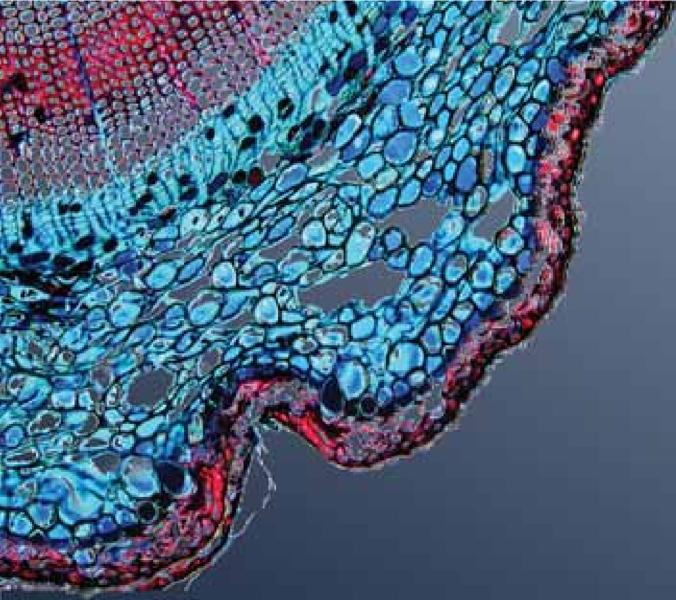
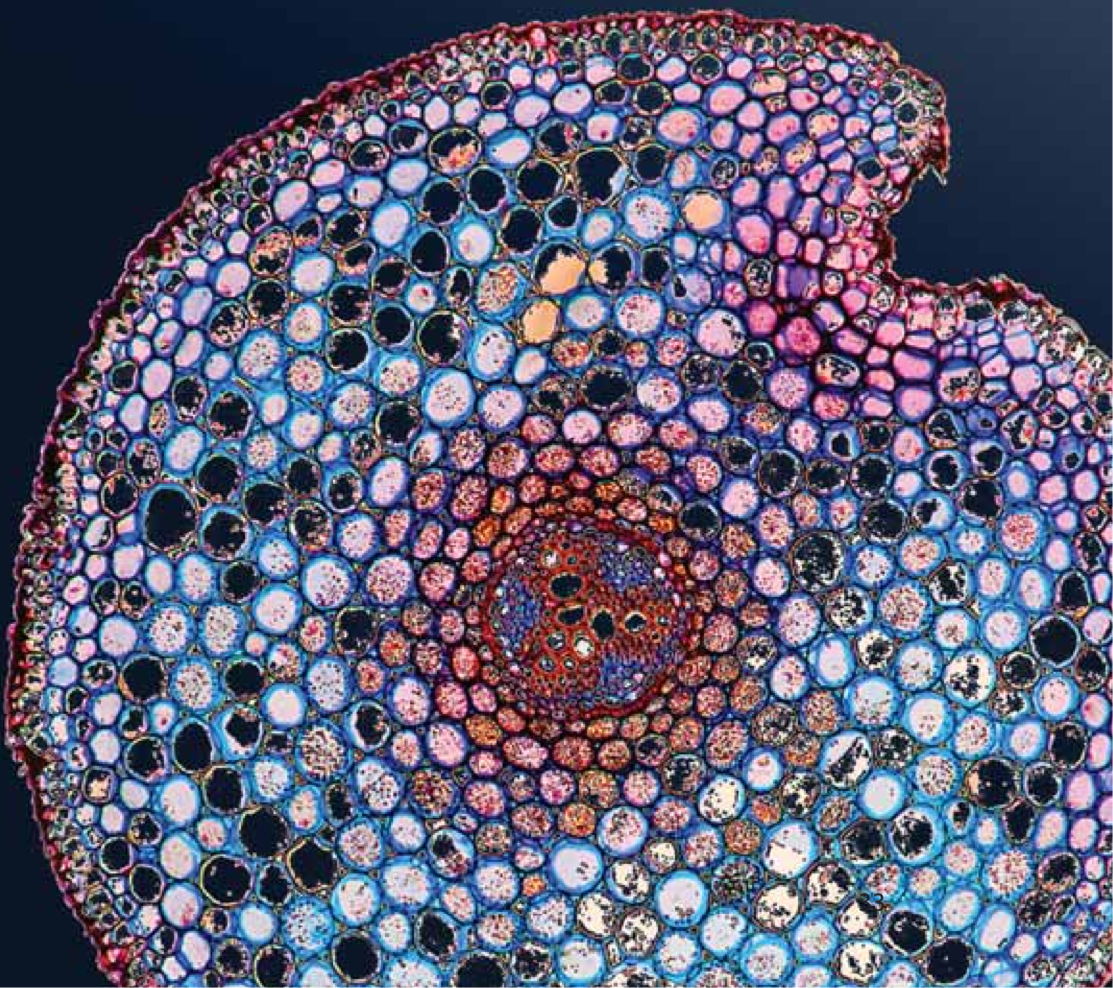


UNESCO SCIENCE REPORT 2010

The Current Status of Science around the World

Executive Summary



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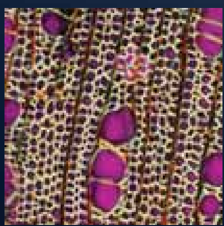

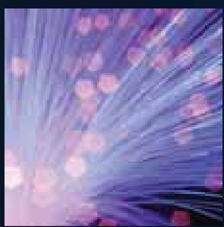

The *UNESCO Science Report 2010* has been produced by the following team within the Division for Science Policy and Sustainable Development at UNESCO:

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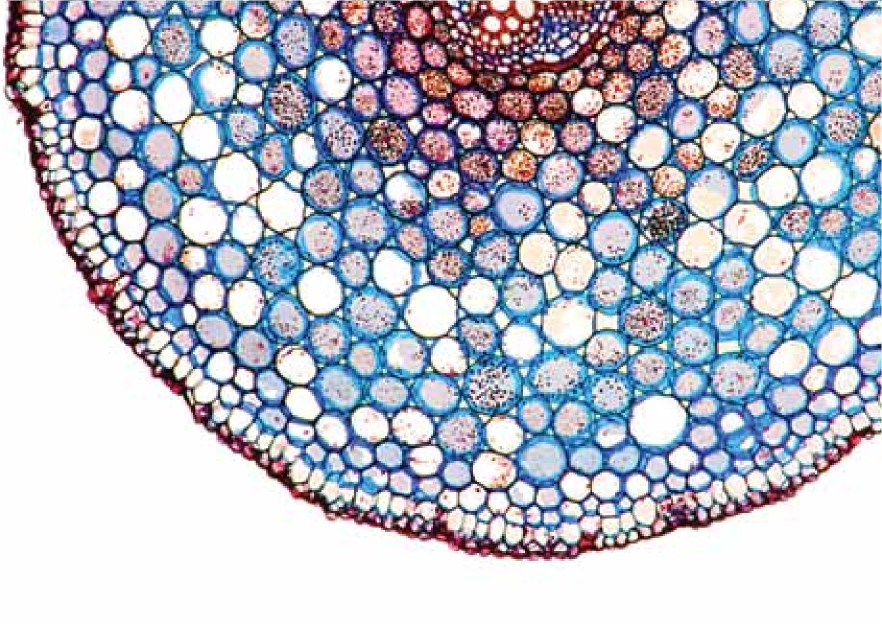
The report is heavily reliant on the expertise of the authors invited to write about the main trends and developments in scientific research, innovation and higher education in the country or region from which they hail. We would thus like to take this opportunity to thank each of the 35 authors for their commitment to making this an authoritative report.

SC–2010/WS/25 Rev

UNESCO SCIENCE REPORT 2010



This Executive Summary is drawn from the first chapter of the *UNESCO Science Report 2010*. It has been printed as a supplement in Arabic, Chinese, English, French, Russian and Spanish.

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Policies for science and technology must always be a mixture of realism and idealism.

Chris Freeman (1921–2010)
father of the 'national innovation system' concept

1 · The growing role of knowledge in the global economy

Hugo Hollanders and Luc Soete

THE GLOBAL PICTURE

The *UNESCO Science Report 2010* takes up from where its predecessor left off five years ago. The aim of this first chapter is to provide a global overview of developments over the past five years. We shall pay particular attention to 'new', 'less known', or 'unexpected' features revealed by the data and the chapters that follow.

We shall begin by briefly reviewing the state of the support system for science against the backdrop of the long, historically unique period of rapid global economic growth from 1996 to 2007. This 'growth spurt' has been driven by new digital technologies and by the emergence of a number of large countries on the world stage. It was brought to a sudden and somewhat brutal halt by the global economic recession triggered by the sub-prime mortgage crisis in the USA in the third quarter of 2008. What impact has this global economic recession had on investment in knowledge? Before we endeavour to answer this question, let us take a closer look at some of the broad trends that have characterized the past decade.

First and foremost, cheap and easy access to new digital technologies such as broadband, Internet and mobile phones have accelerated the diffusion of best-practice technologies, revolutionized the internal and external organization of research and facilitated the implantation abroad of companies' research and development (R&D) centres (David and Foray, 2002). However, it is not only the spread of digital information and communication technologies (ICTs) that has shifted the balance in favour of a more transparent and more level playing field[1]. The growing membership and further development of global institutional frameworks like the World Trade Organization (WTO) governing international knowledge flows in trade, investment and intellectual property rights have also sped up access to critical knowledge. China, for example, only became a member of WTO in December 2001. The playing field now includes a wide variety of capital- and organization-embedded forms of technology transfer which include foreign direct investment (FDI), licenses and other forms of formal and informal knowledge diffusion.

Secondly, countries have been catching up rapidly in terms of both economic growth and investment in knowledge, as expressed by investment in tertiary education and R&D. This can be observed in the burgeoning number of graduates in science and engineering. India, for example, has opted to establish 30 new universities to raise student enrollment from less than 15 million in 2007 to 21 million by 2012. Large emerging developing countries such as Brazil, China, India, Mexico and South Africa are also spending more on R&D than before. This trend can also be observed in the transition economies of the Russian Federation (Russia) and some other Eastern and Central European countries which are gradually climbing back to the levels of investment under the Soviet Union. In some cases, the rise in gross domestic expenditure on R&D (GERD) has been a corollary of strong economic growth rather than the reflection of greater R&D intensity. In Brazil and India, for example, the GERD/GDP ratio has remained stable, whereas in China it has climbed by 50% since 2002 to 1.54% (2008). Similarly, if the GERD/GDP ratio has declined in some African countries, this is not symptomatic of a weaker commitment to R&D. It simply reflects an acceleration in economic growth thanks to oil extraction (in Angola, Equatorial Guinea, Nigeria, etc) and other non-R&D-intensive sectors. If each country has different priorities, the urge to catch up rapidly is irrepressible and has, in turn, driven economic growth worldwide to the highest level in recorded history.

Thirdly, the impact of the global recession on a post-2008 world is not yet reflected in the R&D data but it is evident that the recession has, for the first time, challenged the old North–South technology-based trade and growth models (Krugman, 1970; Soete, 1981; Dosi *et al*., 1990). Increasingly, the global economic recession appears to be challenging Western scientific and technological (S&T) dominance. Whereas Europe and the USA are struggling to free themselves from the grips of the recession, firms from emerging economies like Brazil, China, India and South Africa are witnessing sustained domestic growth and moving upstream in the value chain. Whereas these emerging economies once served as a repository for the outsourcing of manufacturing activities, they have now moved on to autonomous process technology development, product development, design and applied research. China, India and a few other Asian countries, together with some Arab Gulf states, have combined a national targeted technology policy with the aggressive – and successful – pursuit of better academic research within a short space of time. To this end, they have made astute use of both monetary and non-monetary incentives, as well as

1. This does not mean that each player has an equal chance of success but rather that a greater number are playing by the same set of rules.

The Earth at night, showing human population centres

Photo: © Evirgen/ iStockphoto

institutional reforms. Although data are not easy to come by, it is well-known that many academic leaders in American, Australian and European universities have, in the past five years, been offered positions and large research budgets in fast-growing universities in East Asian countries.

In short, achieving knowledge-intensive growth is no longer the sole prerogative of the highly developed nations of the Organisation for Economic Co-operation and Development (OECD). Nor is it the sole prerogative of national policy-making. Value creation depends increasingly on a better use of knowledge, whatever the level of development, whatever its form and whatever its origin: new product and process technologies developed domestically, or the re-use and novel combination of knowledge developed elsewhere. This applies to manufacturing, agriculture and services in both the public and private sectors. Yet, at the same time, there is striking evidence of the persistence – expansion even – in the uneven distribution of research and innovation at the global level. Here, we are no longer comparing countries but regions within countries. Investment in R&D appears to remain concentrated in a relatively small number of locations within a given country[2]. In Brazil, for example, 40% of GERD is spent in the São Paulo region. The proportion is as high as 51% in South Africa's Gauteng Province.

PRE-RECESSION FACTS AND FIGURES

Economic trends: a unique growth spurt

Historically, global economic growth in the years bridging the Millennia has been unique. Over the period 1996–2007, real GDP per capita increased at an average annual rate of 1.88%[3]. At the broad continental level, the highest per-capita growth was witnessed by East Asia and the Pacific (5.85%), Europe and Central Asia (4.87%) and South Asia (4.61%). The figure was 2.42% for the Middle East and North Africa, 2.00% for North America, 1.80% for Latin American and the Caribbean and 1.64% for sub-Saharan Africa. The greatest divergence in growth rates occurred in sub-Saharan Africa: in 28 countries, GDP per capita grew by more than 5% but more than half of the 16 countries which witnessed negative per-capita growth rates were also in sub-Saharan Africa (Table 1).

2. For a more detailed analysis of specialization at the regional level within countries, see the *World Knowledge Report* (forthcoming) published by UNU-Merit.

3. Growth rates reported in this section reflect the average annual increase between 1996 and 2007 of per capita GDP in constant US$ 2 000 from World Bank data.

Table 1: Key indicators on world GDP, population and GERD, 2002 and 2007

	GDP (PPP$ billions)	
	2002	2007
World	**46 272.6**	**66 293.7**
Developed countries	29 341.1	38 557.1
Developing countries	16 364.4	26 810.1
Least developed countries	567.1	926.4
Americas	**15 156.8**	**20 730.9**
North America	11 415.7	15 090.4
Latin America and the Caribbean	3 741.2	5 640.5
Europe	**14 403.4**	**19 194.9**
European Union	11 703.6	14 905.7
Commonwealth of Independent States in Europe	1 544.8	2 546.8
Central, Eastern and Other Europe	1 155.0	1 742.4
Africa	**1 674.0**	**2 552.6**
South Africa	323.8	467.8
Other sub-Saharan countries (excl. South Africa)	639.6	1 023.1
Arab States in Africa	710.6	1 061.7
Asia	**14 345.3**	**22 878.9**
Japan	3 417.2	4 297.5
China	3 663.5	7 103.4
Israel	154.6	192.4
India	1 756.4	3 099.8
Commonwealth of Independent States in Asia	204.7	396.4
Newly Industrialised Economies in Asia	2 769.9	4 063.1
Arab States in Asia	847.3	1 325.1
Other in Asia (excl. Japan, China, Israel, India)	1 531.5	2 401.1
Oceania	**693.1**	**936.4**
Other groupings		
Arab States all	1 557.9	2 386.8
Commonwealth of Independent States all	1 749.5	2 943.2
OECD	29 771.3	39 019.4
European Free Trade Association	424.5	580.5
Sub-Saharan Africa (incl. South Africa)	963.4	1 490.9
Selected countries		
Argentina	298.1	523.4
Brazil	1 322.5	1 842.9
Canada	937.8	1 270.1
Cuba	–	–
Egypt	273.7	404.1
France	1 711.2	2 071.8
Germany	2 275.4	2 846.9
Iran (Islamic Republic of)	503.7	778.8
Mexico	956.3	1 493.2
Republic of Korea	936.0	1 287.7
Russian Federation	1 278.9	2 095.3
Turkey	572.1	938.7
United Kingdom	1 713.7	2 134.0
United States of America	10 417.6	13 741.6

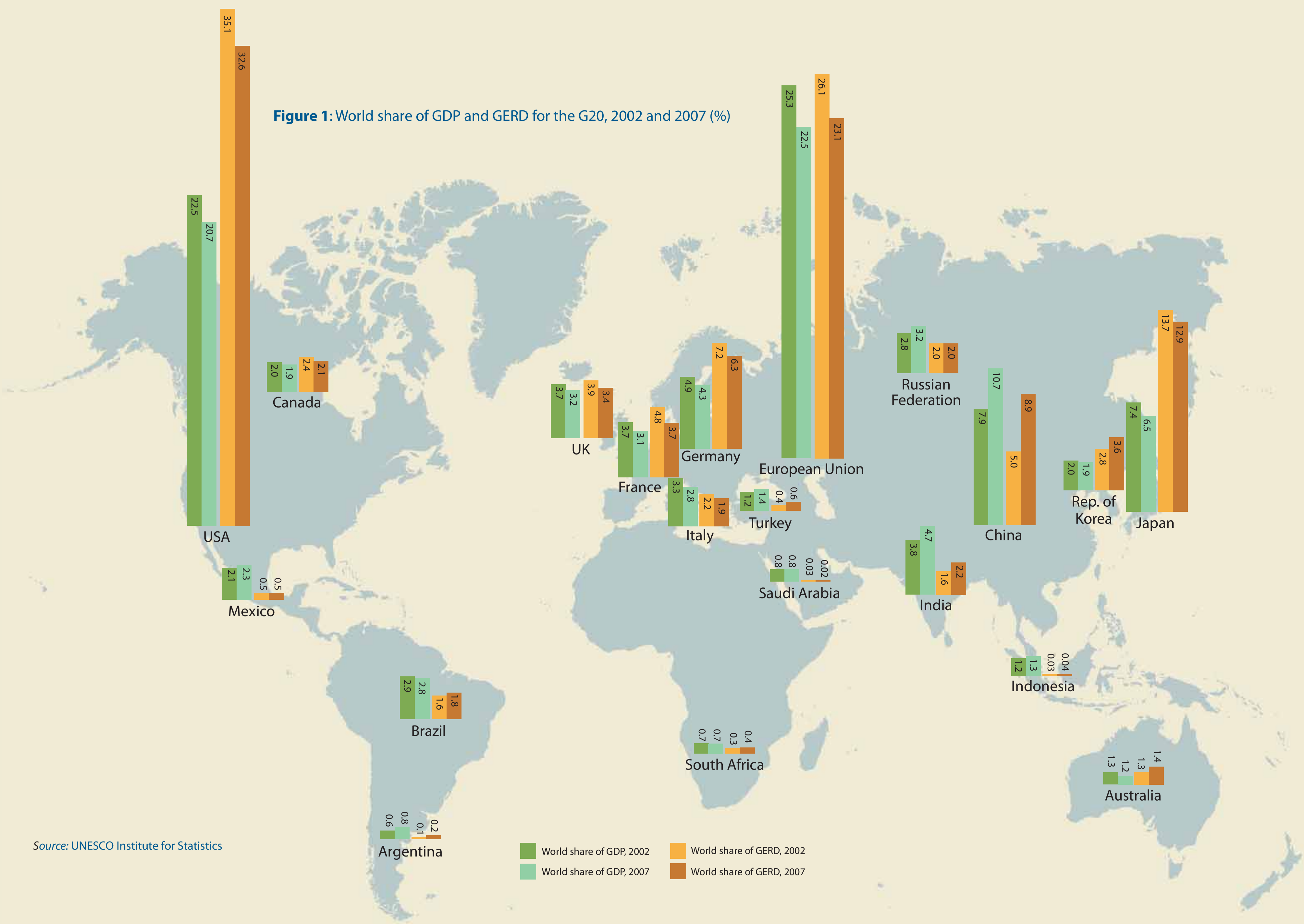
Note: The sum of GERD for some regions does not correspond to the total because of changes in the reference year. Furthermore, in numerous developing countries, data do not cover all sectors of the economy. Therefore, the data presented here for developing countries can be considered a lower bound of their real R&D effort. For the list of countries encompassed by the groupings in this chapter, see Annex I.

World GDP (%)		Population (millions)		World population (%)		GERD (PPP$ billions)		World GERD (%)		GERD as % of GDP		GERD per capita (PPP$)	
2002	2007	2002	2007	2002	2007	2002	2007	2002	2007	2002	2007	2002	2007
100.0	**100.0**	**6 274.3**	**6 670.8**	**100.0**	**100.0**	**790.3**	**1 145.7**	**100.0**	**100.0**	**1.7**	**1.7**	**126.0**	**171.7**
63.4	58.2	1 203.4	1 225.0	19.2	18.4	653.0	873.2	82.6	76.2	2.2	2.3	542.7	712.8
35.4	40.4	4 360.5	4 647.3	69.5	69.7	136.2	271.0	17.2	23.7	0.8	1.0	31.2	58.3
1.2	1.4	710.4	798.5	11.3	12.0	1.1	1.5	0.1	0.1	0.2	0.2	1.5	1.9
32.8	**31.3**	**861.2**	**911.4**	**13.7**	**13.7**	**319.9**	**433.9**	**40.5**	**37.9**	**2.1**	**2.1**	**371.4**	**476.1**
24.7	22.8	325.3	341.6	5.2	5.1	297.8	399.3	37.7	34.9	2.6	2.6	915.3	1 168.8
8.1	8.5	535.9	569.8	8.5	8.5	22.1	34.6	2.8	3.0	0.6	0.6	41.2	60.8
31.1	**29.0**	**796.5**	**804.8**	**12.7**	**12.1**	**238.5**	**314.0**	**30.2**	**27.4**	**1.7**	**1.6**	**299.4**	**390.2**
25.3	22.5	484.2	493.2	7.7	7.4	206.2	264.9	26.1	23.1	1.8	1.8	425.8	537.0
3.3	3.8	207.3	201.6	3.3	3.0	18.3	27.4	2.3	2.4	1.2	1.1	88.5	136.1
2.5	2.6	105.0	109.9	1.7	1.6	13.9	21.7	1.8	1.9	1.2	1.2	132.6	197.2
3.6	**3.9**	**858.9**	**964.7**	**13.7**	**14.5**	**6.9**	**10.2**	**0.9**	**0.9**	**0.4**	**0.4**	**8.0**	**10.6**
0.7	0.7	46.2	49.2	0.7	0.7	2.3^{-1}	4.4	0.3^{e}	0.4	0.7^{-1}	0.9	49.5^{-1}	88.6
1.4	1.5	623.5	709.2	9.9	10.6	1.8	2.6	0.2	0.2	0.3	0.3	2.9	3.7
1.5	1.6	189.3	206.3	3.0	3.1	2.5	3.3	0.3	0.3	0.4	0.3	13.4	15.9
31.0	**34.5**	**3 725.6**	**3 955.5**	**59.4**	**59.3**	**213.9**	**369.3**	**27.1**	**32.2**	**1.5**	**1.6**	**57.4**	**93.4**
7.4	6.5	127.1	127.4	2.0	1.9	108.2	147.9	13.7	12.9	3.2	3.4	851.0	1 161.3
7.9	10.7	1 286.0	1 329.1	20.5	19.9	39.2	102.4	5.0	8.9	1.1	1.4	30.5	77.1
0.3	0.3	6.3	6.9	0.1	0.1	7.1	9.2	0.9	0.8	4.6	4.8	1 121.4	1 321.3
3.8	4.7	1 078.1	1 164.7	17.2	17.5	12.9	24.8	1.6	2.2	0.7	0.8	12.0	21.3
0.4	0.6	72.3	75.4	1.2	1.1	0.5	0.8	0.1	0.1	0.2	0.2	7.0	10.2
6.0	6.1	373.7	399.3	6.0	6.0	40.1	72.3	5.1	6.3	1.4	1.8	107.3	181.1
1.8	2.0	107.0	122.9	1.7	1.8	1.1	1.4	0.1	0.1	0.1	0.1	10.0	11.8
3.3	3.6	675.0	729.7	10.8	10.9	4.8	10.4	0.6	0.9	0.3	0.4	7.1	14.3
1.5	**1.4**	**32.1**	**34.5**	**0.5**	**0.5**	**11.2**	**18.3**	**1.4**	**1.6**	**1.6**	**1.9**	**349.9**	**529.7**
3.4	3.6	296.3	329.2	4.7	4.9	3.6	4.7	0.5	0.4	0.2	0.2	12.2	14.3
3.8	4.4	279.6	277.0	4.5	4.2	18.9	28.2	2.4	2.5	1.1	1.0	67.4	101.9
64.3	58.9	1 149.6	1 189.0	18.3	17.8	661.3	894.7	83.7	78.1	2.2	2.3	575.2	752.5
0.9	0.9	12.1	12.6	0.2	0.2	9.8	13.6	1.2	1.2	2.3	2.3	804.5	1 082.8
2.1	2.2	669.7	758.4	10.7	11.4	4.3	7.0	0.5	0.6	0.4	0.5	6.4	9.2
0.6	0.8	37.7	39.5	0.6	0.6	1.2	2.7	0.1	0.2	0.4	0.5	30.8	67.3
2.9	2.8	179.1	190.1	2.9	2.9	13.0	20.2	1.6	1.8	1.0	1.1	72.7	106.4
2.0	1.9	31.3	32.9	0.5	0.5	19.1	24.1	2.4	2.1	2.0	1.9	611.4	732.3
–	–	11.1	11.2	0.2	0.2	–	–	–	–	0.5	0.4	–	–
0.6	0.6	72.9	80.1	1.2	1.2	0.5^{-2}	0.9	0.1^{e}	0.1	0.2^{-2}	0.2	6.8^{-2}	11.4
3.7	3.1	59.8	61.7	1.0	0.9	38.2	42.3	4.8	3.7	2.2	2.0	637.7	685.5
4.9	4.3	82.2	82.3	1.3	1.2	56.7	72.2	7.2	6.3	2.5	2.5	689.0	877.3
1.1	1.2	68.5	72.4	1.1	1.1	2.8	4.7^{-1}	0.3	0.5^{e}	0.5	0.7^{-1}	40.3	65.6^{-1}
2.1	2.3	102.0	107.5	1.6	1.6	4.2	5.6	0.5	0.5	0.4	0.4	40.9	52.1
2.0	1.9	46.9	48.0	0.7	0.7	22.5	41.3	2.8	3.6	2.4	3.2	479.4	861.9
2.8	3.2	145.3	141.9	2.3	2.1	15.9	23.5	2.0	2.0	1.2	1.1	109.7	165.4
1.2	1.4	68.4	73.0	1.1	1.1	3.0	6.8	0.4	0.6	0.5	0.7	44.0	92.9
3.7	3.2	59.4	60.9	0.9	0.9	30.6	38.7	3.9	3.4	1.8	1.8	515.8	636.1
22.5	20.7	294.0	308.7	4.7	4.6	277.1	373.1	35.1	32.6	2.7	2.7	942.4	1 208.7

-*n* = data refer to *n* years before reference year
e = UNESCO Institute for Statistics estimation based on extrapolations and interpolations

Source: for GERD: UNESCO Institute for Statistics estimations, June 2010; For GDP and PPP conversion factor: World Bank, World Development Indicators, May 2010, and UNESCO Institute for Statistics estimations; for population: United Nations Department of Economic and Social Affairs (2009) *World Population Prospects*: *the 2008 Revision*, and UNESCO Institute for Statistics estimations

Figure 1: World share of GDP and GERD for the G20, 2002 and 2007 (%)



Source: UNESCO Institute for Statistics

Figure 1 presents the 20 largest economic powers in the world. This list includes the Triad[4] and the newly industrializing countries of Mexico and the Republic of Korea, some of the most populated countries in the world such as China, India, Brazil, Russia and Indonesia, and a second layer of emerging economies that include Turkey, Saudi Arabia, Argentina and South Africa. With their newfound economic weight, these countries are challenging many of the rules, regulations and standards that governed the G7 and the Triad with respect to international trade and investment[5]. As we shall now see, they are also challenging the traditional dominance of the Triad when it comes to investment in R&D.

Trends in GERD: a shift in global influence

The world devoted 1.7% of GDP to R&D in 2007, a share that has remained stable since 2002. In monetary terms, however, this translates into US$ 1 146 billion[6], an increase of 45% over 2002 (Table 1). This is slightly higher than the rise in GDP over the same period (43%).

Moreover, behind this increase lies a shift in global influence. Driven largely by China, India and the Republic of Korea, Asia's world share has risen from 27% to 32%, to the detriment of the Triad. Most of the drop in the European Union (EU) can be attributed to its three biggest members: France, Germany and the United Kingdom (UK). Meanwhile, the shares of Africa and the Arab States are low but stable and Oceania has progressed slightly.

We can see from Figure 1 that China's share of world GERD is approaching its world share of GDP, unlike Brazil or India which still contribute much more to global GDP than to global GERD. Of note is that the situation is reversed for the Triad, even though the disparity is very small for the EU. The Republic of Korea is an interesting case in point, in that it follows the pattern of the Triad. Korea's world share of GERD is even double its world share of GDP. One of Korea's top priorities is to raise its GERD/GDP ratio to as much as 5% by 2012.

4. Composed of the European Union, Japan and USA

5. The great majority of the standards governing, for instance, trade in manufactured goods, agriculture and services are based on USA–EU norms.

6. All US$ in the present chapter are purchasing power parity dollars.

Figure 2 correlates the density of both R&D and researchers for a number of key countries and regions. From this figure, we can see that Russia still has a much greater number of researchers than financial resources in its R&D system. Three large newcomers can be seen emerging in the bottom left-hand side of the picture, namely China, Brazil and India, together with Iran and Turkey. Even Africa, as a continent, today represents a sizeable contributor to the global R&D effort. The R&D intensity of these economies or their human capital might still be low but their contribution to the stock of world knowledge is actually rising rapidly. By contrast, the group of least developed countries – the smallest circle in the figure – still plays a marginal role.

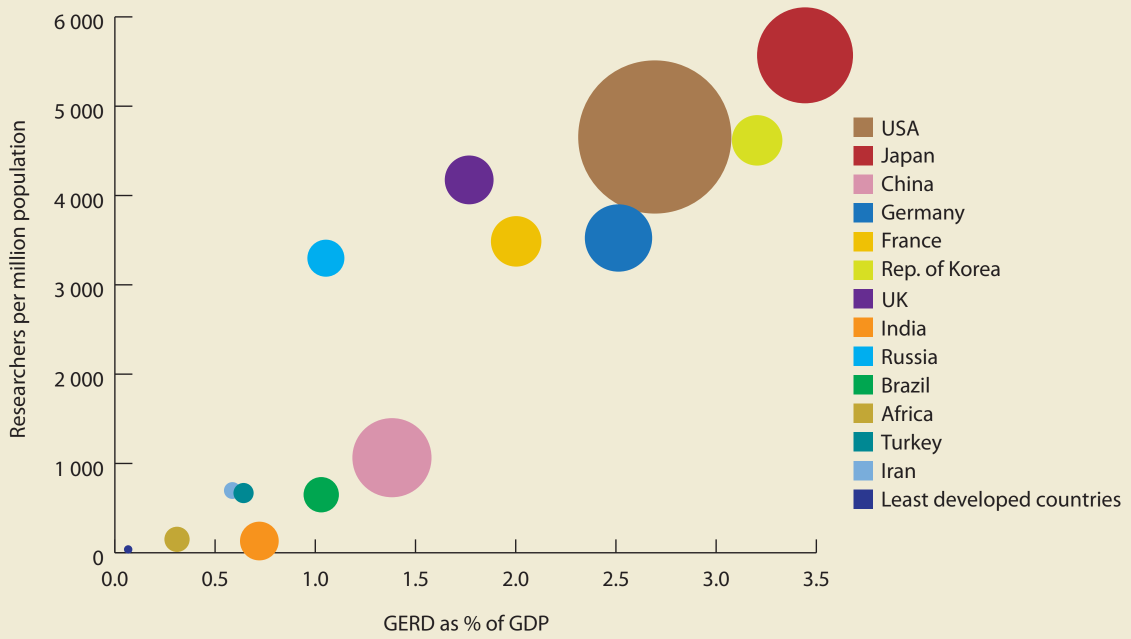
Catching up in business R&D

It is the trends in business investment in R&D (BERD) which best illustrate the rapid geographical changes taking place worldwide in privately funded R&D centres. Increasingly, multinational companies are decentralizing their research activities to parts of both the developed and developing worlds within a strategy to internalize R&D at the global level (Zanatta and Queiroz, 2007). For multinationals, this strategy reduces labour costs and gives companies easier access to markets, local human capital and knowledge, as well as to the host country's natural resources.

The favoured destinations are the so-called Asian 'tigers', the 'old' newly industrialized countries in Asia, and, secondly, Brazil, India and China. However, this is no longer a one-way traffic: firms from emerging economies are now also buying up large firms in developed countries and thereby acquiring the firms' knowledge capital overnight, as the chapter on India neatly illustrates. As a consequence, the global distribution of R&D effort between North and South is shifting rapidly. In 1990, more than 95% of R&D was being carried out in the developed world and just seven OECD economies accounted for more than 92% of world R&D (Coe *et al.,* 1997). By 2002, developed countries accounted for less than 83% of the total and by 2007 for 76%. Furthermore, as the chapters on South Asia and sub-Saharan Africa underscore, a number of countries not generally considered to be R&D-intensive are developing particular sectors like light engineering as a strategy for import substitution, among them Bangladesh.

From 2002 to 2007, the share of BERD in GDP rose sharply in Japan, China and Singapore, with a particularly steep curve in the Republic of Korea. The ratio remained more or

Figure 2: Global investment in R&D in absolute and relative terms, 2007
For selected countries and regions



Note: The size of the circle reflects the size of GERD for the country or grouping.

Source: UNU–MERIT based on data from the UNESCO Institute for Statistics and World Bank

less constant in Brazil, the USA and the EU and even declined in Russia. As a result, by 2007, the Republic of Korea was challenging Japan for the title of technological leader, Singapore had nearly caught up to the USA and China was rubbing shoulders with the EU. Notwithstanding this, the BERD/GDP ratio still remains much lower in India and Brazil than in the Triad.

Trends in human capital: China soon to count the most researchers

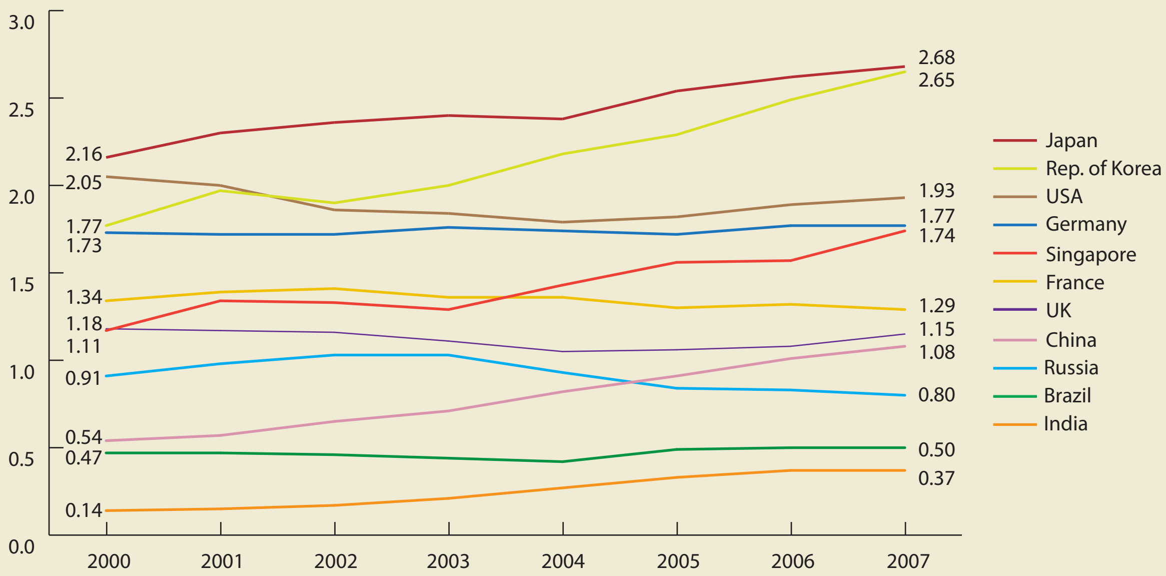
Here, we focus on another core area of R&D input: trends with regard to researchers. As Table 2 highlights, China is on the verge of overtaking both the USA and the EU in terms of sheer numbers of researchers. These three giants each represent about 20% of the world's stock of researchers. If we add Japan's share (10%) and that of Russia (7%), this highlights the extreme concentration of researchers: the 'Big Five' account for about 35% of the world population but three-quarters of all researchers. By contrast, a populous country like India still represents only 2.2% of the world total and the entire continents of Latin America and Africa just 3.5% and 2.2% respectively.

Although the share of researchers in the developing world has grown from 30% in 2002 to 38% in 2007, two-thirds of this growth can be attributed to China alone. Countries are training many more scientists and engineers than before but graduates are having trouble finding qualified positions or attractive working conditions at home. As a result, migration of highly qualified researchers from South to North has become the characteristic feature of the past decade. A 2008 report by the UK Parliamentary Office cited OECD data indicating that, of the 59 million migrants living in OECD countries, 20 million were highly skilled.

Brain drain preoccupies developing countries

Despite voluminous literature on migration, it is almost impossible to draw a systematic, quantitative picture of long-term migration of the highly skilled worldwide. Moreover, not everyone perceives the phenomenon in the same way. Some refer to brain drain, others prefer the term brain strain or brain circulation. Whatever the preferred terminology, several chapters in the present report – among them those on India, South Asia, Turkey and sub-Saharan Africa – highlight the serious issue that brain drain

Figure 3: BERD/GDP ratio for selected countries, 2000–2007 (%)



Source: UNU-MERIT based on data from UNESCO Institute for Statistics

has become and the barriers that this flow of knowledge out of countries creates for domestic R&D. For instance, a national survey by the Sri Lankan National Science Foundation found that the number of economically active scientists in Sri Lanka had dropped from 13 286 to 7 907 between 1996 and 2006. Meanwhile, FDI flowing into India is creating internal brain drain, as domestic firms cannot compete with the attractive compensation packages offered to personnel by foreign firms based in India.

South–South and South–North migration data are not systematically covered by international statistical institutes but can be approximated by combining OECD data on migration of the highly skilled with UNESCO data on bilateral flows of international students (Dunnewijk, 2008). These data reveal that South to North and North to North are dominant directions for migration but that, overall, a much more varied array of destinations is emerging: South Africa, Russia, Ukraine, Malaysia and Jordan have also become attractive destinations for the highly skilled. The diaspora that has settled in South Africa originated from Zimbabwe, Botswana, Namibia and Lesotho; in Russia, from Kazakhstan, Ukraine and Belarus; in Ukraine, from Brunei Darussalam; in the former Czechoslovakia from Iran; in Malaysia from China and India; in Romania from Moldova; in Jordan from the Palestinian Autonomous Territories; in Tajikistan from Uzbekistan; and in Bulgaria from Greece.

A second factor is that the diaspora acts as a useful departure point for the design of policies for more effective technology transfer and knowledge spillovers. This phenomenon motivates countries to elaborate policies to lure highly skilled expatriates back home. This was the case in the Republic of Korea in the past and can be seen in China and elsewhere today. The aim is to encourage the diaspora to use the skills acquired abroad to bring about structural change at home. Moreover, the diaspora may be invited to participate 'from a distance', if the prospect of a permanent return home is unlikely. In Nigeria, Parliament approved the establishment of the Nigerians in the Diaspora Commission in 2010, the aim of which is to identify Nigerian specialists living abroad and encourage them to participate in Nigerian policy and project formulation.

Trends in publications: a new Triad dominates

The number of scientific publications recorded in Thomson Reuters' Science Citation Index (SCI) is the most commonly used indicator for scientific output. It is particularly valuable, in that it allows both for international comparisons at the aggregate level and for

Table 2: Key indicators on world researchers, 2002 and 2007

	Researchers (thousands)		World share of researchers (%)		Researchers per million inhabitants		GERD per researcher (PPP$ thousands)	
	2002	2007	2002	2007	2002	2007	2002	2007
World	**5 810.7**	**7 209.7**	**100.0**	**100.0**	**926.1**	**1 080.8**	**136.0**	**158.9**
Developed countries	4 047.5	4 478.3	69.7	62.1	3 363.5	3 655.8	161.3	195.0
Developing countries	1 734.4	2 696.7	29.8	37.4	397.8	580.3	78.5	100.5
Least developed countries	28.7	34.7	0.5	0.5	40.5	43.4	37.6	43.8
Americas	**1 628.4**	**1 831.9**	**28.0**	**25.4**	**1 890.9**	**2 010.1**	**196.4**	**236.9**
North America	1 458.5	1 579.8	25.1	21.9	4 483.2	4 624.4	204.2	252.8
Latin America and the Caribbean	169.9	252.1	2.9	3.5	317.1	442.5	130.0	137.4
Europe	**1 870.7**	**2 123.6**	**32.2**	**29.5**	**2 348.5**	**2 638.7**	**127.5**	**147.9**
European Union	1 197.9	1 448.3	20.6	20.1	2 473.9	2 936.4	172.1	182.9
Commonwealth of Independent States in Europe	579.6	551.5	10.0	7.6	2 796.1	2 735.3	31.7	49.8
Central, Eastern and Other Europe	93.2	123.8	1.6	1.7	887.2	1 125.9	149.4	175.1
Africa	**129.0**	**158.5**	**2.2**	**2.2**	**150.2**	**164.3**	**53.1**	**64.6**
South Africa	14.2^{-1}	19.3	0.2^{e}	0.3	311.4^{-1}	392.9	158.9^{-1}	225.6
Other sub-Saharan countries (excl. South Africa)	30.8	40.8	0.5	0.6	49.4	57.5	59.5	63.8
Arab States in Africa	84.1	98.4	1.4	1.4	444.1	477.1	30.2	33.3
Asia	**2 064.6**	**2 950.6**	**35.5**	**40.9**	**554.2**	**745.9**	**103.6**	**125.2**
Japan	646.5	710.0	11.1	9.8	5 087.0	5 573.0	167.3	208.4
China	810.5	1 423.4	13.9	19.7	630.3	1 070.9	48.4	72.0
Israel	–	–	–	–	–	–	–	–
India	115.9^{-2}	154.8^{-2}	2.3^{e}	2.2^{e}	111.2^{-2}	136.9^{-2}	102.6^{-2}	126.7^{-2}
Commonwealth of Independent States in Asia	41.4	39.7	0.7	0.6	572.5	525.8	12.3	19.4
Newly Industrialized Economies in Asia	295.8	434.3	5.1	6.0	791.4	1 087.4	135.6	166.6
Arab States in Asia	21.1	24.4	0.4	0.3	197.1	198.7	50.5	59.3
Other in Asia (excl. Japan, China, India, Israel)	93.2	127.1	1.6	1.8	138.1	174.2	51.6	81.8
Oceania	**118.0**	**145.1**	**2.0**	**2.0**	**3 677.6**	**4 208.7**	**95.1**	**125.9**
Other groupings								
Arab States all	105.2	122.8	1.8	1.7	354.9	373.2	34.3	38.4
Commonwealth of Independent States all	621.0	591.2	10.7	8.2	2 221.1	2 133.8	30.4	47.7
OECD	3 588.1	4 152.9	61.7	57.6	3 121.2	3 492.8	184.3	215.5
European Free Trade Association	48.3	52.9	0.8	0.7	3 976.6	4 209.1	202.3	257.3
Sub-Saharan Africa (incl. South Africa)	45.0	60.1	0.8	0.8	67.1	79.2	96.0	115.8
Selected countries								
Argentina	26.1	38.7	0.4	0.5	692.3	979.5	44.4	68.7
Brazil	71.8	124.9	1.2	1.7	400.9	656.9	181.4	162.1
Canada	116.0	139.0^{-1}	2.0	1.9^{e}	3 705.3	$4\ 260.4^{-1}$	165.0	170.7^{-1}
Cuba	–	–	–	–	–	–	–	–
Egypt	–	49.4	–	0.7	–	616.6	–	18.5
France	186.4	215.8	3.2	3.0	3 115.7	3 496.0	204.7	196.1
Germany	265.8	290.9	4.6	4.0	3 232.5	3 532.2	213.1	248.4
Iran (Islamic Republic of)	–	50.5^{-1}	–	0.7^{e}	–	706.1^{-1}	–	93.0^{-1}
Mexico	31.1	37.9	0.5	0.5	305.1	352.9	134.0	147.6
Republic of Korea	141.9	221.9	2.4	3.1	3 022.8	4 627.2	158.6	186.3
Russian Federation	491.9	469.1	8.5	6.5	3 384.8	3 304.7	32.4	50.1
Turkey	24.0	49.7	0.4	0.7	350.8	680.3	125.4	136.5
United Kingdom	198.2	254.6	3.4	3.5	3 336.5	4 180.7	154.6	152.2
United States of America	1 342.5	$1\ 425.6^{-1}$	23.1	20.0^{e}	4 566.0	$4\ 663.3^{-1}$	206.4	243.9^{-1}

-*n* = data refer to *n* years before reference year e = UNESCO Institute for Statistics estimation based on extrapolations and interpolations

Note: Researchers are full-time equivalents. The sum of researchers and the world share do not correspond to the total for some regions because of changes in the reference year or the unavailability of data for some countries.

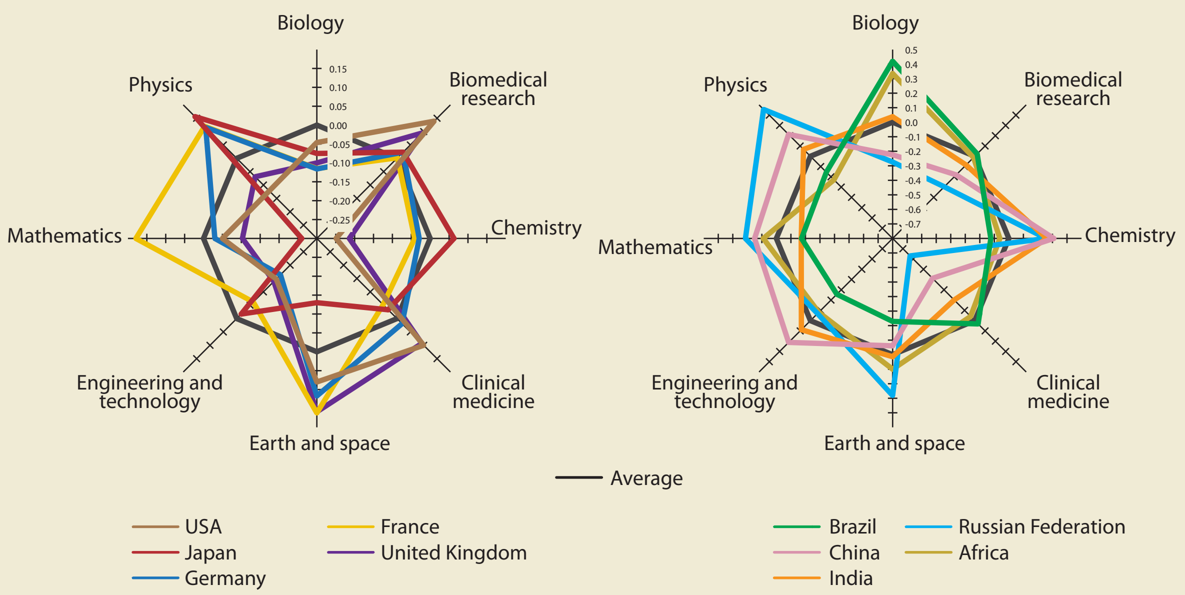
Source: for researchers: UNESCO Institute for Statistics estimations, June 2010; for PPP conversion factor: World Bank, World Development Indicators, May 2010, and UNESCO Institute for Statistics estimations; for population: United Nations Department of Economic and Social Affairs (2009) *World Population Prospects*: *the 2008 Revision*, and UNESCO Institute for Statistics estimations more detailed assessments of particular scientific fields. We begin with the aggregate analysis of scientific publications. As Table 3 highlights, the USA is still the country which leads the world when it comes to scientific output in absolute terms. However, its world share (28%) has fallen more than any other country over the past six years. The leading region for this indicator, the EU, has also seen its share dip by four percentage points to less than 37%. By contrast, China's share has more than doubled in just six years and now represents more than 10% of the world total, second only to the USA, even if the citation rate for Chinese articles remains much lower than for the Triad. Next come Japan and Germany. They are now on a par at just under 8%, Japan's world share having fallen farther than Germany's.

As for the BRIC[7] countries, their share of world publications has shown impressive growth, with the exception of Russia, which saw its share decline from 3.5% in 2002 to 2.7% in 2008. At the continental level, Latin America's share leapt from 3.8% to 4.9% but this was mostly thanks to Brazil. Growth in the Arab world remained sluggish. Africa's share of publications in the SCI made a bound of 25% between 2002 and 2008 from a very low starting point to attain 2.0% of the world total. Here, the rise was most noticeable in South Africa and the Maghreb but every African country saw the number of its articles recorded in the SCI progress. At the global level, scientific publishing is today dominated by a new triad: the USA, Europe and Asia. Given the size of Asia's population, one would expect it to become the dominant scientific continent in the coming years.

In terms of the relative specialization of countries in specific scientific disciplines, Figure 4 points to wide disparities. The first spider's web focuses on the traditionally dominant scientific countries. The black octagon represents the average, so the lines outside this octagon indicate a better-than-average performance in a given field. Of note is France's specialization in mathematics, recently confirmed by the award of the Abel Prize – the mathematical equivalent of the Nobel Prize – to two French mathematicians in 2010.

7. Brazil, Russian Federation, India and China

Figure 4: Scientific specialization of the Triad, BRIC countries and Africa, 2008



Source: UNU-MERIT based on data from Thomson Reuters (Scientific) Inc. Web of Science (Science Citation Index Expanded), compiled for UNESCO by the Canadian Observatoire des sciences et des technologies, May 2010

Table 3: World shares of scientific publications, 2002 and 2008

	Total publications		Change (%)	World share of publications (%)		Biology		Biomedical research	
	2002	2008	2002–2008	2002	2008	2002	2008	2002	2008
World	**733 305**	**986 099**	**34.5**	**100.0**	**100.0**	**58 478**	**84 102**	**99 805**	**123 316**
Developed countries	617 879	742 256	20.1	84.3	75.3	49 315	62 744	89 927	100 424
Developing countries	153 367	315 742	105.9	20.9	32.0	13 158	29 394	14 493	32 091
Least developed countries	2 069	3 766	82.0	0.3	0.4	477	839	226	471
Americas	**274 209**	**348 180**	**27.0**	**37.4**	**35.3**	**23 868**	**33 785**	**47 500**	**54 671**
North America	250 993	306 676	22.2	34.2	31.1	20 234	24 976	44 700	49 590
Latin America and the Caribbean	27 650	48 791	76.5	3.8	4.9	4 321	10 232	3 426	6 216
Europe	**333 317**	**419 454**	**25.8**	**45.5**	**42.5**	**24 133**	**33 809**	**43 037**	**50 464**
European Union	290 184	359 991	24.1	39.6	36.5	21 522	29 516	39 261	45 815
Commonwealth of Independent States in Europe	30 118	32 710	8.6	4.1	3.3	1 153	1 447	2 052	2 054
Central, Eastern and Other Europe	29 195	48 526	66.2	4.0	4.9	2 274	4 348	3 524	5 014
Africa	**11 776**	**19 650**	**66.9**	**1.6**	**2.0**	**2 255**	**3 366**	**1 122**	**2 397**
South Africa	3 538	5 248	48.3	0.5	0.5	828	1 163	481	690
Other sub-Saharan countries (excl. South Africa)	3 399	6 256	84.1	0.5	0.6	1 072	1 575	381	1 110
Arab States in Africa	4 988	8 607	72.6	0.7	0.9	406	746	281	655
Asia	**177 743**	**303 147**	**70.6**	**24.2**	**30.7**	**10 796**	**20 062**	**19 022**	**31 895**
Japan	73 429	74 618	1.6	10.0	7.6	4 682	5 479	9 723	9 771
China	38 206	104 968	174.7	5.2	10.6	1 716	5 672	2 682	9 098
Israel	9 136	10 069	10.2	1.2	1.0	643	662	1 264	1 411
India	18 911	36 261	91.7	2.6	3.7	1 579	3 339	1 901	3 821
Commonwealth of Independent States in Asia	1 413	1 761	24.6	0.2	0.2	41	57	66	88
Newly Industrialized Economies in Asia	33 765	62 855	86.2	4.6	6.4	1 730	3 364	3 240	6 795
Arab States in Asia	3 348	5 366	60.3	0.5	0.5	200	355	239	447
Other in Asia (excl. Japan, China, Israel, India)	16 579	40 358	143.4	2.3	4.1	1 301	3 203	1 313	3 651
Oceania	**23 246**	**33 060**	**42.2**	**3.2**	**3.4**	**4 014**	**5 034**	**3 120**	**4 353**
Other groupings									
Arab States all	8 186	13 574	65.8	1.1	1.4	600	1 078	510	1 063
Commonwealth of Independent States all	31 294	34 217	9.3	4.3	3.5	1 189	1 497	2 110	2 128
OECD	616 214	753 619	22.3	84.0	76.4	49 509	64 020	90 365	102 634
European Free Trade Association	18 223	25 380	39.3	2.5	2.6	1 523	2 262	2 760	3 349
Sub-Saharan Africa (incl. South Africa)	6 819	11 142	63.4	0.9	1.1	1 860	2 636	844	1 751
Selected countries									
Argentina	4 719	6 197	31.3	0.6	0.6	826	1 287	664	883
Brazil	12 573	26 482	110.6	1.7	2.7	1 572	5 526	1 583	3 467
Canada	30 310	43 539	43.6	4.1	4.4	3 351	4 571	4 779	6 018
Cuba	583	775	32.9	0.1	0.1	129	156	65	81
Egypt	2 569	3 963	54.3	0.4	0.4	192	259	146	295
France	47 219	57 133	21.0	6.4	5.8	2 975	3 865	6 563	7 169
Germany	65 500	76 368	16.6	8.9	7.7	3 838	5 155	8 742	10 006
Iran (Islamic Republic of)	2 102	10 894	418.3	0.3	1.1	150	772	129	681
Mexico	5 239	8 262	57.7	0.7	0.8	874	1 669	558	911
Republic of Korea	17 072	32 781	92.0	2.3	3.3	617	1 755	1 893	3 824
Russian Federation	25 493	27 083	6.2	3.5	2.7	1 050	1 317	1 851	1 835
Turkey	8 608	17 787	106.6	1.2	1.8	546	1 435	532	1 155
United Kingdom	61 073	71 302	16.7	8.3	7.2	4 515	4 975	9 586	10 789
United States of America	226 894	272 879	20.3	30.9	27.7	17 349	21 234	41 135	45 125

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 (Scientific) Inc. Web of Science, (Science Citation Index Expanded), compiled for UNESCO by the Canadian Observatoire des sciences et des technologies, May 2010

Publications by field of science

	Chemistry		Clinical medicine		Earth and space		Engineering & technology		Mathematics		Physics	
	2002	2008	2002	2008	2002	2008	2002	2008	2002	2008	2002	2008
	88 310	**114 206**	**229 092**	**307 043**	**41 691**	**60 979**	**96 194**	**139 257**	**23 142**	**37 397**	**96 593**	**119 799**
	66 585	72 185	203 298	251 857	36 644	50 320	73 868	91 320	19 251	27 961	78 991	85 445
	26 002	49 155	32 772	70 921	8 497	17 330	28 019	59 180	5 829	12 938	24 597	44 733
	76	132	928	1 635	138	318	103	177	27	52	94	142
	22 342	**25 803**	**95 140**	**126 471**	**18 611**	**24 883**	**29 465**	**37 841**	**8 355**	**12 114**	**28 928**	**32 612**
	19 378	21 690	89 495	114 674	17 123	22 533	27 183	33 763	7 573	10 765	25 307	28 685
	3 181	4 401	6 751	14 030	2 122	3 228	2 646	4 535	925	1 570	4 278	4 579
	40 404	**44 644**	**104 060**	**135 042**	**21 202**	**30 763**	**39 625**	**53 069**	**11 834**	**18 064**	**49 022**	**53 599**
	33 183	36 221	93 939	119 230	18 091	26 095	33 845	44 182	10 190	15 239	40 153	43 693
	6 117	6 357	1 771	2 115	2 647	3 205	4 108	4 772	1 474	2 066	10 796	10 694
	2 874	4 239	11 172	18 623	2 054	3 924	3 091	6 284	671	1 541	3 535	4 553
	1 535	**2 012**	**3 075**	**5 640**	**918**	**1 486**	**1 306**	**2 358**	**494**	**893**	**1 071**	**1 498**
	307	410	841	1 453	434	520	294	467	127	227	226	318
	117	183	1 323	2 417	245	477	122	226	44	114	95	154
	1 116	1 438	953	1 931	260	527	892	1 688	325	563	755	1 059
	30 017	**50 501**	**40 557**	**65 957**	**7 456**	**15 001**	**32 946**	**58 754**	**5 544**	**11 614**	**31 405**	**49 363**
	9 908	9 809	21 426	21 729	2 505	3 552	10 633	10 194	1 300	1 661	13 252	12 423
	9 499	23 032	3 863	13 595	2 036	5 746	8 734	22 800	1 850	5 384	7 826	19 641
	694	706	3 134	3 357	372	506	1 011	1 143	524	754	1 494	1 530
	4 552	7 163	3 367	7 514	1 160	2 306	2 980	6 108	506	974	2 866	5 036
	279	322	95	124	145	168	130	166	125	204	532	632
	4 590	7 334	6 748	14 468	1 218	2 540	9 075	16 140	1 102	1 905	6 062	10 309
	323	463	1 302	1 934	143	303	721	1 090	154	326	266	448
	2 449	5 314	4 134	9 991	765	1 983	3 685	9 219	561	1 603	2 371	5 394
	1 552	**2 038**	**7 528**	**11 598**	**2 126**	**3 323**	**2 497**	**3 403**	**716**	**985**	**1 693**	**2 326**
	1 405	1 840	2 227	3 758	399	808	1 580	2 711	469	855	996	1 461
	6 358	6 645	1 856	2 230	2 761	3 333	4 224	4 910	1 589	2 266	11 207	11 208
	63 801	71 003	208 163	262 587	35 655	49 492	74 606	94 262	18 435	26 842	75 680	82 779
	1 618	2 021	6 328	9 072	1 501	2 600	1 548	2 507	387	656	2 558	2 913
	420	582	2 135	3 746	658	962	415	675	170	335	317	455
	536	669	1 078	1 316	407	631	362	487	118	229	728	695
	1 656	2 390	3 243	8 799	657	1 028	1 259	2 209	398	708	2 205	2 355
	2 306	3 022	9 761	14 683	2 620	3 877	3 763	5 971	1 102	1 763	2 628	3 634
	71	96	151	214	18	33	57	90	14	26	78	79
	672	861	478	992	111	205	510	714	121	167	339	470
	5 401	6 090	13 069	16 034	3 457	4 899	5 260	7 123	2 399	3 113	8 095	8 840
	7 399	8 344	20 781	24 708	4 256	5 978	7 059	7 746	1 903	2 725	11 522	11 706
	645	2 198	369	2 626	57	433	390	2 484	97	554	265	1 146
	474	716	994	1 749	484	739	610	996	219	322	1 026	1 160
	2 545	4 006	3 017	7 610	539	1 160	4 526	8 004	497	895	3 438	5 527
	5 240	5 308	1 599	1 914	2 468	2 981	3 144	3 329	1 251	1 584	8 890	8 815
	844	1 639	4 243	7 978	450	1 025	1 223	2 910	162	559	608	1 086
	5 469	5 352	22 007	26 754	4 678	6 079	6 715	7 612	1 383	2 197	6 720	7 544
	17 334	18 984	81 871	103 835	15 206	19 819	23 939	28 572	6 724	9 356	23 336	25 954

France also specializes in Earth and space sciences, like Germany. As for Japan, it has several strengths: physics, chemistry, engineering and technology. Interestingly, both the USA and UK specialize in biomedical research, clinical medicine and Earth and space.

The second spider's web focuses on the BRIC countries and Africa. Here, too, we observe some striking differences between countries in their scientific specialization. Russia shows a strong specialization in physics, mathematics and Earth and space sciences. Typically, China specializes heavily in physics, chemistry, mathematics and engineering and technology. By contrast, Africa and Brazil are strong in biology and India excels in chemistry.

These differences in scientific specialization are mirrored in the different country profiles that follow this first chapter. Countries appear to choose areas for scientific knowledge creation based on their own needs (clinical medicine), geographical opportunities (Earth and space sciences and biology) but also based on cultural affinities (mathematics, physics) and expertise born of industrial growth (chemistry).

Trends in scientific output: inequality in private knowledge creation

The fourth indicator on which we focus in this first chapter reflects the success of countries and regions in privately appropriating knowledge through, for example, the number of patents filed with the Triad patent offices, namely: the US Patents and Trademark Office (USPTO), European Patent Office and Japanese Patent Office. Patents filed with these three patent offices are generally considered to be of a high quality. As a technological indicator, patents are a good reflection of the strong cumulative and tacit character of knowledge, embedded as they are in a formally recognized, long-lasting intellectual property right. It is this characteristic which makes it costly to transfer knowledge from one setting to another.

The overall dominance of the USA is striking. This highlights the US technology market's role as the world's leading private market for technology licenses. Japan, Germany and the Republic of Korea are the other countries with the most patent-holders. India's share amounts to barely 0.2% of all Triadic patents, a share comparable to that of Brazil (0.1%) and Russia (0.2%). Table 4 illustrates the extreme concentration of patent applications in North America, Asia and Europe; the rest of the world barely accounts for 2% of the total stock of patents. Most of Africa, Asia and Latin America play no role at all.

India's patents tend to be in chemistry-related fields. Interestingly, the chapter on India considers that the introduction of the Indian Patent Act in 2005 to bring India into compliance with the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) has not had a negative effect on the country's pharmaceutical industry. In support of this argument, the author cites the strong growth in R&D investment since 2000, which was continuing unabated in 2008. However, he also observes that most of these patents are being granted to foreign companies located in India, based on R&D projects carried out in India, in a growing trend.

Of all the indicators used in the *UNESCO Science Report*, it is the patent indicator which points most strikingly to the inequality of knowledge creation at the global level.

The following trend helps to explain the huge volume of patents among OECD economies. In high-income countries, the lifespan of high-tech products is shortening, obliging companies to come up with new products more quickly than before. This can be seen in the rate at which new computers, software, video games and mobile phones, for instance, are appearing on the market.

High-tech firms are themselves largely responsible for this phenomenon, as they have deliberately set out to create new consumer needs by bringing out more sophisticated versions of their products every six months or so. This strategy is also a way of keeping ahead of the competition, wherever it may be. As a consequence, patents that used to be economically valid for several years now have a shorter lifespan. Developing new products and registering new patents every six months or so is an extremely labour- and investment-intensive exercise which obliges companies to innovate at a frenetic rate. With the global recession, companies are finding it harder to maintain this pace.

Knowledge appropriation versus knowledge diffusion

We now take a look at the opposite variable to patents, the number of Internet users. This variable should enable us to gauge whether easier access to information and knowledge has provided opportunities for a more rapid diffusion of S&T. The data on Internet usage in Table 5 paint

Table 4: USPTO and Triadic patent families by inventor's region, 2002 and 2007

	USPTO patents				Triadic patents*			
	Total		World share (%)		Total		World share (%)	
	2002	2007	2002	2007	2002	2006	2002	2006
World	**167 399**	**156 667**	**100.0**	**100.0**	**56 654**	**47 574**	**100.0**	**100.0**
Developed countries	155 712	141 183	93.0	90.1	55 456	45 923	97.9	96.5
Developing countries	12 846	17 344	7.7	11.1	1 579	2 125	2.8	4.5
Least developed countries	13	13	0.0	0.0	4	1	0.0	0.0
Americas	**92 579**	**85 155**	**55.3**	**54.4**	**25 847**	**20 562**	**45.6**	**43.2**
North America	92 245	84 913	55.1	54.2	25 768	20 496	45.5	43.1
Latin America and the Caribbean	450	355	0.3	0.2	115	101	0.2	0.2
Europe	**31 046**	**25 387**	**18.5**	**16.2**	**17 148**	**13 249**	**30.3**	**27.8**
European Union	29 178	23 850	17.4	15.2	16 185	12 540	28.6	26.4
Commonwealth of Independent States in Europe	350	332	0.2	0.2	151	97	0.3	0.2
Central, Eastern and Other Europe	2 120	1 708	1.3	1.1	1 203	958	2.1	2.0
Africa	**151**	**134**	**0.1**	**0.1**	**47**	**48**	**0.1**	**0.1**
South Africa	124	92	0.1	0.1	38	37	0.1	0.1
Other sub-Saharan countries (excl. South Africa)	15	16	0.0	0.0	3	3	0.0	0.0
Arab States in Africa	12	26	0.0	0.0	6	9	0.0	0.0
Asia	**47 512**	**50 313**	**28.4**	**32.1**	**15 463**	**15 197**	**27.3**	**31.9**
Japan	35 360	33 572	21.1	21.4	14 085	13 264	24.9	27.9
China	5 935	7 362	3.5	4.7	160	259	0.3	0.5
Israel	1 151	1 248	0.7	0.8	476	411	0.8	0.9
India	323	741	0.2	0.5	58	96	0.1	0.2
Commonwealth of Independent States in Asia	6	9	0.0	0.0	3	1	0.0	0.0
Newly Industrialized Economies in Asia	4 740	7 465	2.8	4.8	689	1 173	1.2	2.5
Arab States in Asia	46	58	0.0	0.0	15	18	0.0	0.0
Other in Asia (excl. Japan, China, Israel, India)	80	48	0.0	0.0	19	18	0.0	0.0
Oceania	**1 139**	**1 516**	**0.7**	**1.0**	**549**	**834**	**1.0**	**1.8**
Other groupings								
Arab States all	56	84	0.0	0.1	20	27	0.0	0.1
Commonwealth of Independent States all	356	340	0.2	0.2	154	98	0.3	0.2
OECD	159 320	147 240	95.2	94.0	55 863	46 855	98.6	98.5
European Free Trade Association	2 064	1 640	1.2	1.0	1 180	935	2.1	2.0
Sub-Saharan Africa (incl. South Africa)	139	108	0.1	0.1	41	39	0.1	0.1
Selected countries								
Argentina	59	56	0.0	0.0	12	17	0.0	0.0
Brazil	134	124	0.1	0.1	46	46	0.1	0.1
Canada	3 895	3 806	2.3	2.4	962	830	1.7	1.7
Cuba	9	3	0.0	0.0	5	0	0.0	0.0
Egypt	8	22	0.0	0.0	3	4	0.0	0.0
France	4 507	3 631	2.7	2.3	2 833	2 208	5.0	4.6
Germany	12 258	9 713	7.3	6.2	6 515	4 947	11.5	10.4
Iran (Islamic Republic of)	11	7	0.0	0.0	1	3	0.0	0.0
Mexico	134	81	0.1	0.1	26	16	0.0	0.0
Republic of Korea	3 868	6 424	2.3	4.1	523	1 037	0.9	2.2
Russian Federation	346	286	0.2	0.2	149	84	0.3	0.2
Turkey	21	32	0.0	0.0	9	10	0.0	0.0
United Kingdom	4 506	4 007	2.7	2.6	2 441	2 033	4.3	4.3
United States of America	88 999	81 811	53.2	52.2	25 034	19 883	44.2	41.8

*Data for 2006 are incomplete and should be interpreted with caution.

Note: The sum of the numbers, and percentages, for the various regions exceeds the total number, or 100%, 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) and OECD, compiled for UNESCO by the Canadian Observatoire des sciences et des technologies, February 2009 a very different picture to that for patents. We find that the BRIC countries and numerous developing countries are catching up quickly to the USA, Japan and major European countries for this indicator. This shows the crucial importance of the emergence of digital communications like Internet on the world distribution of S&T and, more broadly, knowledge generation. The rapid diffusion of Internet in the South is one of the most promising new trends of this Millennium, as it is likely to bring about a greater convergence in access to S&T over time.

A systemic perspective on the congruence of S&T indicators

The concept of a national innovation system was coined by the late Christopher Freeman in the late 1980s to describe the much broader congruence in Japanese society between all sorts of institutional networks in both 'private and public sectors whose activities and interactions initiate, import, modify and diffuse new technologies' (Freeman, 1987). The set of indicators described above shed light on some features of each country's national system of innovation. One should bear in mind, however, that science, technology and innovation (STI) indicators that were relevant in the past may be less relevant today and even misleading (Freeman and Soete, 2009). Developing countries should not simply rely on adopting STI indicators developed by, and for, OECD countries but rather develop their own STI indicators (Tijssen and Hollanders, 2006). Africa is currently implementing a project to develop, adopt and use common indicators to survey the continent's progress in S&T via the periodic publication of an *African Innovation Outlook*.

Figure 5 illustrates visually the different biases in countries' national innovation systems by matching four indicators. At first sight, the US system appears to be the most balanced: the US circles appear each time in the middle of the figure. However, its position with respect to human capital is weak and out of line with the trend in other highly developed countries: only 24.5% of the US population holds a tertiary degree, whereas in France, Germany or Japan, for instance,the proportion is close to, or greater than, 30%. One would expect the USA to perform better on the tertiary education axis, given its performance for the indicators on the other axes. It is true that the USA has some of the best universities in the world but rankings like that of Shanghai Jiao Tong University focus on research performance rather than the quality of education. In sum, the USA is reliant on a vast inflow of foreign researchers and other highly skilled people to drive the economy.

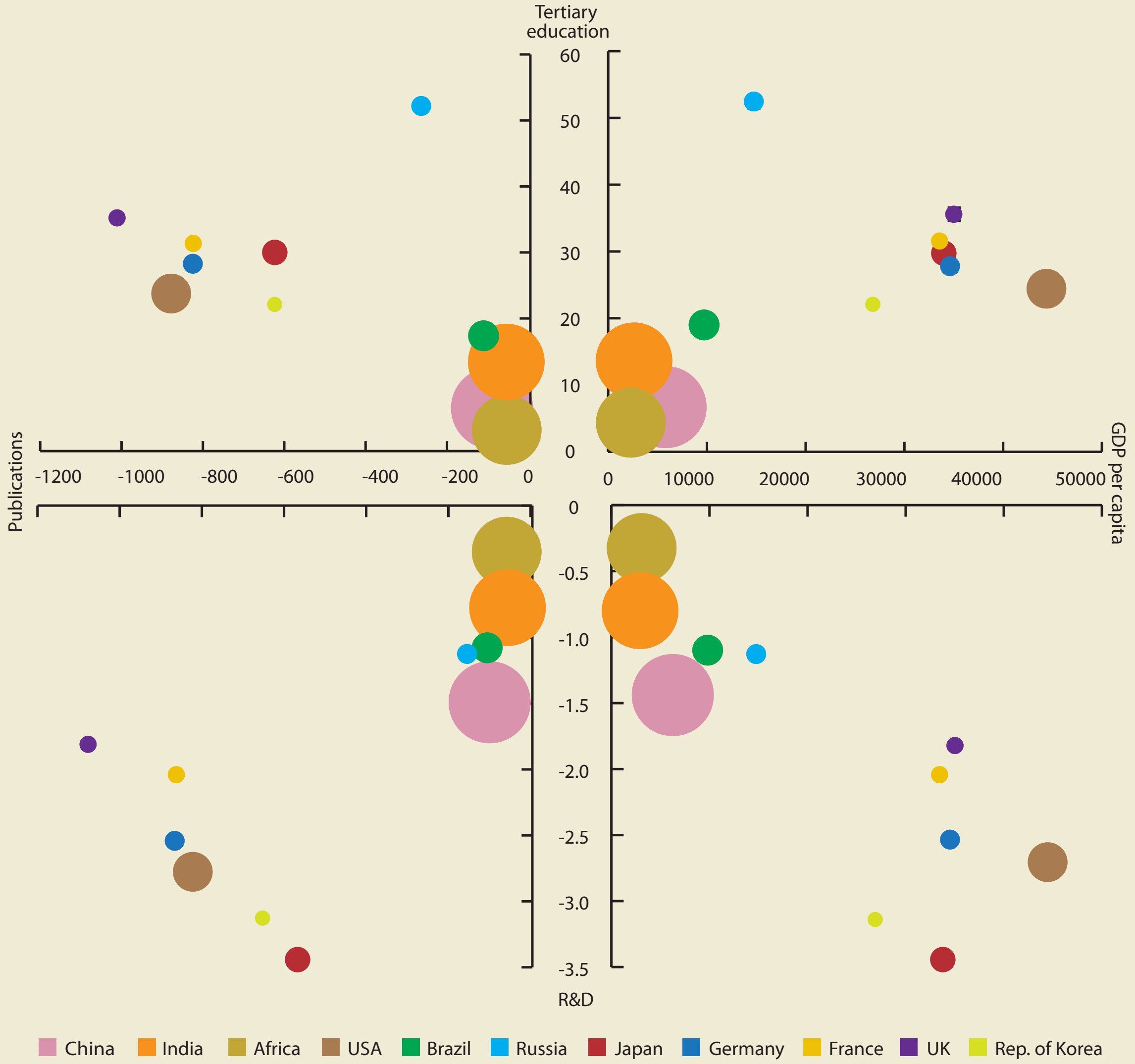
Table 5: Internet users per 100 population, 2002 and 2008

	2002	2008
World	**10.77**	**23.69**
Developed countries	37.99	62.09
Developing countries	5.03	17.41
Less-developed countries	0.26	2.06
Americas	**27.68**	**45.50**
North America	59.06	74.14
Latin America and the Caribbean	8.63	28.34
Europe	**24.95**	**52.59**
European Union	35.29	64.58
Commonwealth of Independent States in Europe	3.83	29.77
Central, Eastern and Other Europe	18.28	40.40
Africa	**1.20**	**8.14**
South Africa	6.71	8.43
Other Sub-Saharan countries (excl. South Africa)	0.52	5.68
Arab States in Africa	2.11	16.61
Asia	**5.79**	**16.41**
Japan	46.59	71.42
China	4.60	22.28
Israel	17.76	49.64
India	1.54	4.38
Commonwealth of Independent States in Asia	1.72	12.30
Newly Industrialized Economies in Asia	15.05	23.47
Arab States in Asia	4.05	15.93
Other in Asia (excl. Japan, China, Israel, India)	2.19	11.51
Oceania	**43.62**	**54.04**
Other groupings		
Arab States all	2.81	16.35
Commonwealth of Independent States all	3.28	24.97
OECD	42.25	64.03
European Free Trade Association	66.08	78.17
Sub-Saharan Africa (incl. South Africa)	0.94	5.86
Selected countries		
Argentina	10.88	28.11
Brazil	9.15	37.52
Canada	61.59	75.53
Cuba	3.77	12.94
Egypt	2.72	16.65
France	30.18	70.68
Germany	48.82	77.91
Iran (Islamic Republic of)	4.63	31.37
Mexico	10.50	21.43
Republic of Korea	59.80	81.00
Russian Federation	4.13	32.11
Turkey	11.38	34.37
United Kingdom	56.48	78.39
United States of America	58.79	74.00

Source: International Telecommunications Union, World telecommunications / ICT indicators database, June 2010, and UNESCO Institute for Statistics estimations; United Nations Department of Economic and Social Affairs (2009) *World Population Prospects: the 2008 Revision*, and UNESCO Institute for Statistics estimations

Japan provides a contrast. It clearly lags behind other highly developed countries in terms of scientific publications and GDP per capita. Its innovation system appears weak when it comes to translating the country's big investment in human research capital and R&D into sufficient scientific and economic value. The UK suffers from exactly the opposite problem: its performance in terms of scientific publications and economic wealth creation is by far superior to its investment in human research capital and R&D. Russia, on the other hand, shines when it comes to investment in human capital but fails on all other counts. China is still typically in a catching-up phase: its heavy investment in R&D has as yet not paid off but, of course, its economic structure remains dominated by non-technology-intensive activities.

Figure 5. The systemic matching between key S&T indicators, 2007
Selected countries and regions



Note: The size of the circles reflects the population size for each country or region studied.

Source: UNU–MERIT based on data from the UNESCO Institute for Statistics and World Bank

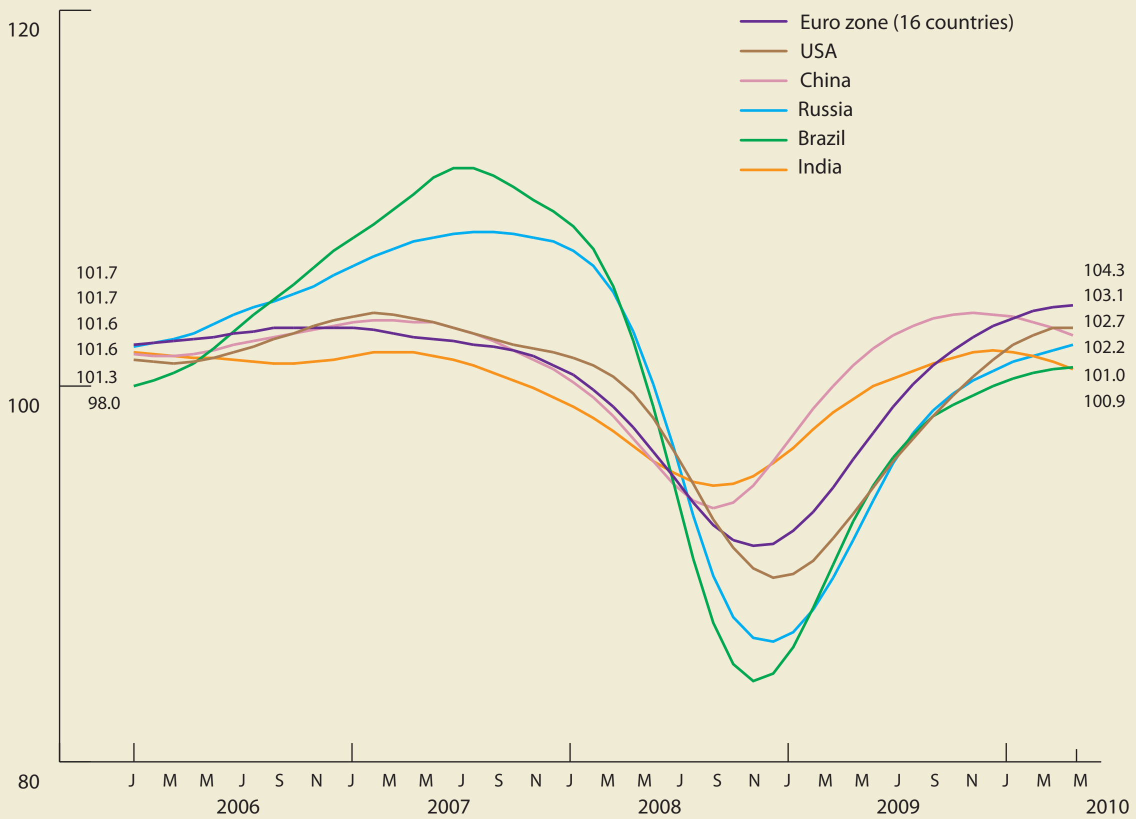
The national biases in Figure 5 also point to some of the implications for countries of the international migration of researchers and more broadly human capital. It is not surprising that there will be a lot of emigration from a country like Russia and a lot of immigration towards the USA, given the current biases in their national innovation systems.

IS THE GLOBAL ECONOMIC RECESSION BAD FOR KNOWLEDGE CREATION?

The global recession is likely to have had a severe impact on investment in knowledge across the globe. Many of the knowledge indicators described for 2007 and earlier may have been affected in the process and, hence, could not reliably predict the situation in 2009 or 2010. R&D budgets, especially, tend to be vulnerable to cutbacks in times of crisis. Patents and publications will in turn be affected by the drop in R&D expenditure but this will probably occur in the longer run and affect scientific output less directly, owing to pipeline effects that smother sharp fluctuations. As for trends in education of the labour force, this sector tends to be less affected by short-term distortions.

There are a couple of short-term indicators which might shed some light on the impact of the recession thus far. Here, we use the OECD´s composite leading indicator (CLI), which is available on short notice. This indicator uses monthly (de-trended) data on industrial production as a proxy for economic activity. It is a leading indicator because industrial production recovers early in an economic cycle. A turning point in the CLI signals that a turning point in the business cycle can be expected within 6–9 months. China showed a turning point as early as November 2008 and, consequently, an upturn in the business cycle in May–August 2009, as expected.

Figure 6. Industrial production in the BRIC countries, USA and Euro zone, 2006–2010



Source: OECD, Composite Leading Indicators (Amplitude adjusted series): http://stats.oecd.org/Index.aspx?DatasetCode=MEI_CLI

We can also interpret from the information in Figure 6 that Brazil was 10% above its long-term level for industrial production in 2007 before falling brutally to about 85% of this value in the first month of 2009. Industrial production in India and the Euro zone only stumbled, falling from around 103% to 90%. Recovery is expected to be strong enough to raise the level of industrial production above its long-term trend level. However, the data for the most recent months (June 2010) reveal that the rate of recovery is slowing down, raising concerns about a possible double dip.

In short, we can say that, between October 2008 and March 2009, the first signs of recovery appeared. Asia in general and China in particular were the first to recover. It is unlikely that R&D expenditure in China has been affected by the global economic recession because industrial production fell only 7% below its long-term trend value for a relatively short period. Moreover, circumstantial evidence on firms provided by the EU's R&D investment scoreboard in 2009 shows that China's R&D effort in 2008 actually increased, at least in telecommunications. There is no reason to assume that 2009 and 2010 will be much different, since China's economy grew by more than 7% even in 2007 and 2008.

For Brazil and India, on the other hand, it is likely that their total R&D effort will come under pressure in 2008 and 2009, due to the relatively low level of industrial production over a prolonged period of time. In fact, between July 2008 and March 2010, industrial production remained below its long-term trend level. On a brighter note, these countries have been catching up to the developed countries in terms of GERD for several years now. One might therefore expect more of a lull in these countries' rising R&D intensity than a significant drop.

As for the world's largest R&D-intensive firms, circumstantial evidence for 2009 reveals that the majority of the big R&D spenders in the USA cut their R&D expenditure by 5–25% that year, while a minority increased spending by 6–19%. Overall though, the USA and EU are most likely to keep their total R&D intensity at around 2007 levels. This means that both GDP and R&D expenditure will decline by equal shares, thereby keeping R&D intensity more or less constant over the year 2009–2010 (Battelle, 2009).

A CLOSER LOOK AT INDIVIDUAL COUNTRIES AND REGIONS

The choice of countries and regions in the *UNESCO Science Report 2010* nicely reflects the heterogeneity of S&T around the world, from the highly developed OECD nations to the four large emerging BRIC countries and the large number of developing countries which are playing a growing role in the global research effort. Here, we summarize the most insightful conclusions emerging from the regional and country studies in Chapters 2 to 21.

In the **United States of America** (Chapter 2), R&D has prospered over the past five years and continues to be an absolute government priority. A good example is the funding for the National Science Foundation, which doubled at the request of the Bush administration in 2007 and is set to double again under the Obama administration. Although the recession born of the sub-prime crisis hit the economy hard in 2009 and 2010, universities and research centres have continued to receive generous funding from both public funds and private endowments and industrial funds.

Whereas the Obama administration included a significant one-off investment in STI that also benefited R&D in the second stimulus package towards the end of 2009, there is now a clear risk that any increase in federal funding will be offset by reductions in funding by both state governments and private funds. Notwithstanding this, one important commitment by the Obama administration is to increase GERD from 2.7% to 3% of GDP. The administration is emphasizing energy R&D, especially clean energy.

Unlike public research, industrial R&D appears to have been hit relatively hard by the recession with a large number of researchers being laid off. Among the biggest R&D spenders have been the pharmaceutical industries, badly affected by the recession. In fact, the chapter notes that the pharmaceutical industry was already showing signs of stress before the recession, as the huge investment made in R&D does not appear to have resulted in many 'blockbuster' drugs recently.

The US university system still leads the world when it comes to research: in 2006, 44% of all S&T articles published in journals indexed in the SCI included at least one US-based author. Furthermore, of the top 25 institutions ranked by the Shanghai Jiao Tong University's Institute of Higher Education in 2008, 19 were based in the USA.

Canada (Chapter 3) has been less affected by the global economic recession than either the USA or Europe, thanks to its strong banking system and a real-estate market that avoided many of its neighbour's excesses. Furthermore, low inflation coupled with income from Canada's abundant natural resources have cushioned the impact of the global recession on the country's economy.

In March 2010, the federal government committed to investing in a range of new measures to foster research over the period 2010–2011. These include postdoctoral fellowships, as well as more general research funding for grant councils and regional innovation clusters. A considerable share of this funding goes towards research on particle and nuclear physics, as well as next-generation satellite technology. With the USA next door, Canada cannot afford to be complacent.

Steady investment in R&D appears to be paying off: between 2002 and 2008, the number of Canadian scientific publications in the SCI grew by nearly 14 000. However, if Canada can boast of a dynamic academic sector and generous public spending on STI and R&D, many businesses have not yet assimilated a 'knowledge creation' culture. Canada's productivity problem is first and foremost a business innovation problem. The result of the poor R&D performance in business is that academic research often appears to be a surrogate for industrial R&D.

The federal government has set out to foster public–private partnerships recently via two successful initiatives: an agreement between the federal government and the Association of Canadian Universities and Colleges to double the volume of research and triple the number of research results which are commercialized; and the Network of Centres of Excellence, which now total 17 across the country.

Chapter 4 on **Latin America** notes a persistent and glaring income gap between rich and poor across the continent. STI policies could play an important role in reducing inequality. However, it is proving difficult to establish ties between STI policies on the one hand and social policies on the other. The structural conditions prior to the global recession were particularly favourable to reform, in that they combined political stability with the longest period of strong economic growth (2002–2008) that the region had seen since 1980, thanks to a booming global commodities market.

Several Latin American countries have implemented an array of policies to foster innovation, in particular Argentina, Brazil and Chile. However, despite there being about 30 types of STI policy instruments in use across the region, national innovation systems remain weak. This is the case even among such keen proponents of STI policies as Brazil and Chile. The major stumbling block is the lack of linkages between the different actors of the national innovation system. For instance, good research coming out of the local academic sector does not tend to be picked up and used by the local productive sector. More generally, R&D investment remains low and bureaucracies inefficient. Training and building a critical mass of highly skilled personnel has become another burning issue.

The economic recession has generated an employment crisis that may well exacerbate poverty in the region and thus further increase the tension between STI policy and specialization, on the one hand, and poverty alleviation and social policies on the other.

Brazil (Chapter 5) experienced a booming economy in the years leading up to the global recession. Such a healthy economy should be conducive to business investment. However, patent numbers remain low and R&D activities sluggish in the business sector, leaving most of the funding effort to the public sector (55%). In addition, the majority of researchers are academics (63%) and the Brazilian economy is increasingly suffering from a shortage of PhD graduates. Researchers also remain unevenly spread across the country with national output being dominated by a handful of top universities.

The federal government is conscious of the problem. In 2007, it adopted a *Plan of Action in Science, Technology and Innovation for Brazilian Development* (2007–2010) which sets out to raise R&D expenditure from 1.07% of GDP in 2007 to 1.5% of GDP in 2010. Another target is to augment the number of scholarships and fellowships available to university students and researchers from 102 000 in 2007 to 170 000 by 2011. One key objective is to nurture an innovation-friendly environment in firms by strengthening industrial, technological and export policies, and increasing both the number of active researchers in the private sector and the number of business incubators and technoparks.

Cuba (Chapter 6) is a particularly interesting case study. Cuba's human development is among the highest in the region, on a par with Mexico. In terms of overall spending on S&T, however, it has slipped below the regional mean, the consequence of a slightly lesser effort on Cuba's part and, above all, a greater commitment to S&T across Latin America. Business funding in Cuba has halved in recent years to just 18% of GERD.

Cuban enrollment in higher education is impressive, on the other hand, with first-year student rolls having doubled between 2004–2005 and 2007–2008, thanks largely to a surge in medical students. What is more, in 2008, 53.5% of S&T professionals were women. Many STI professionals work in public research institutes across the country, although the low number of researchers among R&D personnel (7%) is troubling.

The research strategy in Cuba is centred around a number of National Research Programmes in Science and Technology. A recent programme focusing on ICT managed to increase Internet access from 2% of the population in 2006 to nearly 12% a year later. Although Cuba is known for the development and production of pharmaceuticals, other priorities are emerging. These include energy R&D and disaster monitoring and mitigation, in light of the threat of stronger hurricanes, droughts, coral bleaching and flooding in future as a consequence of climate change. Cuba has begun modernizing its research infrastructure, notably its meteorological services.

The countries of the **Caribbean Common Market** (Chapter 7) have suffered acutely from the peak in international food and commodity prices in recent years. Jamaica, for instance, spent more on petroleum imports in 2007 than the total value of its exports. This situation has been exacerbated by the global recession, which has hit the crucial tourist industry hard.

Two of the region's largest countries, Jamaica and Trinidad and Tobago, have now put together long-term development plans (*Vision 2030* and *Vision 2020*, respectively) that emphasize the importance of STI for development. Expenditure on R&D remains dismally low, however, and private R&D moribund. Only the higher education sector is booming: two new universities have been established since 2004 on the island of Trinidad and the introduction of free tertiary education in Trinidad and Tobago in 2006 caused student enrollment rates to rise overnight. However, the leap in the student population has not been matched by a proportionate increase in academic staff numbers, putting research under strain. The region has great expectations for the Caribbean Science Foundation launched in September 2010 to revitalize R&D.

As Chapter 8 on the **European Union (EU)** highlights, the EU is increasingly a heterogeneous group of countries. Although the new member states are catching up in economic terms, there remains a yawning gap between the richest and poorest member states. When it comes to innovation, however, this heterogeneity knows no borders. Regions within a country that perform particularly well in innovation are dotted across the EU rather than being confined to the older (and richer) member states.

Although the EU is the undisputed world leader for publications recorded in the SCI, it is struggling to increase expenditure on R&D and develop innovation. This is visible in its inability to meet both the Lisbon and Barcelona targets of raising GERD to 3% of GDP by 2010. Another issue member states are struggling with across the EU concerns the institutional reforms of the university system. The dual challenge here is to improve the quality of research and revitalize the EU's poorly funded institutions of higher education.

On a more positive note, what sets the EU apart from many other regions is its willingness to acknowledge that it can only improve its performance in STI and R&D by pooling the capabilities of member states. This attitude has spawned a number of multilateral European agencies and programmes. These vary from large research organizations like the European Organization for Nuclear Research (CERN) where individual countries collaborate on the EU's Framework Programmes for Research and Technological Development to the Joint Technology Initiative and EUREKA, designed to stimulate research in industry. A number of new EU organizations have been set up, or are in the process of being set up, including the European Science Foundation and European Institute of Innovation and Technology, as well as funding agencies like the European Research Council.

Until the global economic recession hit in late 2008, all countries in **Southeast Europe** (Chapter 9) were growing at an average rate of around 3% a year. However, the region is particularly heterogeneous in terms of its socio-economic development, with a ten-fold difference between the richest (such as Greece and Slovenia) and poorest (Moldova) countries. Whereas the most advanced countries are implementing EU-focused strategies with an emphasis on innovation, the stragglers are still at the stage of attempting to design or implement a basic S&T policy and establish an R&D system. Two of the smaller countries are, of course, still in their infancy: Montenegro only gained independence in 2006 and Kosovo in 2008.

Today, demand for R&D and skilled personnel remains low in all but Slovenia, despite a growing number of tertiary graduates. Two reasons for the lack of demand for R&D are the small size of firms and their lack of capacity. For the non-EU members in the region, European integration represents the only viable project for ensuring social and political coherence. Without strong STI policies, the region is in danger of falling further behind the rest of Europe.

Turkey (Chapter 10) has been emphasizing STI policies in recent years. Between 2003 and 2007, GERD more than doubled and business expenditure on R&D grew by 60%. Domestic patent filings and grants also rose more than four-fold from 2002 to 2007. It is the private sector that has been driving economic growth since 2003.

A number of policy measures have been put in place to support STI. These include the *Vision 2023* Project in 2002–2004, the launch of the Turkish Research Area in 2004 and a major five-year implementation plan for the *National Science and Technology Strategy* (2005–2010). The *Ninth Development Plan* (2007–2013) has likewise focused on STI as a building block for Turkey.

However, challenges remain. The *Vision 2023* Project was a technology foresight exercise but it has unfortunately not spawned any policy initiatives to build capacity in priority technology areas. Moreover, the density of researchers remains poor and enrollment in tertiary education is lower than for countries with a similar income. Turkey also has an underdeveloped venture capital market and an insufficient number of high-growth firms. The government has introduced a number of measures to stimulate private-sector R&D, foster university–industry collaboration and develop international co-operation in R&D. These measures include tax incentives for technoparks, of which there were 18 in 2008.

The **Russian Federation** (Chapter 11) had been experiencing an economic boom in the years before the severe economic downturn towards the end of 2008. This was largely due to high oil prices, an initial weak currency and strong domestic demand. Both consumption and investment were high. The country reacted to the crisis by adopting an extensive recovery package but it is feared that this package may increase the government's tendency to intervene directly in the economy rather than furthering the kind of institutional reform needed to bring about modernization, especially as regards STI policy.

Without such institutional reforms, the national innovation system will continue to suffer from poor linkages between the different actors. Currently, there is a lack of co-ordination across departments, a high level of administrative complexity and poor linkages between science, academia and industry. These factors all act as barriers to co-operation and innovation. A notable feature is the imbalance between the country's STI performance and the growing mass of financial resources dedicated to R&D but jealously guarded within public research institutions where they are out of reach for industry and universities. As a result, universities play a minor role in new knowledge creation: they contribute just 6.7% of GERD, a stable figure for the past two decades, and only one in three universities performs R&D, compared to half in 1995. Private universities hardly perform any research at all. The higher education system has undergone widespread reform in recent years with the introduction of bachelor's and masters programmes which now cohabit with the Soviet degree system. By 2009, more than half of university staff held the equivalent of a PhD.

STI policies need to allow for greater academic mobility and co-operation; they also need to lay the groundwork for a radical modernization of the professional training of scientists and engineers. The latter point is all the more urgent in light of the country's ageing research population: 40% are above the official retirement age. Boosting support for university research has become one of the most important strategic orientations of STI and education policies in Russia. Since 2006, the National Priority Project for Education and a follow-up programme have provided 84 universities considered to be centres of excellence with an additional US$ 30 million each approximately to promote human resource development, high-quality R&D and educational projects, as well as permit the acquisition of research equipment.

No country in **Central Asia** (Chapter 12) devotes more than 0.25% of GDP to R&D. This is even the case for Kazakhstan and Uzbekistan, the countries with the most developed science systems. Other concerns are the ageing 'Soviet-generation' research population and an inadequate legal framework which is partly responsible for the low level of innovation by scientific organizations and private enterprises.

STI policy initiatives in the region include the Intellectual Nation 2020 programme unveiled in Kazakhstan in 2009. It plans to develop a network of schools in natural and exact sciences for gifted pupils and to raise GERD to 2.5% of GDP by 2020. Kazakhstan can already count on several technoparks. Tajikistan has also adopted a plan for S&T covering 2007–2015. As for Turkmenistan, it has also witnessed a revival of science since 2007, after research was virtually shut down for many years under the previous presidency. In Uzbekistan, a key measure has been the establishment of a Committee for the Co-ordination of the Development of Science and Technology in 2006. After identifying seven priority areas for R&D, the committee invited universities and scientific organizations to submit research proposals within a competitive bidding process. By the end of 2011, some 1098 projects will have been implemented within 25 broad research programmes in basic and applied research and experimental development.

Chapter 13 on the **Arab States** analyses the reasons for the lack of a national S&T strategy or policy in most Arab states, although all have sectoral policies for agriculture, water, energy and so on. Even where S&T strategies exist, innovation tends to be absent from these, primarily due to weak linkages between public and private R&D. However, Bahrain, Morocco, Qatar, Saudi Arabia, Tunisia, the United Arab Emirates, followed more recently by Jordan and Egypt, are tackling this issue by setting up science parks.

S&T policies and strategies are also beginning to emerge. Saudi Arabia adopted a national plan for S&T back in 2003 and, in 2006, Qatar implemented a five-year plan to increase GERD to 2.8% (from 0.33%). The planned submission of an S&T strategy for the entire Arab region to the Arab summit in 2011 for adoption is another promising sign. The future plan is expected to address the important issue of facilitating the mobility of scientists within the region and to enhance collaborative research with the sizeable community of expatriate Arab scientists. It is also expected to propose both national and pan-Arab initiatives in about 14 priority areas, including water, food, agriculture and energy. The plan may also recommend the launch of an online Arab S&T observatory, as a key to implementing measures at the country level will lie in first identifying some of the national challenges that Arab countries face.

Also promising is the number of funds for STI set up in the region in recent years. These include the 2008 EU–Egypt Innovation Fund and two national funds: the Mohammed bin Rashid Al Maktoum Foundation in the United Arab Emirates (2007) and the Middle East Science Fund in Jordan (2009).

Chapter 14 on **sub-Saharan Africa** highlights the move by a growing number of African countries to enhance their S&T capacity as part of poverty alleviation strategies. In 2008 alone, 14 countries requested UNESCO's assistance with science policy reviews. Although GDP per capita rose in the majority of African countries between 2002 and 2008, it remains low by world standards, a factor which has an impact on investment in STI. Moreover, GERD still attracts less public funding than the military, health or education sectors. South Africa is the only country which comes close to the 1% mark for R&D intensity (0.93% in 2007).

South Africa also dominates scientific publications, representing a 46.4% of the sub-continent's share, far ahead of the two next most prolific countries, Nigeria (11.4%) and Kenya (6.6%). Of note is that the number of articles recorded in the SCI has progressed for all sub-Saharan countries, even if only 17 could count more than 100 articles in this database in 2008.

A major challenge is the low literacy rate and poor quality of education, even if both literacy and enrollment rates have climbed in the past decade. To address these issues, the African Union issued a *Plan of Action for the Second Decade of Education for Africa* in 2006. Another major challenge is brain drain: at least one-third of all African researchers were living and working abroad in 2009. A growing number of countries are tackling the root cause of this problem by raising the salaries of academics and providing other incentives. Cameroon, for instance, used the writing-off of part of its debt to create a permanent fund in early 2009 which tripled the salaries of academics overnight. The number of academics appears to have already swelled by about one-third and the volume of scientific articles produced by state universities has likewise risen.

Five years after the adoption of *Africa's Science and Technology Consolidated Plan of Action* (CPA) covering the period 2008–2013, progress has been made in biosciences and water research and the first set of pan-African R&D statistics is due to be delivered in 2010. Concern has been voiced in some quarters, however, at the rate of progress. The CPA is intended to act as a framework for channelling greater funds into S&T across the continent but, five years on, the proposed mechanism for channelling this funding, the African Science and Innovation Facility, has not yet materialized.

South Asia (Chapter 15) has enjoyed reasonably good growth rates in the past few years and not suffered unduly from the global recession, with the notable exception of Pakistan which has seen its growth rates drop from 6.8% in 2007 to 2.7% in 2009. Pakistan is the country that spends the most on R&D (0.67% of GDP in 2007), IT and higher education of the countries under study, which do not include India and Iran. However, most R&D funding in Pakistan is consumed by the military sector (60%).

The region suffers from a lack of investment in STI. Moreover, there is a lack of linkages between public and private actors and no university–industry collaboration to speak of. It is noted in the chapter that, overall, Pakistan, Bangladesh and Sri Lanka seem better at producing basic knowledge than commercializing it. It will be interesting to follow the fortunes of the Sri Lanka Institute of Nanotechnology, which was set up in 2008 within a joint venture between the National Science Foundation and domestic corporate giants that include Brindix, Dialog and Hayleys. The new institute professes to take 'an industry-focused approach'.

In addition to the lack of innovation, South Asia suffers from low levels of literacy and education. Governments face the dual challenges of widening access while simultaneously making the education system relevant to the national economy. They are aware of the task at hand: Afghanistan, Bangladesh, Pakistan and Sri Lanka are all at various stages of higher education reform. Fortunately, they can count on several high-quality academic institutions in the region.

Iran (Chapter 16) is heavily reliant on its oil industry, which currently accounts for four-fifths of GDP. This situation weighs heavily on the country's STI policies, since these are not a priority for generating future prosperity. With research being funded mostly (73%) out of the public purse and with an interventionist government pursuing its own priorities, R&D tends to be focused on nuclear technology, nanotechnology, satellite launching and stem cell research. Policy research bears little relevance to national issues and remains cut off from socio-economic realities.

The most recent document outlining Iran's strategy for S&T is enshrined in the *Fourth Development Plan* (2005–2009). It focuses mainly on improving the university system at a time of strong demand for higher education: 81 000 students graduated in 2009, compared to 10 000 nine years earlier.

India (Chapter 17) is one of the world's fastest-growing economies, alongside China. Having been relatively spared by the global recession, it is pursuing a path of rapid growth. The past few years have seen a rise in private investment in R&D, with the majority of new companies belonging to knowledge-intensive sectors. A growing number of foreign companies are also establishing R&D centres on Indian soil. Most of these foreign centres focus on ICTs. In fact, India has become the world's leading exporter of IT services. Aerospace exports are also growing by 74% a year. Meanwhile, major Indian companies like Tata have been investing in high-tech companies abroad, in pursuit of technology.

In 2003, the government committed to raising overall research expenditure from 0.8% to 2% of GDP by 2007. Although GERD had only attained 0.88% of GDP in 2008, this target sent a clear signal that public policy was focusing on R&D. Moreover, the *Eleventh Five-Year Plan* to 2012 not only emphasizes innovation but also foresees a massive outlay on STI via a budgetary increase of 220%.

There is a general trend in India towards recognizing the 'I' in STI in both the policy and business sectors. Moreover, the adoption of the Indian Patent Act in 2005 to bring India into compliance with the TRIPS agreement has not caused the domestic pharmaceutical industry to slump, contrary to predictions. The pharmaceutical industry is flourishing, even if the domination of foreign firms in patents continues to cast a shadow. Another challenge is the steady flow of highly skilled people out of India and out of domestic firms unable to compete with the advantages offered by their India-based foreign rivals. The biggest challenge of all, however, will be for India to improve both the quantity and quality of Indian S&T personnel. The central government's decision to create 30 universities across the country, including 14 world-class innovation universities, augurs well for the future.

China (Chapter 18) has made great strides in economic development in the past decade with consistently impressive growth rates. In August 2010, China even overtook Japan to become the second-largest national economy in the world. Its R&D intensity has also been multiplied by a factor of six. Today, only the USA publishes more scientific articles, although the impact factor of Chinese articles in the SCI remains much lower than for the Triad, China figuring just behind the Republic of Korea and on a par with India for citations of scientific papers.

The government has issued a number of key policies in the past four years to maintain a high growth rate and become an innovation-driven nation by 2020, the ambitious target of the *Outline of the Medium- and Long-term Plan* for *National Science and Technology Development* adopted in 2005. The main mechanisms incite enterprises to invest more in innovation and Chinese researchers to return home from abroad. The government also plans to recruit 2000 foreign experts over the next 5–10 years to work in national laboratories, leading enterprises and research institutes, as well as in a number of universities. Another target is to raise the GERD/GDP ratio from 1.5% to 2.5% by 2020.

In parallel, the *Eleventh Five-Year Plan* to 2010 is developing STI infrastructure at a gruelling pace, with 12 new megafacilities and 300 national key laboratories planned, among other institutions. Another focus is the environment. As part of the strategy to reduce energy consumption and emissions of major pollutants, the government plans to ensure that non-fossil energy sources represent 15% of energy consumption by 2020.

Today, the main barriers to innovation are the rapidly growing innovation risk that enterprises face, the lack of support for systemic innovation and exploration, and weak market demand for innovation.

Japan (Chapter 19) was hit hard by the global recession in 2008. After stagnating at around 2% between 2002 and 2007, growth in GDP dropped below zero, plunging major companies into distress and resulting in bankruptcies and a surge in unemployment rates.

Japanese manufacturers have traditionally excelled in steadily improving production processes and accumulating production know-how within their organizations to achieve the ultimate goal of high-quality products at competitive prices. However, this Japanese model is losing its effectiveness in many industrial fields, as China, the Republic of Korea and other nations with lower labour costs emerge as tough competitors. Under such circumstances, Japanese manufacturers have come to believe that they must constantly innovate to survive in the global market.

One consequence of this new mindset has been the rapid expansion in university–industry collaboration in recent years, resulting in numerous university start-ups. In parallel, both R&D expenditure and the number of researchers seem to be rising in the private sector. In fact, Japan retains a dominant STI position in key industries such as automobiles, electronic components, digital cameras and machine tools.

In 2004, all Japanese universities were semi-privatized and turned into 'national university corporations', with both faculty and staff losing their status as public servants. The chapter argues that many academic policies imported chiefly from the USA, such as competitive R&D funding, centres of excellence and a shift towards more frequent temporary academic positions, may have undermined the unique features of the existing university system by helping the top universities but damaging R&D capacities at other universities and destroying old domestic research networks.

Chapter 20 focuses on what is probably the world's most committed country to STI: the **Republic of Korea**. It had been enjoying high growth rates for a decade before GDP shrank by 5.6% in 2008. Nevertheless, by 2009, the economy was already expanding again, thanks to a government-led stimulus package. Part of that package included greater R&D funding to stimulate national STI. As a result, public spending on R&D actually grew in 2008–2009.

The Republic of Korea considers STI to be at the heart of economic progress and crucial to achieving a number of national goals. One of the top priorities is to increase GERD to an impressive 5% by 2012, up from an already high 3.4% in 2008. Strong investment is coupled with strong policies. For instance, Initiatives for Establishing a National Technology Innovation System was implemented in 2004 with 30 priority tasks. In 2008, the new government implemented a follow-on strategy called the *Science and Technology Basic Plan (2008–2013)* which has set itself as many as 50 priority tasks. These two plans now constitute the basic framework for STI policy. In addition, a low carbon, green growth policy was declared a key national agenda in 2008.

The final chapter on **Southeast Asia and Oceania** (Chapter 21) covers a vast geographical area stretching from Australia and New Zealand to Singapore, Thailand, Indonesia and the 22 Pacific Island countries and territories. The global economic recession has largely spared this part of the world.

In Cambodia, Thailand and Fiji, science is given a low priority so the global recession has had little impact. Countries more attached to STI, such as Singapore, Australia and New Zealand, reacted to the recession by sharpening their STI policies and aligning them more on national priorities. One R&D priority common to just about all countries in the region is sustainable development and the role that STI can play in combating climate change.

Singapore stands out as the region's most rapidly growing investor in science. Between 2000 and 2007, its R&D intensity climbed from 1.9% to 2.5%. According to the World Bank, only Viet Nam and Singapore improved their ranking in the Knowledge Index between 1995 and 2008. Growth has been largely driven by Singapore-based scientists, many of whom have come from abroad to work in its well-funded laboratories. Between 2000 and 2007, the number of FTE researchers rose by 50% to an impressive 6 088 per million population. A key national strategy has been to cluster research institutes in ICTs and biomedical research into two national knowledge hubs. This strategy has paid off, as Singapore is an emerging hub for biomedical and engineering technologies.

However, Singapore is not the only country in the region to have shifted its focus from S&T policies to STI policies. Moreover, there is a growing emphasis in the region on cross-sector R&D, such as through collaborative-project funding schemes. The face of collaborative research is changing. The rapid rise of China and India has had a knock-on effect on S&T capacity in Southeast Asia and Oceania. For example, the commodities boom led largely by India and China in recent years fed mining-related R&D in Australia, resulting in greater business R&D.

It is no coincidence that academics based in China and India figure among the top three countries of origin for co-authors in several countries in the region. Researchers are also spending more time abroad as part of their training and ongoing collaborative projects. There is clearly a higher level of international engagement and co-operation in the region than before.

CONCLUSION

Key messages

What conclusions can be drawn from the analysis above? ***First and foremost***, the disparity in development levels from one country and region to another remains striking. In 2007, per-capita income in the USA was estimated to be 30 times higher on average than in sub-Saharan Africa. Differences in economic growth rates have been compounded over the years, leading to 'divergence, big time' over the past 150 years in income levels between rich and poor countries. In the late 19th century, for instance, Nigeria was considered to be no more than a decade behind the United Kingdom in terms of technological development. The origin of this divergence in economic growth can be found in the disparate levels of investment in knowledge over long periods of time. Even today, the USA still invests more in R&D than the rest of the G7 countries combined. Four-fifths of the world's top universities also happen to be on American soil.

The past decade has challenged this picture, largely thanks to the proliferation of digital ICTs, which have made codified knowledge accessible worldwide. For sure, some early newcomers, like the Republic of Korea, had been steadily catching up to, and even leap-frogging over, countries since the 20th century by developing first their industrial capacity then S&T. But others, such as China, Brazil or India, have initiated a new, three-way process of catching up simultaneously in the industrial, scientific and technological spheres.

As a result, the past five years on which the present *UNESCO Science Report* focuses have really begun to challenge the traditional leadership of the USA. The global economic recession has compounded the situation, even if it is too early for this to be fully encapsulated in the data. The USA has been harder hit than Brazil, China or India, thereby enabling these three countries to progress faster than they would have done otherwise. Furthermore, as highlighted in the chapters on China and India, we seem to be on the verge of a structural break in the pattern of knowledge contribution to growth at the level of the global economy. This is also reflected in the arrival on the world scene of large, multinational firms from emerging countries which are moving into a wide variety of sectors that range from mature industries such as steel-making, automobile manufacturing and consumer goods to high-tech industries like pharmaceuticals and aircraft manufacturing. Companies in these emerging economies are increasingly opting for cross-border mergers and acquisitions to secure technological knowledge overnight.

Thirdly, the increase in the stock of 'world knowledge', as epitomized by new digital technologies and discoveries in life sciences or nanotechnologies, is creating fantastic opportunities for emerging nations to attain higher levels of social welfare and productivity. It is in this sense that the old notion of a technological gap can today be considered a blessing for those economies possessing sufficient absorptive capacity and efficiency to enable them to exploit their 'advantage of relative backwardness'. Countries lagging behind can grow faster than the early leaders of technology by building on the backlog of unexploited technology and benefiting from lower risks. They are already managing to leapfrog over the expensive investment in infrastructure that mobilized the finances of developed countries in the 20th century, thanks to the development of wireless telecommunications and wireless education (via satellites, etc), wireless energy (windmills, solar panels, etc) and wireless health (telemedicine, portable medical scanners, etc).

Other factors are also creating unique advantages in terms of knowledge growth. This is particularly well illustrated by the rapidly expanding pool of highly skilled labour in China and India, among others, the large numbers of redundant workers in farming and petty trade, the relative gain in the replacement of obsolete equipment with state-of-the-art technologies and the spillover effects of investment in new technology. The recognition of the importance of knowledge acquisition is a common thread running through all chapters. In Bangladesh, for instance, light engineering is producing import-substitution products that are creating employment and alleviating poverty. Endogenous technologies include ferries, power plants, machinery and spare parts. But Bangladesh is also developing the high-tech sector of pharmaceuticals. It is now 97% self-sufficient in pharmaceuticals and even exports them to Europe.

Fourthly, there is growing recognition that it is the systemic 'congruence' between the various knowledge components of the innovation system that counts when it comes to devising a successful growth strategy, as we have seen in Figure 5. In many mainly middle- and high-income countries, there is a distinct shift occurring from S&T policy to STI policy. This is having the effect of steering countries away from the linear approach starting with basic research and ending up with innovation towards more complex, systemic notions of innovation. University–industry collaboration, centres of excellence and competitive research funding are all becoming popular among countries looking to increase their STI capacity. However, as the chapter on Japan illustrates, such shifts are not easy to implement. At a time when Japan's global influence in R&D is slipping somewhat, the author of this chapter argues that the 'imported' policies cited above may have damaged the existing academic system in Japan, favouring the best institutions to the detriment of others which have been allowed to fall behind. It is true that, now and then, 'imported' policies will indeed conflict with 'home-grown' policies. To complicate matters further, even countries which have integrated this systemic congruence in their STI policies still tend to underestimate it in their overall development policies.

Fifthly, there is a growing emphasis in STI policy on sustainability and green technologies. This trend can be found in practically every single chapter of the *UNESCO Science Report*, even in parts of the world not generally characterized by a large STI effort, such as in the Arab region and sub-Saharan Africa. This holds not only for clean energy and climate research but also for the repercussions on S&T fields upstream. Space science and technology, for example, are a rapidly growing field for many developing and emerging countries. Driven by concerns about climate change and environmental degradation, developing countries are attempting to monitor their territory more closely, often via North–South or South–South collaboration, as in the case of Brazil and China for the design of Earth observation satellites, or via projects like Kopernicus–Africa involving the African Union and European Union. At the same time, space science and technology are of course being harnessed to provide ICT infrastructure for use in wireless applications in health, education and other fields. Climate change-related research has emerged as an R&D priority when it was almost totally absent from the *UNESCO Science Report 2005*. As a general broad policy comment, one can today reasonably argue that laggard regions or nations always do well to improve their absorptive capacity and remove any 'barriers' preventing the flow of positive technological spillovers from technologically leading economies, be they from the North or South.

Last but not least, national STI policies clearly face a radically new global landscape today, one in which the territorial policy focus is coming under severe pressure. On the one hand, the steep drop in the marginal cost of reproduction and diffusion of information has led to a world in which geographical borders are less and less relevant for research and innovation. Knowledge accumulation and knowledge diffusion are able to take place at a faster pace, involving a growing number of new entrants and providing a threat to established institutions and positions. This globalizing trend affects research and innovation in a variety of ways. On the other hand, contrary to a possibly somewhat simplistic reasoning, globalization does not lead to a flat world, one in which gaps in research and innovation capabilities across countries and regions are constantly narrowed. Quite to the contrary, if there is clear evidence of a concentration of knowledge production and innovation emerging *across* a wider variety of countries than before within Asia, Africa and Latin America, this knowledge is growing at a highly differentiated pace *within* countries.

REFERENCES

Battelle (2009) *Global R&D Funding Forecast*. Cleveland, Ohio, USA. Available at: www.battelle.org/news/pdfs/2009RDFundingfinalreport.pdf

Coe, D. T.; Helpman, E.; Hoffmaister, A.W. (1997) North–South R&D spillovers. *Economic Journal,* 107, 134–149.

David, P. and Foray, D. (2002) An introduction to the economy of the knowledge society. *International Social Science Journal (UNESCO*) 171, 9.

Dosi, G.; Pavitt, K.; Soete, L. (1990) *The Economics of Technical Change and International Trade*. New York University Press. Washington Square, New York.

Dunnewijk, Theo (2008) Global Migration of the Highly Skilled: A Tentative and Quantitative Approach. *UNU-MERIT Working Paper* 2008–070.

European Commission (2009) *EU Industrial R&D Investment Scoreboard.* Institute for Prospective Technological Studies, European Commission.

Freeman, C. (1992) *The Economics of Hope*. Frances Pinter, London.

—— (1987) *Technology Policy and Economic Performance: Lessons from Japan*. Frances Pinter, London.

Freeman, C. and Soete, L. (2009) Developing science, technology and innovation indicators: What we can learn from the past. *Research Policy* 38 (4), pp. 583–589.

Krugman, Paul (1979) A model of innovation, technology transfer and the world distribution of income. *Journal of Political Economy,* vol. 87, issue 2, pages 253–266.

Soete, L. (2005) On the dynamics of innovation policy: a Dutch perspective, in: P. de Gijsel and H. Schenk (eds) *The Birth of a New Economics Faculty in the Netherlands*. Springer, Dordrecht, pp. 127–149.

—— (1981) A general test of the technological gap trade theory. *Weltwirtschafliches Archiv* 117, 638–650.

Tijssen, R. and Hollanders, H. (2006) Using science and technology indicators to support knowledge-based economies. *United Nations University Policy Brief 11*.

Zanatta, M. and Queiroz, S. (2007) The role of national policies in the attraction and promotion of MNEs' R&D activities in developing countries. *International Review of Applied Economics*, 21(3), 419–435.

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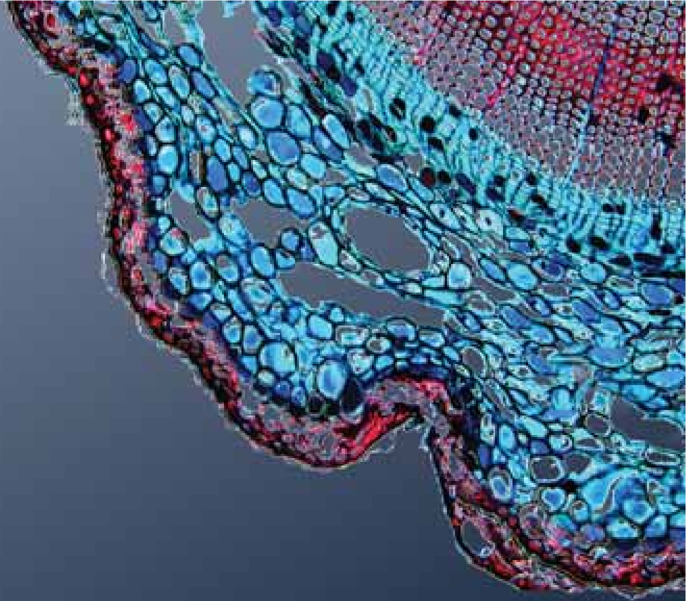

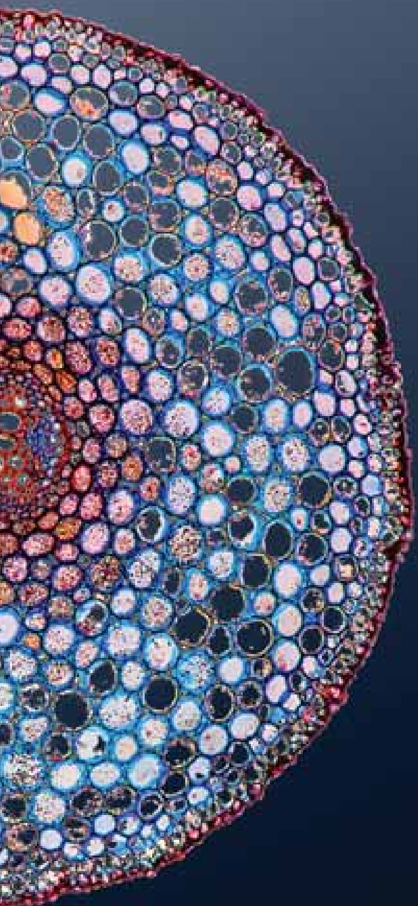

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