrated circuits but to the contribution of Indians and Chinese to this innovation hub's success.

The fly in the ointment is that cross-border flows of knowledge in the form of researchers, scientific co-authorship, invention co-ownership and research funding are also strongly dependent on factors that have little to do with science. These days, mercantilism characterizes much of national STI policy-making. All governments are keen to increase high-tech exports but few are prepared to discuss removing non-tariff barriers (such as government procurement) that may be constraining their imports. Everyone wishes to attract foreign R&D centres and skilled professionals (scientists, engineers, doctors, etc.) but few are prepared to discuss frameworks for facilitating cross-border movement (in both directions). The EU's decision to adopt 'scientific visas' as of 2016 within its Innovation Union to facilitate the cross-border movement of specialists is one attempt to remove some of these barriers.

Import substitution has exerted a strong influence on development policy in recent decades. Today, there is a growing debate as to the merits of protectionist industrial policies. The authors of the chapter on Brazil (Chapter 8), for instance, argue that import substitution policies have removed the incentive for endogenous enterprises to innovate, since they do not have to compete internationally.

Good governance is good for science

Good governance accompanies progress at each stage of the innovation-driven development process. Absence of corruption in the university system is essential to ensure that institutions are producing qualified graduates. At the other end of the innovation cycle, a highly corrupt business environment is a strong disincentive for the emergence of innovation-driven competition. For instance, companies will have little incentive to invest in R&D, if they cannot rely on the justice system to defend their intellectual property. Scientific fraud is also more likely to occur in environments characterized by poor governance standards.

The *UNESCO Science Report* highlights numerous examples where countries have recognized the need for better governance to foster endogenous science and innovation. With exemplary frankness, Uzbekistan's Committee for Coordination of Science and Technology Development has identified 'strengthening the rule of law' as one of the country's eight priorities for boosting R&D to 2020 (Chapter 14). Southeast Europe's own *2020 Strategy* identifies 'effective public services, anti-corruption and justice' as being one of the five pillars of the region's new growth strategy. In neighbouring Moldova, 13% of the 2012 state programme for R&D has been allocated to the 'consolidation of the rule of law and utilization of cultural heritage in the perspective of European integration.' The chapter on the Arab States places considerable emphasis on the need to improve governance, transparency, the rule of law and the fight against corruption to reap greater benefits from investment in science and technology, together with 'enhancing reward for initiative and drive' and developing 'a healthy climate for business.' Last but not least, the chapters on Latin America and Southern Africa highlight the strong link between government effectiveness and scientific productivity.

The consequences for science of the 'resource curse'

Resource extraction can allow a country to accumulate significant wealth but long-term, sustained economic growth is seldom driven by reliance on natural resources. A number of countries appear to be failing to seize the opportunity offered by resource-driven growth to strengthen the foundations of their economies. It is tempting to infer from this that, in countries awash with natural resources, high-growth from resource extraction provides a disincentive for the business sector to focus on innovation and sustainable development.

The end of the latest commodities boom, coupled with the collapse in global oil prices since 2014, has underscored the vulnerability of national innovation systems in a wide range of resource-rich countries that are currently struggling to remain competitive: Canada (Chapter 4), Australia (Chapter 27), Brazil (Chapter 8), the oil-exporting Arab States (Chapter 17), Azerbaijan (Chapter 12), Central Asia (Chapter 14) and the Russian Federation (Chapter 13). Other countries with a traditionally heavy reliance on commodity exports for their economic expansion have been making more decisive efforts to prioritize knowledge-driven development, as illustrated by the chapters on Iran (Chapter 15) and Malaysia (Chapter 26).

Under normal circumstances, resource-rich countries can afford the luxury of importing the technologies they need for as long as the bonanza lasts (Gulf States, Brazil, etc.). In exceptional cases where resource-rich countries are faced with an embargo on technology, they tend to opt for import substitution strategies. For instance, since mid-2014, the Russian Federation (Chapter 13) has broadened its import substitution programmes in response to trade sanctions that are affecting imports of key technologies. The case of Iran (Chapter 15) illustrates how a long-running trade embargo can incite a country to invest in endogenous technological development.

It is worth noting that several oil-rent economies expressed interest in developing renewable energy *before* global oil prices began falling in mid-2014, including Algeria, Gabon, the United Arab Emirates and Saudi Arabia. The *UNESCO Science Report 2010* had observed a paradigm shift towards green growth. It is evident from the current report that this trend has since accelerated and is seducing an ever-greater number of countries, even if levels of public investment may not always be commensurate with ambitions.

The emphasis is often on developing coping strategies to protect agriculture, reduce disaster risk and/or diversify the national energy mix, in order to ensure long-term food, water and energy security. Countries are also becoming increasingly aware of the value of their natural capital, as illustrated by the recommendation in the *Gaborone Declaration on Sustainability* (2012) for African countries to integrate the value of natural capital into national accounting and corporate planning. Among high-income economies (EU, Republic of Korea, Japan, etc), a firm commitment to sustainable development is often coupled with the desire to maintain competitiveness in global markets that are increasingly leaning towards green technologies; global investment in renewable energy technologies increased by 16% in 2014, triggered by an 80% decrease in the manufacturing costs of solar energy systems. It is to be expected that the trend towards green growth will accentuate, as countries strive to implement the new Sustainable Development Goals.

Looking ahead: *Agenda 2030*

On 25 September 2015, the United Nations adopted the *2030 Agenda for Sustainable Development.* This ambitious new phase transitions from the Millennium Development Goals (2000–2015) to a new set of integrated Sustainable Development Goals (2015–2030). The new agenda is universal and, thus, applies to developing and developed countries alike. It comprises no fewer than 17 goals and 169 targets. Progress towards these goals over the next 15 years will need to be informed by evidence, which is why a series of indicators will be identified by March 2016 to help countries monitor their progress towards each target. The goals balance the three economic, environmental and social pillars of sustainable development, while embracing other pillars of the United Nations' mission related to human rights, peace and security. STI is woven into the fabric of *Agenda 2030*, since it will be essential for achieving many of these goals.

Although the Sustainable Development Goals have been adopted by governments, it is evident that they will only be reached if all stakeholder groups take ownership of them. The scientific community is already on board. As we have seen from the *UNESCO Science Report: towards 2030*, the focus of scientific discovery has shifted towards problem-solving, in order to tackle pressing developmental challenges.

This shift in research priorities is evident in the amount of research funds currently being allocated to applied science (see p. 6). In parallel, both governments and businesses are increasingly investing in the development of 'green technologies' and 'green cities'. At the same time, we should not forget that 'basic science and applied science are two sides of the same coin,' as recalled by the Scientific Advisory Board to the Secretary General of the United Nations (see p. 9). They are 'interconnected and interdependent [and], thus, complement each other in providing innovative solutions to the challenges humanity faces on the pathway to sustainable development.' An adequate investment in both basic sciences and applied research and development will be critical to reaching the goals of *Agenda 2030.*

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