Policy-makers should ... focus not just on designing incentives for firms to engage in R&D [but also] facilitate non-research-related innovation, particularly in relation to technology transfer.

Elvis Korku Avenyo, Chiao-Ling Chien, Hugo Hollanders, Luciana Marins, Martin Schaaper and **Bart Verspagen**

Car assembly plant in Lovech, Bulgaria in 2012.
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2 · Tracking trends in innovation and mobility

Elvis Korku Avenyo, Chiao-Ling Chien, Hugo Hollanders, Luciana Marins, Martin Schaaper and Bart Verspagen

INTRODUCTION

Innovation is spreading its reach across the globe

With the rise of the so-called 'emerging' economies, research and development (R&D) are spreading their reach across the globe. Multinational firms are playing an important role in this process. By establishing research facilities (R&D units) in foreign countries, they are fostering knowledge transfer and the accrued mobility of research personnel. Importantly, this phenomenon is a two-way street. Multinational firms from Brazil, the Russian Federation, India, China and South Africa (the BRICS countries) are not only a magnet for foreign multinationals; these firms 'born in the BRICS' are also purchasing high-tech companies in North America and Europe and thereby acquiring skilled personnel and a portfolio of patents overnight. Nowhere is this more visible than in China and India, which together now contribute more to global expenditure on business R&D than Western Europe (Figure 2.1). In 2014, for instance, the Indian firm Motherson Sumi Systems Ltd purchased Ohio-based Stoneridge Harness Inc.'s wiring harness for US$ 65.7 million (see Chapter 22).

Different work cultures

Both private and (semi-) public agents innovate but their different work cultures affect the way in which the knowledge generated is diffused. Traditionally, scientists working in public institutions like universities have been motivated by the desire to establish a reputation that is dependent on openness. Their success depends on being first to report a discovery by publishing it in widely accessible journals, on other scientists acknowledging this discovery and building upon it in their own work. This implies that making knowledge available to colleagues and the wider public is a key element of the work of academic scientists.

Scientists working in private firms, on the other hand, have a different motivation. Respecting their employer's interests calls for secrecy and the appropriation of knowledge rather than allowing it to circulate freely. The marketplace being characterized by competition, a firm is obliged to appropriate the knowledge that it develops – in the form of goods, services and processes – to prevent competitors from imitating the discovery at a lesser cost.

Firms use a whole range of strategies to protect their knowledge, from patents and other intellectual property rights to secrecy. Although they will eventually make this knowledge available to the general public through the market, this protection of their knowledge limits its diffusion. This trade-off between the right of firms to protect their knowledge and the public good is the basis of every system of intellectual property rights employed in the global economy.

Public knowledge is not affected by this trade-off but much of the knowledge generated today involves contributions from both public and private actors. This can affect the rate at which knowledge is diffused. One obvious example is the influence of new knowledge on agricultural productivity. The so-called Green Revolution in the mid-20th century depended almost exclusively on research done by public laboratories and universities. This made the knowledge generated by the Green Revolution readily available for farmers worldwide and provided a great boost to agricultural productivity in many developing countries. However, when the advent of genetic science and modern biotechnology in the late 20th century gave agricultural productivity another boost, the situation was very different because, by this time, private firms had come to play a leading role. They protected their knowledge, leading to a much stronger dependence of farmers and others on a handful of multinational firms that could act as monopolies. This has given rise to heated debates about the economic and ethical sides of private firms developing 'breakthrough' technologies but limiting the diffusion of these.

Private science is increasingly mobile

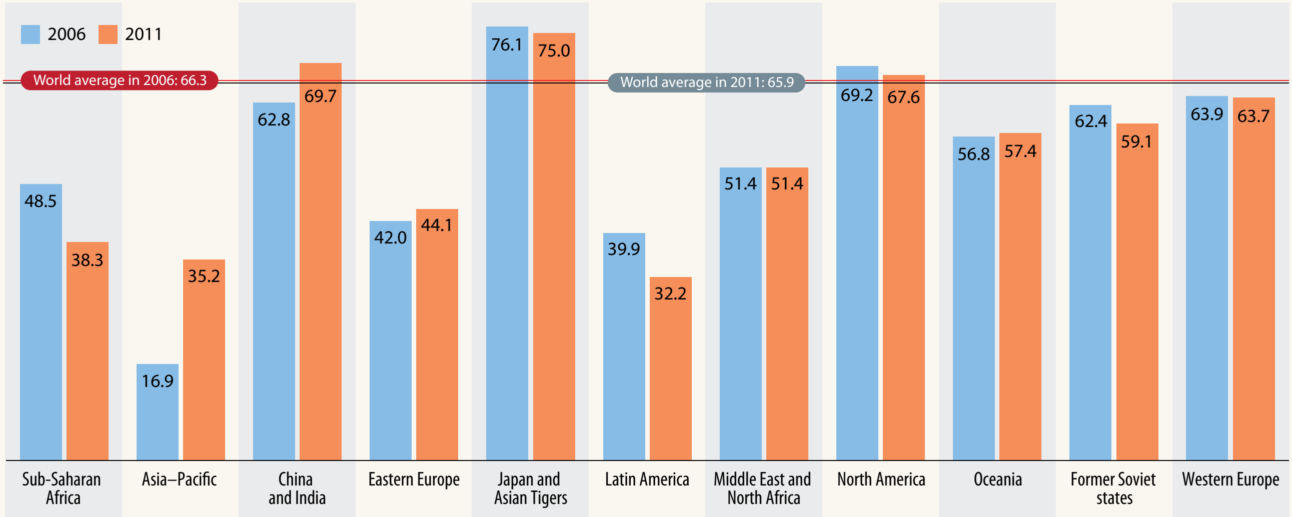
Another difference between the 'culture' of public and private science and technology concerns the degree of mobility. Private science is increasingly mobile, public science is not. Here, we are not referring to individual researchers working in the public and private sectors, who tend to see mobility as a way of furthering their careers. Rather, we are referring to differences at institutional level. Increasingly, firms are relocating their research laboratories abroad. Universities, by and large, remain much more immobile, with only a small minority setting up campuses abroad. Thus, the private sector potentially has a much bigger role to play than universities in spreading the 'resource balance' in science and technology around the world.

In 2013, the UNESCO Institute for Statistics launched its first international survey of innovation by manufacturing firms. For the first time, a database containing innovation-related indicators for 65 countries at different stages of development was made available to the public. In the following pages, we shall be exploring the types of innovation being implemented by private firms and the linkages they need with other socio-economic actors in order to innovate.

Figure 2.1: **Trends in business R&D, 2001–2011**

The contribution of business R&D to GERD has dropped since 2006 in sub-Saharan Africa, the Americas and the former Soviet states

Share of business R&D in GERD at national level, 2006 and 2011 (%)



1.08%

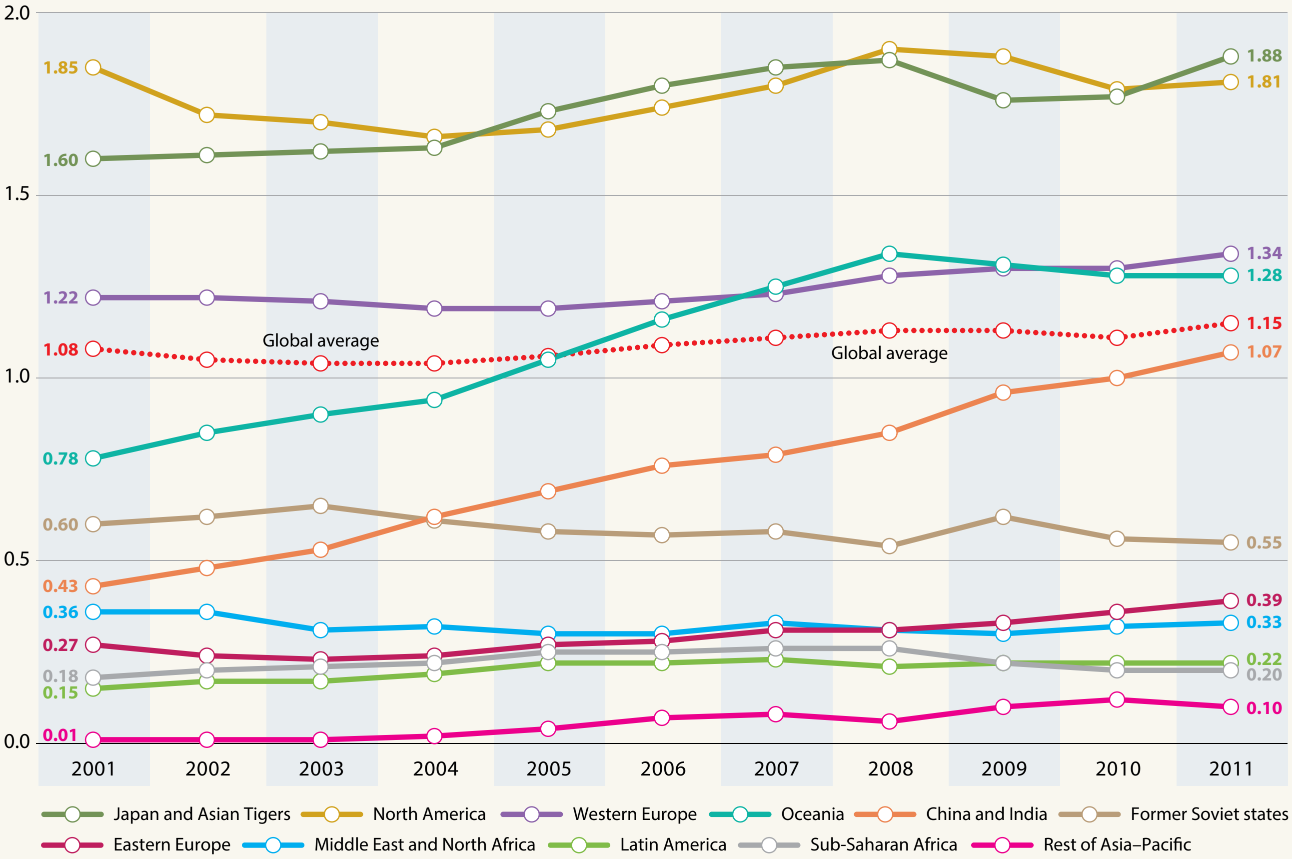
Global average for business R&D as a share of GDP in 2001

1.15%

Global average for business R&D as a share of GDP in 2011

Business R&D only contributes 0.2% of GDP in Latin America and sub-Saharan Africa

Business R&D as a share of national GDP, 2001–2011 (%)



5.1%

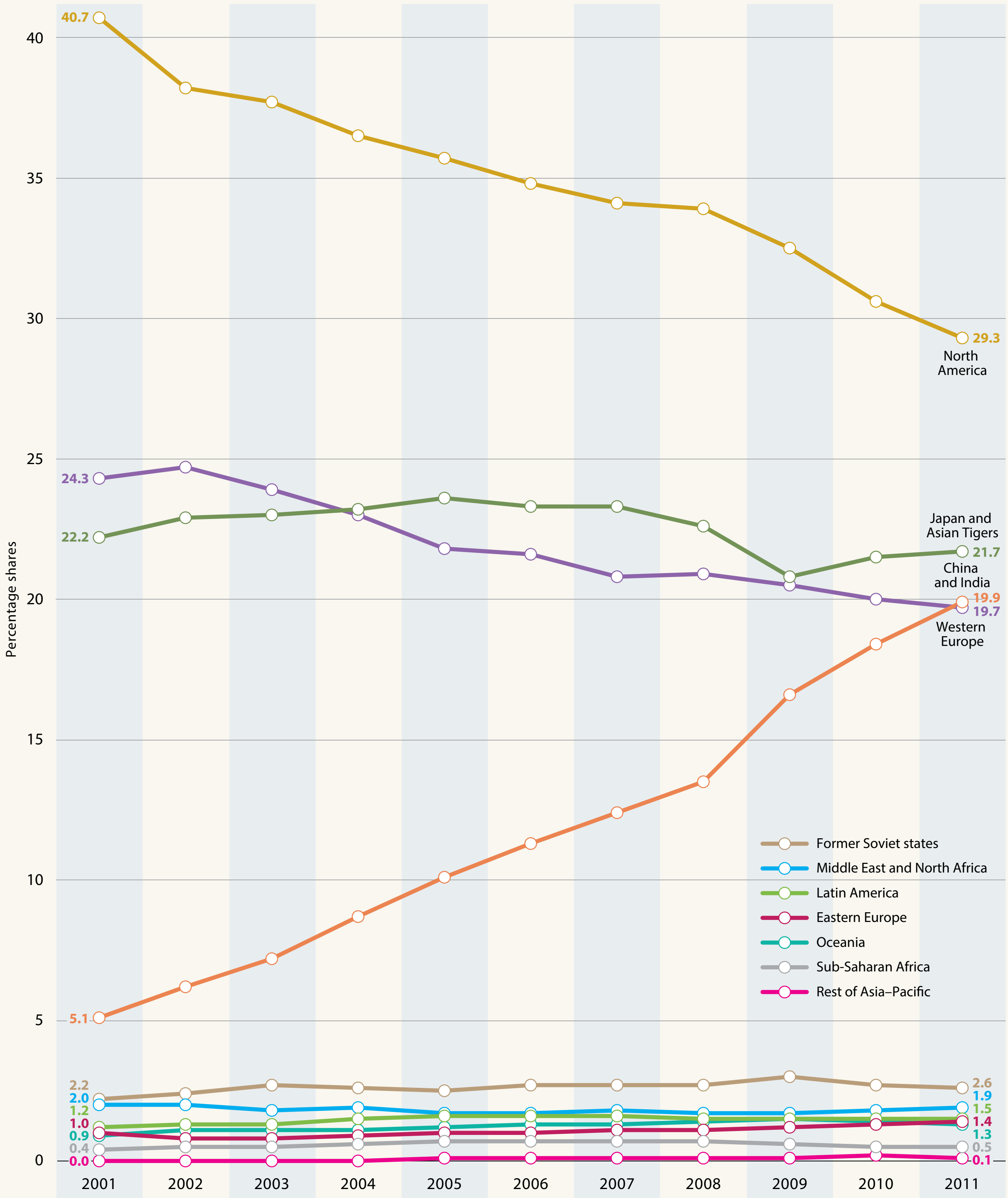
China and India's share of global business R&D in 2001

19.9%

China and India's share of global business R&D in 2011

China and India are capturing a greater share of business R&D, to the detriment of Western Europe and North America

World shares of business R&D, 2001–2011 (%), calculated in PPP$



Note: In the present chapter, the Middle East and North Africa encompasses Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Syria, Tunisia, Yemen and United Arab Emirates. See Annex 1 for the composition of the the Asian Tigers.

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

We shall also be establishing a profile of where foreign direct investment (FDI) is going around the world. Instead of ranking countries from 'most to least or best to worst,' we shall be identifying common features, as well as dissimilarities, presented by firms in countries of different income levels which are engaging in innovation. The second part of our essay will be devoted to analysing current trends in scientific mobility and the implications of these trends for a country's capacity to innovate.

TRENDS IN INNOVATION

Innovative behaviour varies according to income level

The role played by innovation in the process of economic development has long been acknowledged. Some would even argue that this relationship was first evoked more than 200 years ago in the works of English economist Adam Smith (1776) or in those of German essayist Karl Marx (1867), long before the term was formally coined by the Austrian economist Joseph Schumpeter (1942).

In the second half of the 20th century, countries began gradually including innovation in their political agenda, which raised the need to provide policy-makers with empirical evidence. Over the past two decades, a lot of work has been done to standardize the international definition of innovation and design indicators. This work culminated in the first version of the *Oslo Manual* in 1992, subsequently updated by the Organisation for Economic Co-operation and Development (OECD) and Eurostat, the European statistics office, in 1997 and 2005. Despite these efforts, measuring innovation[1] remains a challenge and the variations in the methodological procedures adopted by countries – even when the guidelines of the *Oslo Manual* are followed – hinders the production of fully harmonized indicators.

According to the 2013 survey of firms, product innovation is the most common form of innovation in 11 high-income countries and process innovation in 12 high-income countries (Figure 2.2). In Germany, around half of firms are product innovators and almost as many are marketing innovators (48%) and organizational (46%) innovators, a profile similar to that found in Canada.

Among the low- and middle-income countries that responded to the questionnaire, the profile of innovation varies considerably from one country to another; in Costa Rica, for instance, 68% of manufacturing firms are product innovators; Cuba, on the other hand, has a high share of organizational innovators (65%), whereas marketing innovators prevail in Indonesia (55%) and Malaysia (50%). In the group of low- and middle-income countries surveyed, process innovation is the least implemented type. This is somewhat preoccupying, given the supportive role that process innovation plays in the implementation of other types of innovation.

Overall, marketing innovation is the least implemented type of innovation among the 65 countries surveyed. In addition, the share of innovators among manufacturing firms varies from 10% to 50%, regardless of the type of innovation being implemented, and only a few high-income countries present even shares for all four types of innovation.

Germany has the highest innovation rate among high-income countries

From this point on, the discussion will focus only on product and process innovation. Overall, the innovation rate found in high-income countries – in other words, the share of firms engaging actively in innovation – matches the share of innovative firms. This means that the innovation rate is chiefly composed of firms that have implemented at least one product or process innovation over the reference period covered by the national innovation survey, which is usually three years.

Germany presents the highest innovation rate among high-income countries. The fact that many firms have abandoned innovation altogether or are living off ongoing activities does not hamper Germany's innovative performance as, when these firms are set aside, Germany still has one of the highest shares of innovators: 59%.

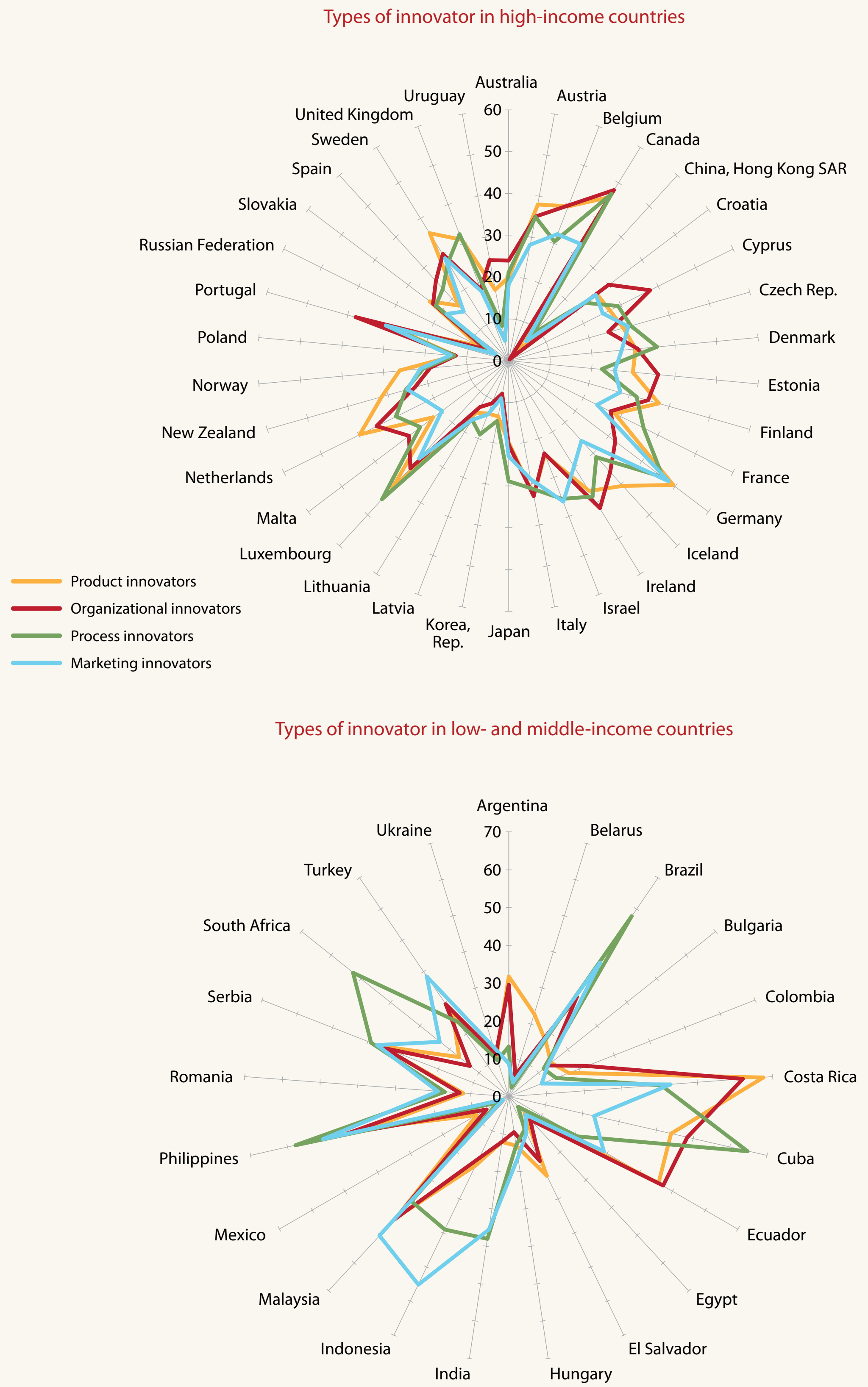
A similar trend can be observed in the group of low- and middle-income countries surveyed, with some exceptions. In Panama, for instance, around 26% of the firms surveyed declared they had only abandoned or ongoing innovation activities. This means that, despite having an innovation rate of 73%, the share of firms actually implementing innovation in Panama only amounts to 47%.

In the BRICS countries, product innovators prevail in South Africa and the Russian Federation, whereas China and India present similar shares of both types of innovators (Figure 2.3). In Brazil, the share of firms implementing process innovation is remarkably higher than the share implementing product innovation. In India, almost half of the innovation rate is composed of firms with abandoned or ongoing innovation activities.

1. See the glossary on p. 738 for the definition of terms related to innovation in the present chapter. For more information about the timeframe and methodology adopted by the countries surveyed, see UIS (2015).

Figure 2.2: **Types of innovator around the world**

Share of manufacturing firms (%)



Source: UNESCO Institute for Statistics, September 2014

Figure 2.3: **Innovation rate of firms in the BRICS**

Share of manufacturing firms (%)

Source: UNESCO Institute for Statistics, September 2014

Firms still prefer to keep investment in knowledge at home

How do firms move their resources devoted to science, technology and innovation (STI) across national borders? Although it is hard to track this phenomenon, some trends can be deduced from a database on FDI related to knowledge, the fDi Markets[2] database. We shall be examining four project categories from this database: R&D projects, the hard core of private-sector investment in knowledge; design, development and testing, the largest category, which comprises less original research than the first category; education and training; and ICTs and internet infrastructure. A basic finding of the literature on firms' investment trends is that R&D and other forms of knowledge-related investment are traditionally less globalized than other forms of investment; although multinational firms often locate their production or services-related activities such as sales and customer support abroad, they are more reluctant to do the same for investment in knowledge. This is changing but there is still a tendency to keep investment in knowledge 'at home'. For instance, a survey of the largest spenders on R&D in the European Union (EU) in 2014 found that two out of three companies considered their home country to be the most attractive location for R&D (Box 2.1).

Two broad motives for the international re-location of R&D have been identified. The first is called home-base exploiting; in other words, the adaptation of existing knowledge for new markets in the targeted markets themselves, in order to benefit from local information and the skills of local workers. This leads to a re-location of R&D in those countries where the multinational firm is also manufacturing and selling its products.

A second motive is called home-base augmenting; this targets specific knowledge found at foreign locations. This approach stems from the idea that knowledge is specific to a given location and cannot easily be transferred over long geographical distances. A reason for this may be the existence of a university or public research laboratory with very specific expertise, or a common labour market offering the skills needed to implement the R&D project that the firm has in mind.

2. The fDi Markets database contains information about individual investment projects, the firm making the investment, its country of origin and destination, as well as the date and amount of the investment (US$ 1 000).

Box 2.1: European companies rate countries' attractiveness for relocating their R&D

A survey commissioned by the European Commission in 2014 of the biggest spenders on R&D in the EU has revealed that two out of three companies consider their home country to be the most attractive location for R&D.

Beyond the home country, the USA, Germany, China and India are considered the most attractive locations in terms of human resources, knowledge-sharing and proximity to other company sites, technology poles, incubators and suppliers.

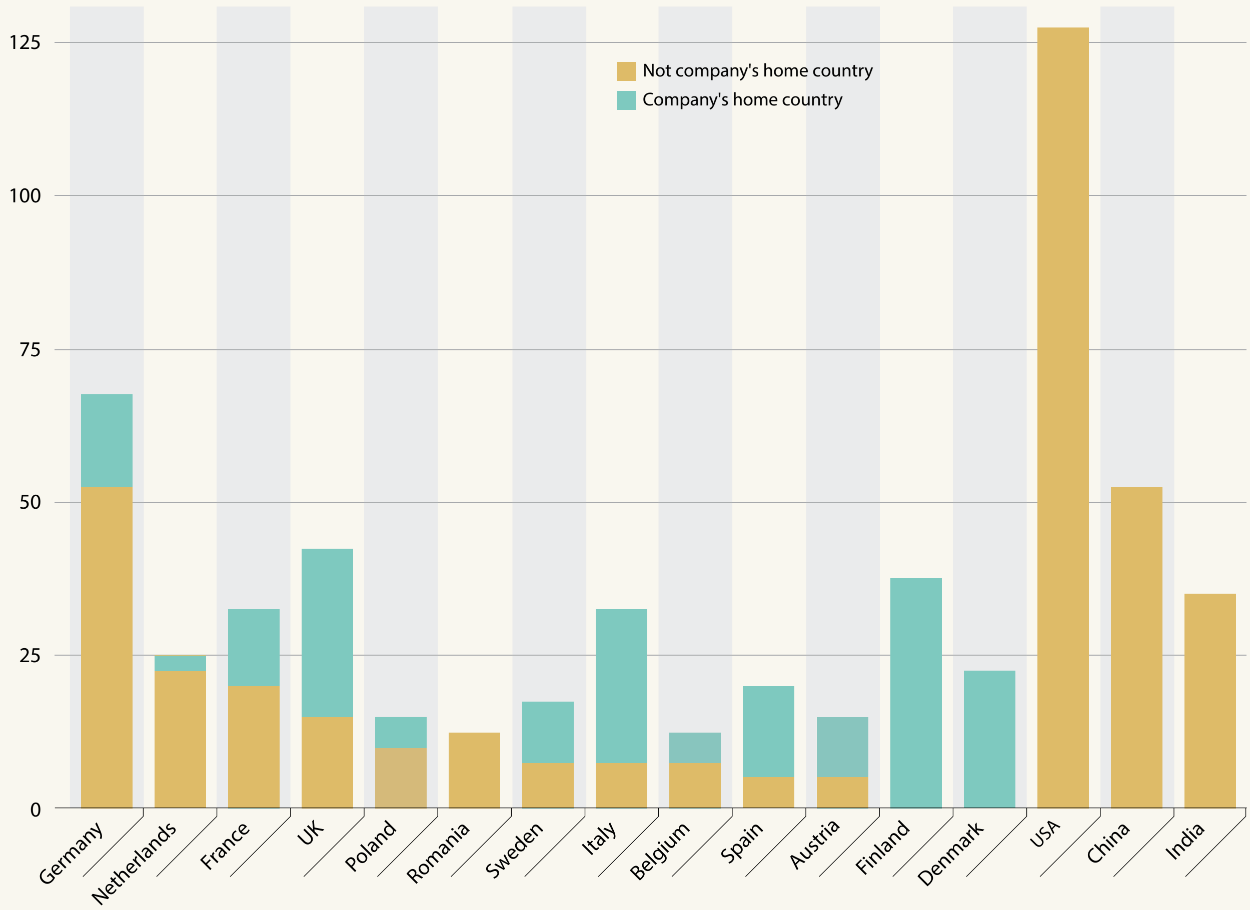
Within the EU, the quality of R&D personnel and knowledge-sharing opportunities with universities and public organizations are considered the most important criteria. Other important factors are proximity to other company sites (for Belgium, Denmark, Germany, France, Italy, Finland and Sweden) and the quantity of R&D personnel (for Italy, Austria, Poland and the UK).

Companies consider the USA as being more attractive for R&D in terms of market size and growth rate, whereas EU countries stand out for the quality of their R&D personnel in the labour market and the level of public support for R&D via grants, direct funding and fiscal incentives.

When contemplating the idea of setting up R&D units in China and India, EU companies tend to look first at market size and economic growth rate, as well as the quantity and labour cost of R&D personnel. China and India are not considered attractive in terms of intellectual property rights – especially as concerns enforcement – or public support for R&D via grants and direct funding, public–private partnerships and financing of non-R&D types of investment.

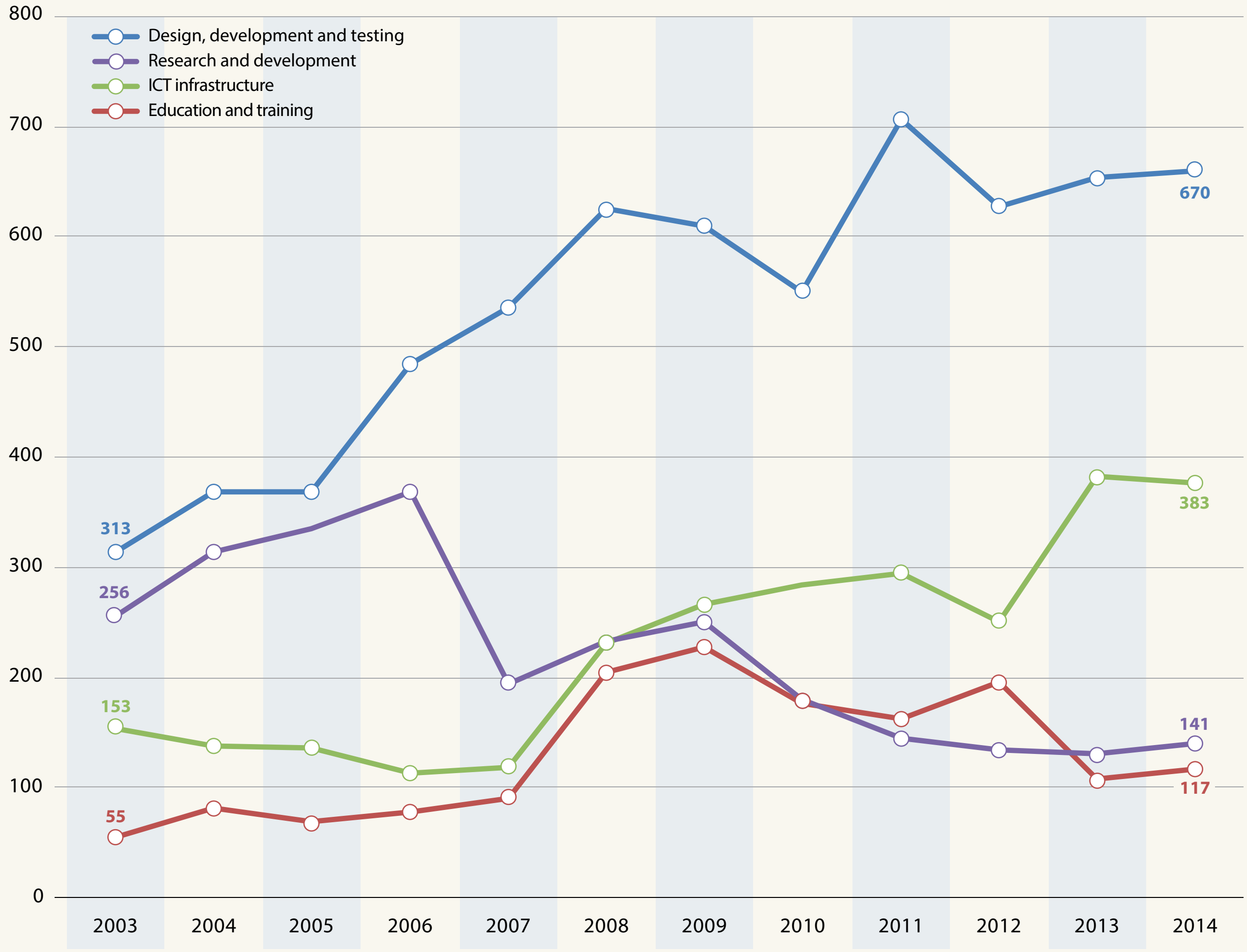
Source: (text and Figure 2.4): Executive Summary from: Joint Research Centre Institute for Prospective Technological Studies (2014) *The 2014 EU Survey on Industrial R&D Investment Trends.* See: http://iri.jrc.ec.europa.eu/survey14.html

Figure 2.4: **Most attractive countries for business R&D according to EU firms, 2014**



Note: Survey based on an attractiveness index compiled for 161 responses from 186 companies.

Figure 2.5: **Trend in number of projects in the FDI Markets database, 2003–2014**



Source: fDi Markets database, May 2015

Home-base augmenting R&D is generally seen as more 'radical', in the sense that it has greater implications for the technological capabilities of both the destination and the region in which the investment project originates. We have no way of distinguishing between these two motives directly but it would seem reasonable to expect that the 'design, development and testing' category will generally be aimed more at home-base exploiting projects than the R&D category.

A drop in the number of R&D-related FDI projects

Figure 2.5 presents an overview of the trends in the number of projects in each category. Note that the data for 2014 are incomplete. We prefer this simple count to studying the trends in invested dollars because the average investment amount per project stays roughly constant over time but varies greatly between the ICT infrastructure category and the other three. There are clear differences between the four categories, with the number of R&D projects clearly falling over time, the design category and the ICT infrastructure category rising over time and education fluctuating slightly.

The financial crisis is visible in aggregate economic indicators from 2008 onwards. The crisis does not seem to have had a marked influence on the investment projects recorded in the fDi Markets database. The top five sectors (out of 39) for FDI-related projects are software and IT services; communications; business services; pharmaceuticals; and semiconductors (Table 2.1). These five sectors cover 65% of all knowledge-related FDI projects. The R&D category is dominated by the three related sectors of pharmaceuticals, biotechnology and chemicals (57% of projects). As for the design, development and testing category, here, the trio of sectors in the top five concerns semiconductors, industrial machinery and chemicals. In the education category, the top ranking goes to business services, industrial machinery and original equipment manufacturers (OEM) in the automotive industry.

A growing tendency to converge

There is a strong concentration of private R&D in the developed parts of the globe, where about 90% of all R&D-related FDI projects originate, even if China's growing private

Table 2.1: **Sectorial distribution of knowledge-related FDI projects, 2003–2014**

Sector	Overall rank	Share of total projects (%)	Rank for R&D	Share of total projects (%)	Rank for design, development and testing	Share of total projects (%)	Rank for education	Share of total projects (%)	Rank for ICT infrastructure	Share of total projects (%)
Software & IT services	1	26	2	15	1	37	2	11	2	21
Communications	2	23	4	8	2	10	4	6	1	76
Business services	3	7	33		7	–	1	37	3	1
Pharmaceuticals	4	5	1	19	11	–	24	–	10	–
Semiconductors	5	4	6		3	7	14	–	10	–
Chemicals	–	–	3	8	5	5	–	–	–	–
Biotechnology	–	–	5	8	–	–	–	–	–	–
Industrial machinery	–	–	–	–	4	5	3	7	–	–
Automotive	–	–	–	–	–	–	5	6	–	–
Financial services	–	–	–	–	–	–	–	–	3	1
Transportation	–	–	–	–	–	–	–	–	5	0
Top 5 (%)	–	65	–	57	–	65	–	67	–	99

Source: fDi Markets database, May 2015

sector makes it a rising power (Figure 2.6). When Western Europe, North America, Japan and the Asian Tigers are on the receiving end of FDI, however, they only account for about 55% of all projects. This implies that FDI streams are tending to create a more even distribution of R&D around the world. Those parts of the world with a small share of global business R&D are attracting a relatively large share of R&D-related FDI projects from regions that are home to the great majority of private R&D (Figure 2.6).

Much of this tendency to 'converge' comes from China and India. Taken together, they attract almost 29% of all R&D-related FDI projects. China attracts the most but the number of projects is only about one-third larger than for India. By contrast, just 4.4% of these projects originate in these two countries. Africa stands out for the very low number of projects it attracts, less than 1% of the global total. As the first map[3] shows in Figure 2.6, both the destination and origin of projects are very concentrated, even within countries. China, India and, to a lesser extent, Brazil, attract numerous R&D projects but, within these large countries, only a small number of cities attract the majority of projects. In China, these locations are mostly located in coastal regions, including Hong Kong and Beijing. In India, it is Bangalore, Mumbai and Hyderabad in the south which attract the majority of projects. In Brazil, the two top cities are São Paulo and Rio de Janeiro. Africa is almost virgin territory, with the Johannesburg–Pretoria region being the only hotspot.

3. In order to keep the maps in Figure 2.6 readable, projects are documented only when at least one of the sides is not a high-income region, namely North America, Western Europe, Japan, the Asian Tigers and Oceania. Some projects do not have information on the cities.

Projects in design, development and testing paint a similar picture to that for R&D-related projects. China and India attract a slightly larger share of total FDI projects in this category, as do the other regions. Africa has crossed the 1% threshold for this category. It would seem that this type of project is more prone to globalization than those in the pure R&D category, perhaps because the knowledge embedded in design, development and testing is slightly easier to transfer – as evidenced by the larger number of FDI projects in this category – as the knowledge in this category is more akin to home-base exploiting than home-base augmenting. The map here shows the same hotspots in China, India, Brazil and South Africa as in the first map for R&D-related projects but also some additional ones, notably in Mexico (Guadalajara and Mexico City), Argentina (Buenos Aires) and South Africa (Cape Town).

In the learning and education category, the Middle East and Africa attract relatively large shares of projects. When it comes to ICT infrastructure, though, Latin America, Eastern Europe and Africa all stand out on the receiving end. The maps for these two categories tend to reproduce the same hotspots as the map of R&D-related FDI projects.

As an intermediate conclusion, we could say that the distribution of knowledge-related FDI projects is tending to become more evenly spread across the world. This is a slow trend clearly visible. However, even in terms of the very broad global regions that we used, there are large differences between different parts of the globe. Some parts of the world, such as China and India, are able to attract foreign R&D; others, such as Africa, are much less able to do so. Thus, even if convergence is taking place, it is not complete convergence in a geographical sense.

Figure 2.6: **Trends in knowledge-related FDI projects, 2003–2014**

Hardly any R&D-related projects are destined for Africa; most go to China and India

Share of total projects (%)

Source of R&D-related FDI projects	Destination of R&D-related FDI projects: Western Europe	China and India	Japan and Asian Tigers	North America	Latin America	Eastern Europe	Middle East and North Africa	Former Soviet states	Africa	Oceania	Total
Western Europe	10.6	8.3	4.3	6.0	1.8	2.4	1.1	0.8	0.5	0.5	36.2
China and India	1.7	0.3	0.7	0.9	0.1	0.1	0.4		0.1	0.1	4.4
Japan and Asian Tigers	2.0	4.6	2.5	2.0	0.1	0.2	0.1	0.3	0.0	0.2	12.1
North America	13.1	14.8	6.5	1.9	2.2	1.6	1.9	0.9	0.3	0.8	44.1
Latin America	0.1		0.0	–	0.0	–	–	–	–	0.0	0.2
Eastern Europe	0.2	0.0	0.0			0.0		0.1			0.4
Middle East and North Africa	0.3	0.3	0.0	0.3	–	0.1	–	0.0	–	–	1.1
Former Soviet states	0.2	0.0	–	0.1	–	–	–	0.0	–	–	0.3
Africa	0.0	–	–	–	–	–	–	–	–	–	0.0
Oceania	0.2	0.2	0.2	0.1	–	–	–	–	–	–	0.7
Total	28.4	28.7	14.3	11.3	4.3	4.5	3.5	2.2	0.8	1.6	

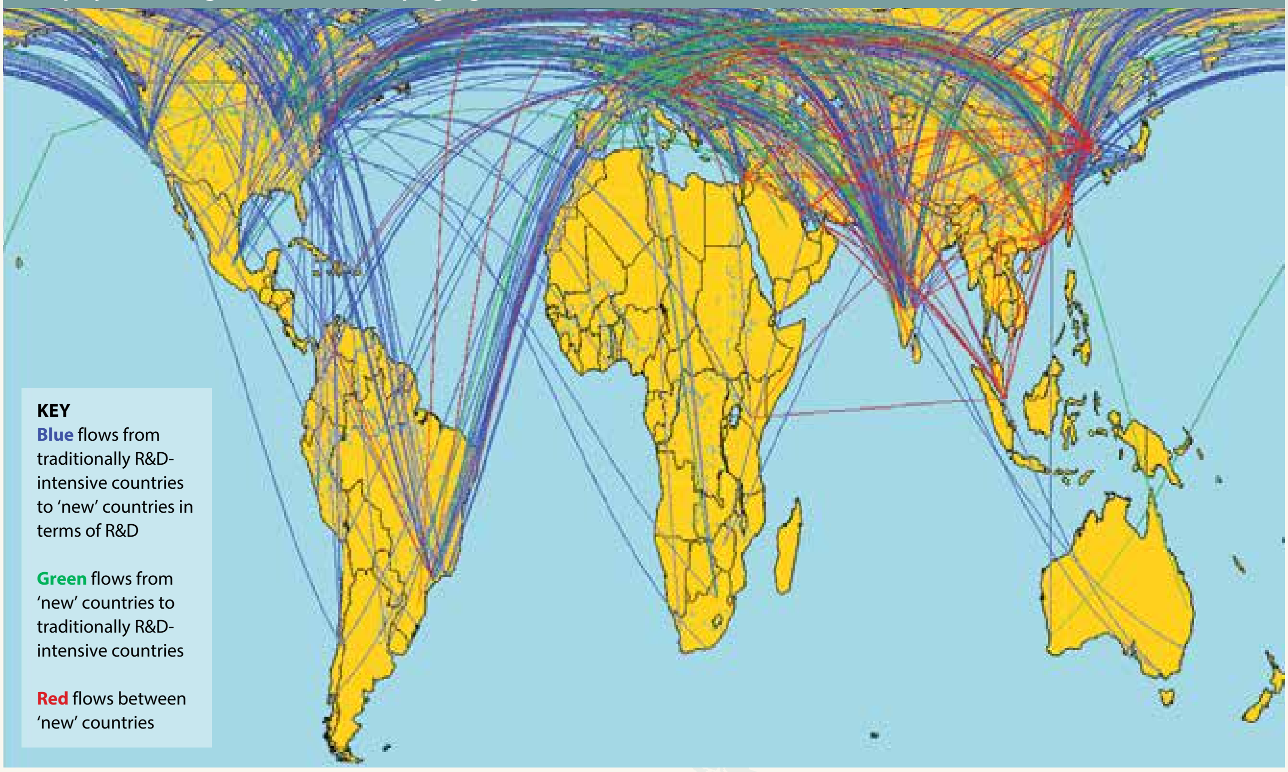
4.3%

Share of R&D-related projects destined for Latin America

28.7%

Share of R&D-related projects destined for China and India

R&D projects flowing to and from developing regions



Source: UNU-Merit

China and India are the greatest beneficiaries of projects in design, development and testing

Share of total projects (%)

Source of projects in design, development and testing	Destination: Western Europe	China and India	Japan and Asian Tigers	North America	Latin America	Eastern Europe	Middle East and North Africa	Former Soviet states	Africa	Oceania	Total
Western Europe	8.4	8.6	3.6	5.8	2.1	3.9	1.3	0.7	0.6	0.5	35.5
China and India	1.6	0.5	0.8	1.2	0.6	0.2	0.2	0.0	0.1	0.2	5.4
Japan and Asian Tigers	2.2	3.4	2.0	1.9	0.2	0.2	0.1	0.1	0.0	0.1	10.3
North America	11.0	17.4	5.4	2.0	2.8	2.5	1.5	1.0	0.3	0.9	44.9
Latin America	0.1	0.0	0.0	0.1	0.4	0.0	0.0		0.0	–	0.6
Eastern Europe	0.1	0.0	–	0.0	0.0	0.2	0.0	0.1		–	0.5
Middle East and North Africa	0.2	0.5	0.1	0.1	0.0	0.1	0.2	0.0	–	–	1.2
Former Soviet states	0.1	0.0	0.0	0.0	0.0	0.1	–	0.1	–	–	0.4
Africa	0.1	0.1	0.0	–	0.0	0.0	–	–	–	–	0.2
Oceania	0.1	0.1	0.1	0.1	–	–	0.0	0.0	0.0	0.1	0.6
Total	23.8	30.6	12.1	11.3	6.1	7.2	3.4	2.1	1.1	1.8	

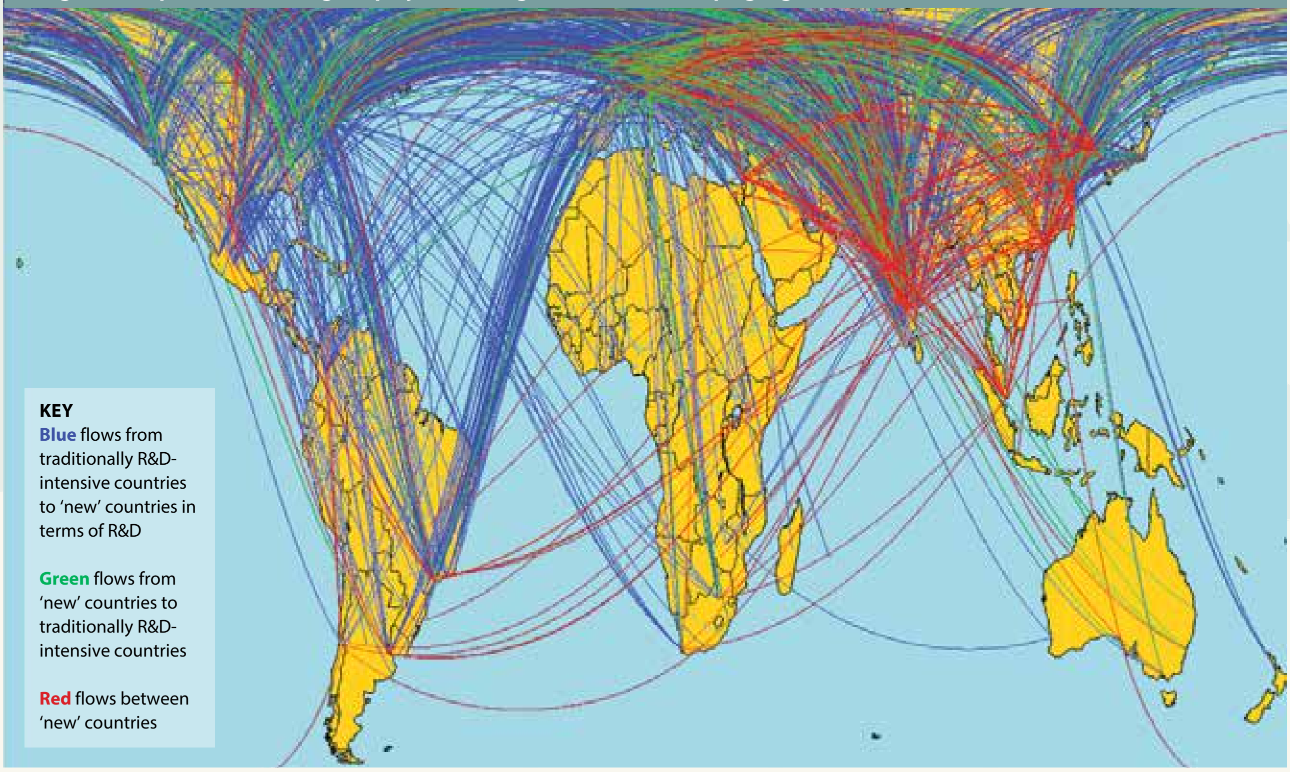
1.1%

Share of projects in design, development and testing destined for Africa

30.6%

Share of projects in design, development and testing destined for China and India

Design, development and testing FDI projects flowing to and from developing regions



Source: UNU-Merit

Figure 2.6 *(continued)*

Western Europe, China and India attract four out of ten projects in education

Share of total projects (%)

Source of FDI projets in education	Western Europe	China and India	Japan and Asian Tigers	North America	Latin America	Eastern Europe	Middle East and North Africa	Former Soviet states	Africa	Oceania	Total
	Destination of FDI projects in education										
Western Europe	8.6	7.6	5.2	4.3	2.2	2.4	4.0	1.8	2.2	0.9	**39.2**
China and India	0.7	0.9	0.8	0.5	0.9	0.2	2.0	0.1	1.1	0.1	**7.1**
Japan and Asian Tigers	2.3	3.0	2.0	1.5	0.6	0.7	0.7	0.2	0.5	0.3	**11.8**
North America	7.8	9.0	4.7	0.9	2.2	1.7	4.7	1.1	1.4	0.9	**34.3**
Latin America	0.1	0.7	0.1	–	0.1	–	–	–	0.1	–	**1.1**
Eastern Europe	0.2	–	–	0.1	–	–	–	0.1	–	–	**0.3**
Middle East and North Africa	0.5	0.5	0.2	0.1	0.1	–	1.2	–	0.1	–	**2.7**
Former Soviet states	–	0.1	0.1	–	–	–	0.1	0.1	–	–	**0.3**
Africa	–	–	–	–	–	–	0.1	–	0.5	–	**0.5**
Oceania	0.1	0.4	0.3	0.1	–	–	0.1	–	–	0.1	**1.1**
Total	**20.4**	**22.1**	**13.3**	**7.5**	**5.9**	**4.9**	**12.8**	**3.4**	**5.9**	**2.2**	

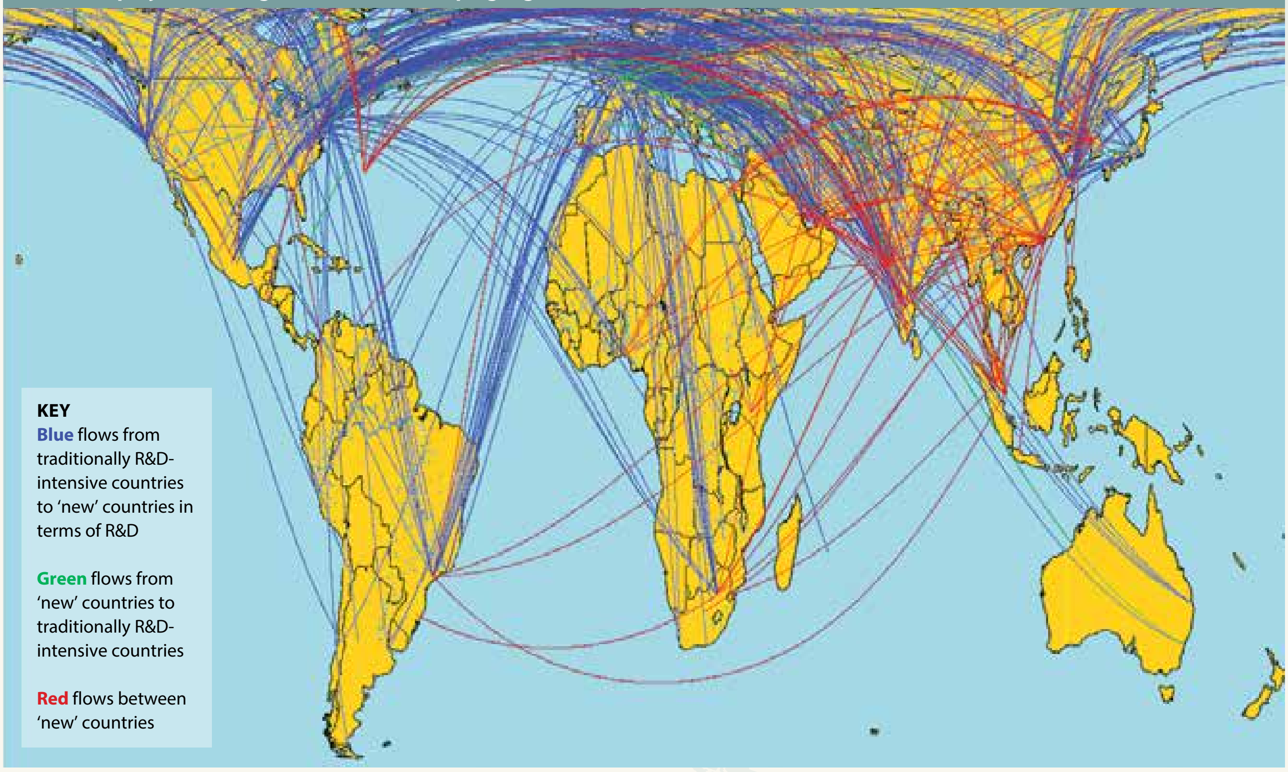
5.9%

Africa and Latin America attract the same share of projects in education

22.1%

Share of projects in education destined for China and India

Education projects flowing to and from developing regions



Source: UNU-Merit

Africa attracts more FDI projects in ICT infrastructure than in other categories

Share of total projects (%)

Source of projects in design, development and testing	Destination of FDI projects in ICT infrastructure										
	Western Europe	China and India	Japan and Asian Tigers	North America	Latin America	Eastern Europe	Middle East and North Africa	Former Soviet states	Africa	Oceania	Total
Western Europe	11.2	1.3	2.7	3.2	5.8	5.5	0.9	3.0	2.0	1.1	36.6
China and India	0.4	0.0	0.6	0.5	0.2	–	0.1	0.2	1.1	0.1	3.3
Japan and Asian Tigers	1.3	1.7	2.0	1.0	0.3	0.2	0.3	0.1	0.4	0.8	8.1
North America	13.0	3.5	7.0	2.4	4.4	1.4	0.6	0.5	0.7	2.4	35.8
Latin America	0.6	–	–	0.1	3.4	0.2	–	–	–	–	4.2
Eastern Europe	0.4	0.0	0.2	0.0	–	0.6	0.0	0.3	–	–	1.5
Middle East and North Africa	0.4	0.1	0.1	0.1	0.1	0.0	1.1	0.0	0.7	–	2.7
Former Soviet states	0.1	–	0.2	–	0.0	0.0	–	1.2	–	–	1.6
Africa	0.3	–	–		0.0	0.0	0.1		2.4		2.8
Oceania	0.2	0.1	0.2	0.1	0.0	–	–	–	–	0.1	0.8
Total	27.8	6.7	13.0	7.5	14.3	7.9	3.2	5.3	7.2	4.5	

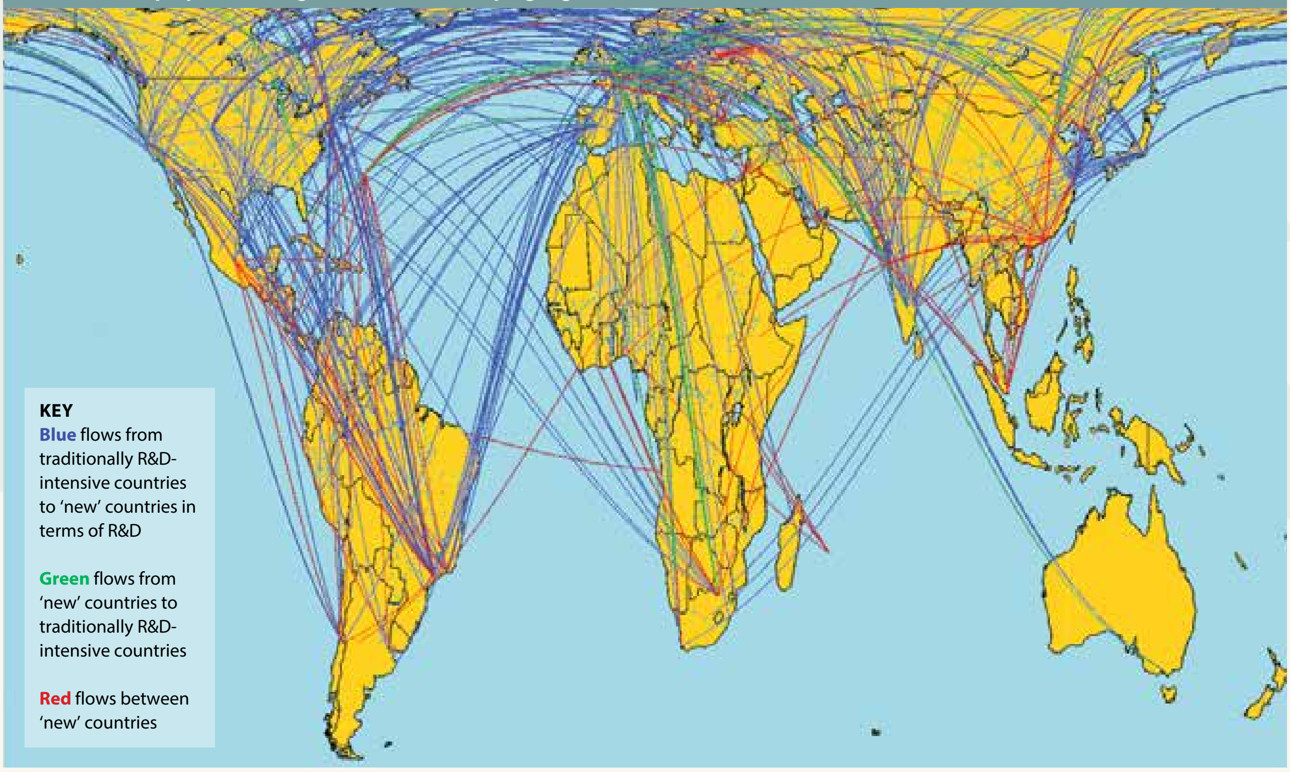
7.2%

Share of FDI projects in ICT infrastructure destined for Africa

14.3%

Share of FDI projects in ICT infrastructure destined for Latin America

Infrastructure projects flowing to and from developing regions



Source: UNU-Merit

Firms prefer in-house R&D to outsourcing

For years, R&D measures were used as a proxy for innovation on the assumption that engagement in R&D would automatically lead to the marketing of innovative products and processes. Nowadays, it has been recognized that the innovation process encompasses activities other than R&D. The relationship between these two phenomena is nevertheless still of great interest.

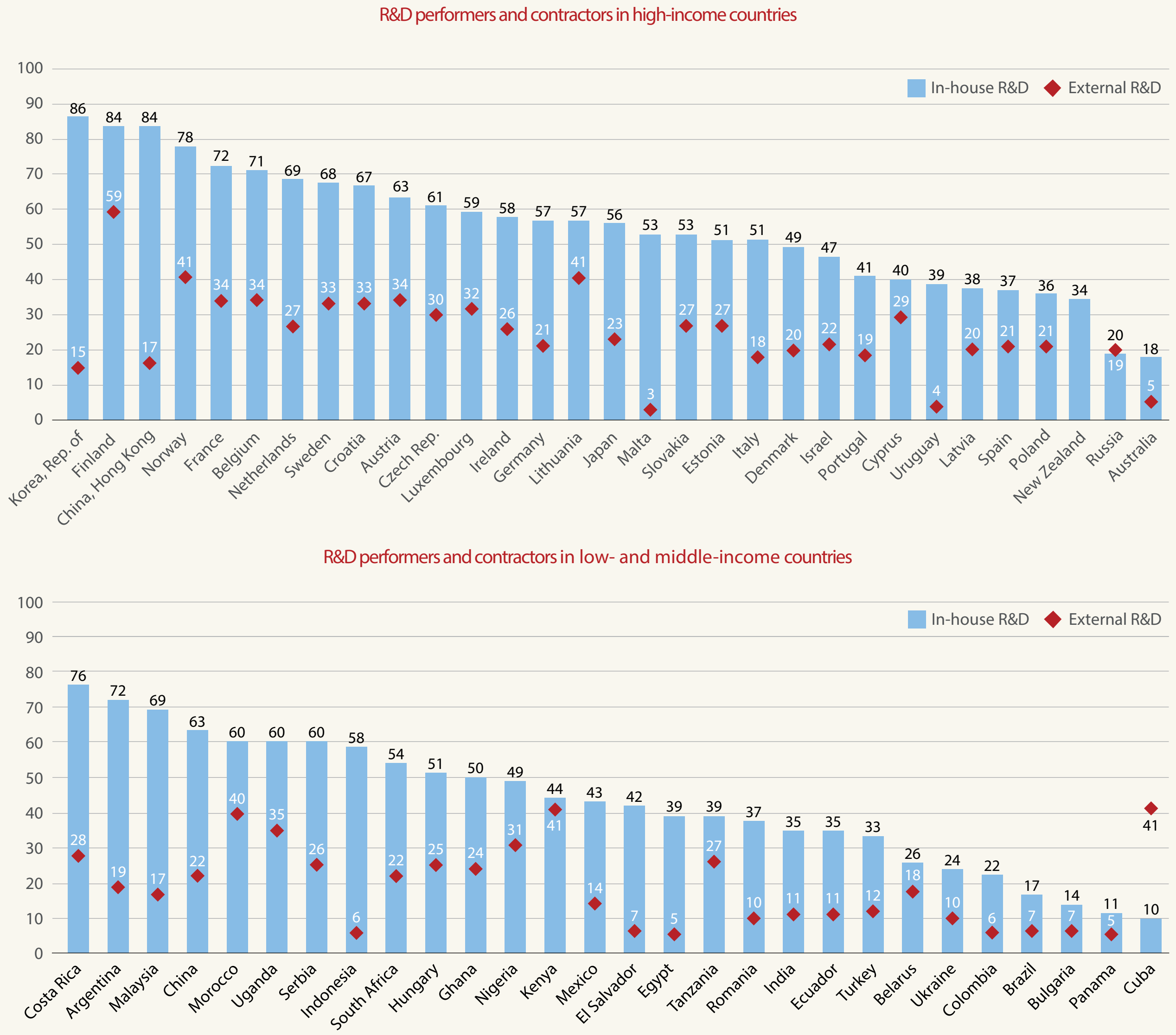
In the EU's Community Innovation Survey, which is followed by many countries worldwide, the harmonized questionnaire asks about engagement in in-house and outsourced (or external) R&D but also other activities related to innovation, such as the acquisition of machinery, equipment and software and the acquisition of other external knowledge.

Generally speaking, firms prefer in-house R&D to outsourcing, the most notable exception being Cuba (Figure 2.7). In the Republic of Korea, there is even a large gap between the share of firms performing R&D internally (86%) and externally (15%). This same phenomenon is to be found in Hong Kong (China): 84% and 17% respectively. On mainland China, almost two-thirds of firms perform in-house R&D (Box 2.2).

Overall, whereas, in 65% of high-income countries, more than half of firms perform in-house R&D, this is observed in only 40% of low- and middle-income countries. It is interesting to observe that not all firms active in innovation engage in R&D, whatever the income status of the country. This supports the argument that innovation is broader than R&D and that firms may be innovators without actually being R&D performers.

Figure 2.7: **Firms with in-house or external R&D among surveyed countries**

Share of innovation-active firms (%)



Source: UNESCO Institute for Statistics, September 2014

Box 2.2: **Innovation in the BRICS**

The great majority of firms in low- and middle-income economies acquire machinery, equipment and software to give themselves the technological edge that will enable them to innovate. The BRICS countries are no exception to the rule.

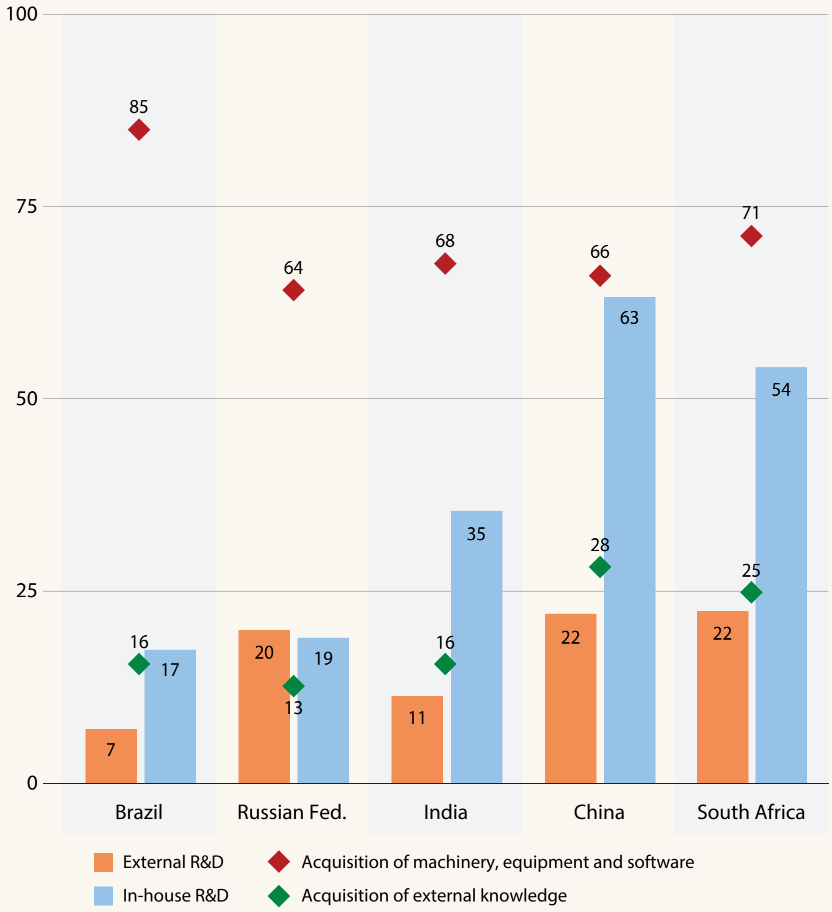
Among BRICS countries, China is the country with the highest share of firms engaging in the acquisition of external knowledge. In China, about 30% of firms engaged in innovation purchase existing know-how and licence patented and non-patented inventions or other types of external knowledge.

China also has the greatest proportion of firms performing in-house R&D (63%). This is slightly lower than the proportion of firms acquiring machinery, equipment and software. The gap between these two activities is much higher in India, the Russian Federation and, above all, Brazil.

The Russian Federation has a slightly higher share of firms outsourcing R&D than performing it in-house. Brazil has the lowest rate of outsourcing of the five countries, just 7% of firms.

Figure 2.8: **Profile of the type of innovation done by firms in BRICS countries**

Share of innovation-active manufacturing firms (%)



Source: UNESCO Institute for Statistics, September 2014

Little interaction with universities

As the innovation process is interactive, firms tend to rely on their ties to other sources of knowledge for information and co-operation. Internal sources of information are most frequently rated as highly important by firms in countries of all income levels. This is even the predominant source of information in all but one high-income country (Table 2.2). Only in the Russian Federation is another source of information highly important, that supplied by clients or customers.

In the other BRICS countries, both customers and internal sources predominate as highly important sources of information: in China and India, 60% and 59% of firms respectively rate their customers as such. Also of note is that firms in Brazil and India rate their suppliers equally highly.

Although the majority of firms in low- and middle-income countries also rate internal sources of information as being highly important, there are more countries in this category where clients or customers prevail. Moreover, suppliers are rated as highly important by 53% of the firms active in innovation in Argentina, making them most important source of information in this country.

Cuba is the only country where as many as 25% of firms consider the government or public research institutes as being highly important sources of information. Overall, most firms do not consider government sources – including institutions of higher education – as highly important sources of information.

A similar situation prevails in terms of partnerships. Very few firms interact with government institutions such as universities and public research institutes (Table 2.3). The low proportion of firms co-operating with universities is of concern, given the contribution that the latter make to the generation and dissemination of knowledge and technology and their role as suppliers of graduates to firms (Figure 2.9).

Table 2.2: **Highly important sources of information for firms**

Share of innovation-active manufacturing firms (%)

	SOURCES OF INFORMATION									
	Internal	Market				Institutional		Other		
	Within your enterprise or enterprise group	Suppliers of equipment, materials, components or software	Clients or customers	Competitors or other enterprises in your sector	Consultants, commercial labs or private R&D institutes	Universities or other higher education institutions	Government or public research institutes	Conferences, trade fairs, exhibitions	Scientific journals and trade/ technical publications	Professional and industry associations
High-income countries										
Australia	72.9	28.6	42.1	21.0	13.7	1.2	2.9	10.0	23.0	16.3
Belgium	55.1	26.7	28.7	8.4	4.7	5.2	1.6	11.7	6.7	3.1
Croatia	44.0	27.7	33.2	14.5	5.3	2.7	0.5	14.1	8.2	2.4
Cyprus	92.8	71.9	63.4	48.1	41.3	6.0	5.5	63.0	31.5	20.4
Czech Rep.	42.7	21.8	36.8	18.5	3.9	4.3	2.3	13.3	3.8	1.9
Estonia	30.1	29.4	18.8	9.3	5.8	4.2	1.1	12.7	2.0	1.3
Finland	63.4	17.3	41.1	11.7	3.6	4.5	2.8	8.8	3.4	2.5
France	51.2	19.9	27.8	9.4	6.2	3.4	3.1	10.8	7.9	5.5
Israel	79.3	17.6	19.1	7.9	7.5	3.7	2.2	13.7	6.7	2.1
Italy	35.5	18.8	17.6	4.5	15.1	3.7	1.0	9.7	3.7	4.4
Japan	33.7	20.7	30.5	7.5	6.2	5.1	4.8	4.6	2.0	2.9
Latvia	44.4	23.3	23.9	16.5	7.8	3.4	1.6	20.2	7.1	3.4
Lithuania	37.5	15.6	18.9	12.2	4.1	2.9	3.8	13.1	2.2	0.5
Luxembourg	68.3	36.5	46.1	24.6	12.6	7.8	3.6	38.3	24.0	18.6
Malta	46.0	39.0	38.0	21.0	10.0	4.0	2.0	13.0	2.0	3.0
New Zealand	86.4	51.0	76.3	43.1	43.4	10.2	16.0	45.9	48.3	21.4
Norway	79.1	50.4	78.3	30.0	9.4	7.2	10.5	10.5	16.0	30.4
Poland	48.2	20.2	19.2	10.1	5.2	5.8	7.3	14.8	10.3	4.8
Portugal	33.9	18.5	30.3	10.2	5.9	3.2	2.2	13.9	6.0	4.3
Korea, Rep.	47.4	16.1	27.7	11.3	3.4	3.9	6.1	6.7	5.2	4.9
Russian Fed.	32.9	14.1	34.9	11.3	1.7	1.9	–	7.4	12.0	4.1
Slovakia	50.5	27.2	41.6	18.1	2.8	2.5	0.6	12.4	13.6	1.4
Spain	45.5	24.2	20.9	10.4	8.7	5.0	7.7	8.7	4.7	3.9
Uruguay	52.9	24.2	40.3	21.2	13.6	5.8	–	27.1	18.0	–
Low- and middle-income countries										
Argentina	26.4	52.7	36.3	16.4	28.5	40.0	42.4	–	–	–
Brazil	41.3	41.9	43.1	23.8	10.2	7.0	–	–	–	–
Bulgaria	28.6	22.4	26.1	13.6	5.5	–	–	13.6	9.4	5.1
China	49.5	21.6	59.7	29.6	17.1	8.9	24.7	26.7	12.0	14.8
Colombia	97.6	42.5	52.6	32.1	28.4	16.2	8.0	43.7	47.3	24.5
Cuba	13.6	–	11.5	5.1	–	19.6	24.7	–	–	–
Ecuador	67.0	34.9	59.0	27.1	10.7	2.0	2.2	22.2	42.5	6.3
Egypt	75.9	32.1	16. 1	17.0	2.7	1.8	0.9	22.3	13.4	4.5
El Salvador	–	26.4	40.3	5.4	15.2	3.8	1.8	13.9	10.3	–
Hungary	50.5	26.4	37.4	21.3	13.0	9.9	3.3	16.6	9.6	7.7
India	58.5	43.3	59.0	32.6	16.8	7.9	11.0	29.7	15.1	24.5
Indonesia	0.4	1.3	1.8	1.3	0.9	0.4	0.4	0.9	0.9	0.9
Kenya	95.7	88.2	90.3	80.6	52.7	37.6	39.8	71.0	64.5	72.0
Malaysia	42.4	34.5	39.0	27.9	15.0	9.5	16.7	28.1	21.7	23.6
Mexico	92.2	43.6	71.9	44.0	19.0	26.4	23.6	36.9	24.5	–
Morocco	–	51.3	56.4	15.4	17.9	6.4	12.8	43.6	34.6	25.6
Nigeria	51.7	39.3	51.7	30.0	14.6	6.8	4.1	11.5	7.1	20.2
Panama	43.6	10.9	15.2	6.6	5.2	2.4	2.4	5.2	0.5	1.9
Philippines	70.7	49.5	66.2	37.9	21.2	10.1	7.1	21.7	16.7	15.7
Romania	42.1	31.8	33.5	20.5	5.2	3.3	2.0	14.3	10.2	3.5
Serbia	36.2	18.3	27.3	10.5	7.8	5.3	2.6	14.8	10.3	5.7
South Africa	44.0	17.9	41.8	11.6	6.9	3.1	2.3	12.9	16.7	8.4
Tanzania	61.9	32.1	66.7	27.4	16.7	7.1	11.9	16.7	9.5	20.2
Turkey	32.6	29.1	33.9	18.0	5.2	3.7	2.8	19.7	9.4	6.9
Uganda	60.9	24.8	49.0	23.0	12.2	3.2	5.0	16.4	8.3	11.3
Ukraine	28.6	22.4	21.9	11.0	4.7	1.9	4.6	14.7	9.1	4.0

Source: UNESCO Institute for Statistics, September 2014

Table 2.3: **Partners with which firms co-operate in innovation**

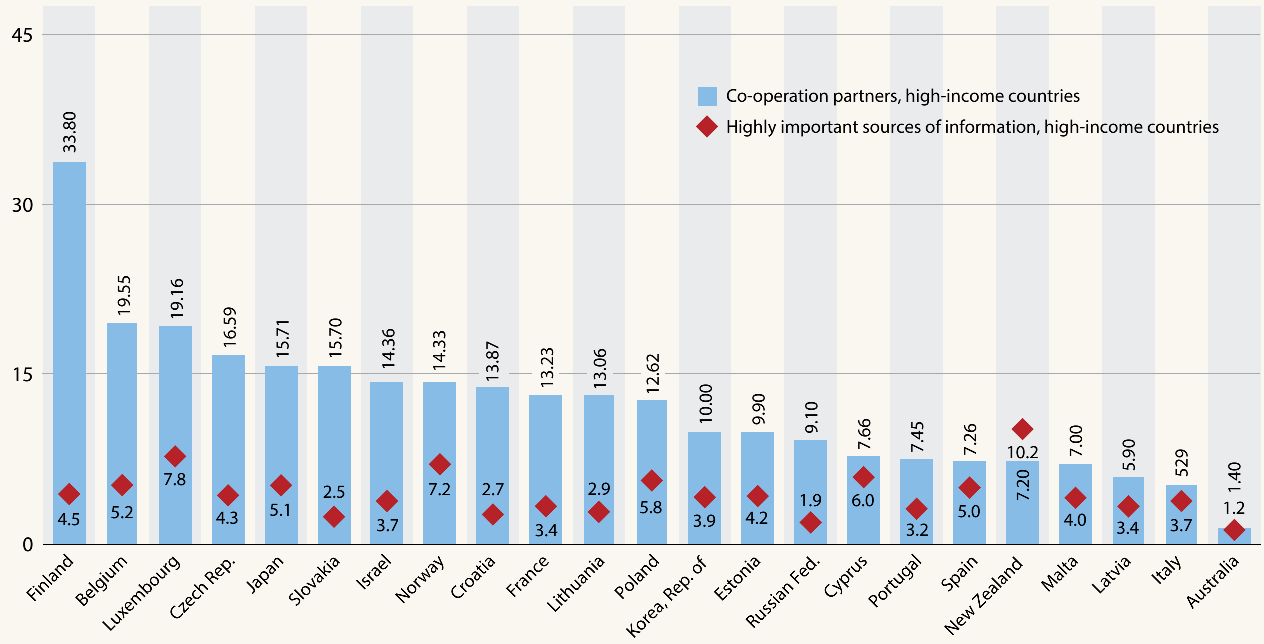
Share of innovation-active manufacturing firms (%)

	CO-OPERATION						
	Other enterprises within your enterprise group	Suppliers of equipment, materials, components or software	Clients or customers	Competitors or other enterprises in your sector	Consultants, commercial labs or private R&D institutes	Universities or other higher education institutions	Government or public research institutes
High-income countries							
Australia	21.4	49.4	41.6	21.4	36.2	1.4	5.6
Austria	21.2	30.2	22.8	8.0	20.2	24.7	11.6
Belgium	17.7	32.4	19.2	9.3	16.5	19.6	10.8
Croatia	8.6	26.1	21.6	13.9	12.3	13.9	9.1
Cyprus	8.1	51.9	45.5	37.0	34.0	7.7	9.4
Czech Rep.	14.5	25.6	21.1	10.0	14.0	16.6	6.6
Denmark	16.8	28.9	25.1	9.1	17.2	14.5	10.5
Estonia	20.3	23.6	23.1	10.5	11.3	9.9	2.5
Finland	23.6	38.1	41.6	33.2	34.2	33.8	24.8
France	16.1	23.6	20.2	9.8	14.3	13.2	10.8
Germany	8.6	14.2	13.5	3.0	8.7	17.1	8.1
Iceland	6.2	9.5	23.7	3.8	1.9	10.4	15.6
Ireland	15.4	19.6	17.0	4.1	15.1	13.0	10.0
Israel	–	28.8	40.1	15.4	20.3	14.4	10.1
Italy	2.2	6.7	5.1	2.7	6.6	5.3	2.2
Japan	–	31.7	31.5	19.9	16.9	15.7	14.4
Korea, Rep.	–	11.5	12.8	8.1	6.3	10.0	12.8
Latvia	14.0	20.8	19.6	14.0	10.6	5.9	1.9
Lithuania	17.7	31.3	24.2	11.3	14.8	13.1	8.6
Luxembourg	22.8	31.7	29.9	19.2	22.8	19.2	22.8
Malta	13.0	12.0	8.0	4.0	7.0	7.0	3.0
Netherlands	14.5	26.3	14.7	7.7	13.7	11.0	7.8
New Zealand	–	18.2	18.7	16.6	–	7.2	5.9
Norway	16.8	22.1	22.0	7.6	19.4	14.3	18.1
Poland	11.2	22.7	15.2	7.7	10.1	12.6	9.0
Portugal	5.1	13.0	12.2	4.7	8.3	7.5	4.8
Russian Fed.	12.6	16.7	10.9	3.9	5.1	9.1	15.6
Slovakia	18.6	31.5	27.8	20.8	16.1	15.7	10.8
Spain	5.5	10.4	6.7	3.5	6.3	7.3	9.7
Sweden	33.3	35.9	30.7	14.2	29.7	18.3	8.8
UK	6.2	9.4	11.0	3.8	4.5	4.7	2.5
Low- and middle-income countries							
Argentina	–	12.9	7.6	3.5	9.3	14.5	16.1
Brazil	–	10.0	12.8	5.2	6.2	6.3	–
Bulgaria	3.9	13.6	11.2	6.4	5.8	5.7	3.0
Colombia	–	29.4	21.0	4.1	15.5	11.2	5.3
Costa Rica	–	63.9	61.1	16.5	49.6	35.3	8.1
Cuba	–	15.3	28.5	22.1	–	14.9	26.4
Ecuador	–	62.4	70.2	24.1	22.1	5.7	3.0
Egypt	–	3.6	7.1	0.9	7.1	1.8	0.9
El Salvador	–	36.9	42.1	1.3	15.3	5.5	3.4
Hungary	15.5	26.9	21.1	16.4	20.1	23.1	9.9
Indonesia	–	25.7	15.9	8.0	10.2	8.4	4.9
Kenya	–	53.8	68.8	54.8	51.6	46.2	40.9
Malaysia	–	32.9	28.8	21.2	25.5	20.7	17.4
Mexico	–	–	–	9.7	–	7.0	6.1
Morocco	–	25.6	–	–	19.2	3.8	–
Panama	–	64.5	0.5	18.5	3.8	1.4	7.6
Philippines	91.2	92.6	94.1	67.6	64.7	47.1	50.0
Romania	2.8	11.7	10.6	6.2	5.9	7.2	3.1
Serbia	16.6	19.4	18.3	13.0	12.4	12.5	9.8
South Africa	14.2	30.3	31.8	18.6	21.1	16.2	16.2
Turkey	10.4	11.6	10.7	7.4	7.9	6.4	6.6
Ukraine	–	16.5	11.5	5.3	5.7	4.2	6.6

Source: UNESCO Institute for Statistics, September 2014

Figure 2.9: **Firms' linkages with universities and related institutions**

Share of innovation-active manufacturing firms (%)



TRENDS IN SCIENTIFIC MOBILITY

The diaspora can boost innovation at home and abroad

Although new technologies like the internet have opened up possibilities for virtual mobility, physical movement remains crucial to cross-fertilize ideas and spread scientific discoveries across time and space. The following discussion will be examining recent trends in international scientific mobility, defined as the cross-border physical movement of people who participate in research training or research work. For the purpose of this analysis, we shall draw on the international learning mobility and career of doctorate-holders studies undertaken jointly by the UNESCO Institute for Statistics, OECD and Eurostat.

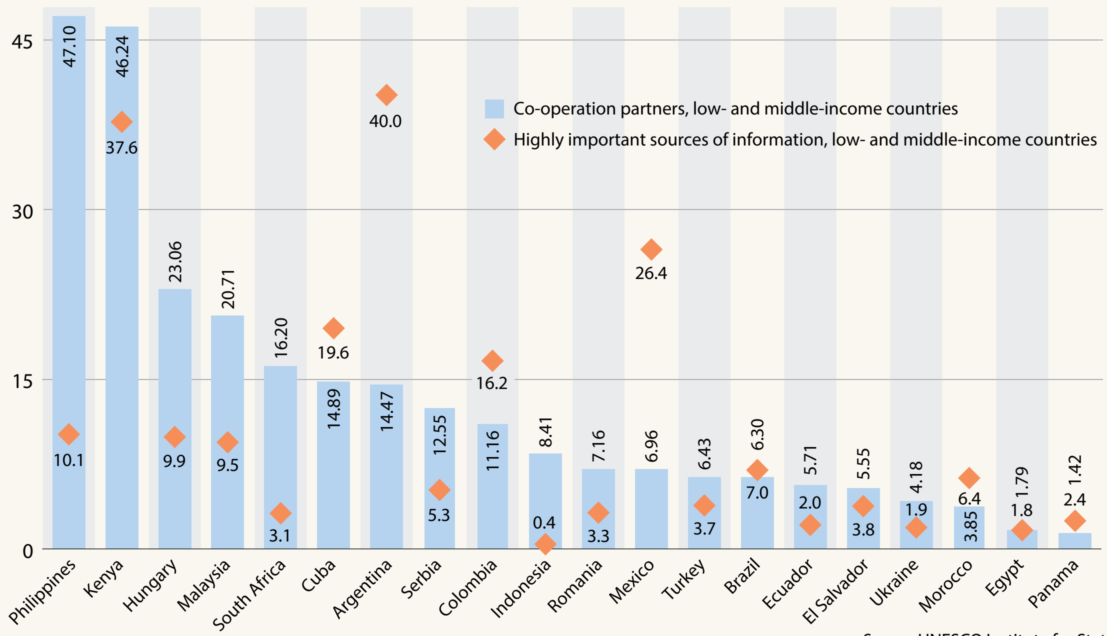
There is a wealth of evidence to support the claim that diaspora knowledge networks can transform the local and international environment for innovation. As far back as the 1960s and 1970s, the Korean and Taiwanese diaspora were persuaded to leave California's Silicon Valley to establish science parks in their homeland (Agunias and Newland, 2012). Another example is the Colombian network of scientists and engineers abroad, which was set up in 1991 to reconnect expatriates with their home country (Meyer and Wattiaux, 2006).

A more recent case study concerns the Indian diaspora's role in India's information technology (IT) industry, which contributed as much as 7.5% to India's GDP in 2012. Perhaps the most famous Indian expatriate in the IT industry is Satya Nadella, an engineer who was appointed chief executive officer of Microsoft in 2014 after joining the multinational in 1992. In the 1990s, many Indians working in the USA's IT industry began collaborating with their counterparts in India and outsourcing their work. A 2012 survey shows that 12 of the top 20 IT firms in India have expatriate Indians as founders, co-founders, chief executive officers or managing directors (Pande, 2014). In 2009, the Indian government launched the Global Indian Network of Knowledge to facilitate knowledge exchange between the diaspora and India in business, IT and education (Pande, 2014).

Between 2006 and 2015, the Dutch government implemented the Temporary Return of Qualified Nationals projects to help a number of post-conflict countries build their technological capacity and transfer knowledge. The voluntary return of highly qualified overseas nationals to Afghanistan for a maximum of six months to help rebuild their country has already brought about technological change and innovation in education, engineering and health (Siegel and Kuschminder, 2012). Elsewhere, temporary returnees have introduced new technology, revised university curricula and trained local instructors, among other things. One factor contributing to the project's success is the participants' substantial knowledge of the local language and culture.

Scientific mobility nurtures international research collaboration

When Woolley *et al.* (2008) surveyed scientists in six Asia–Pacific countries, they found that those who had obtained research degrees and trained overseas were also active participants in international research collaboration. Jöns (2009) discovered



Source: UNESCO Institute for Statistics, September 2014

that research collaboration between visiting academics and their German colleagues survived beyond the end of the academic's stay. Meanwhile, Jonkers and Tijssen (2008) found that the growth in China's internationally co-authored publications could be explained by the high population of the Chinese scientific diaspora established in various host countries; they also found that Chinese returnees had an impressive record of international copublications.

International scientific collaboration is obviously invaluable for tackling global scientific issues such as climate change and water, food or energy security and for integrating local and regional actors into the global scientific community. It has also been widely used as a strategy for helping universities improve the quality and quantity of their research output. Halevi and Moed (2014) argue that countries in a phase of *building up* their capacity begin establishing projects with foreign research teams in scientifically advanced countries, in particular; these projects are often funded by foreign or international agencies with a focus on specific topics. This trend is evident in countries such as Pakistan and Cambodia where the great majority of scientific articles have international co-authors (see Figures 21.8 and 27.8). Later, when countries' research capacity increases, they move on to the phase of *consolidation and expansion.* Ultimately, countries enter the phase of *internationalization:* their research institutions start functioning as fully fledged partners and increasingly take the lead in international scientific co-operation, as has happened in Japan and Singapore (see Chapters 24 and 27).

Competition for skilled workers likely to intensify

A number of governments are keen to promote scientific mobility as a route to building research capacity or maintaining an innovative environment. In the coming years, the competition for skilled workers from the global pool will most likely intensify. This trend will depend in part on factors such as levels of investment in science and technology around the world and demographic trends, such as low birth rates and ageing populations in some countries (de Wit, 2008). Countries are already formulating broader policies to attract and retain highly skilled migrants and international students, in order to establish an innovative environment or maintain it (Cornell University *et al.*, 2014).

Brazil and China are among countries showing a renewed policy interest in promoting mobility. In 2011, the Brazilian government launched the Science without Borders programme to consolidate and expand the national innovation system through international exchanges. In the three years to 2014, the government awarded 100 000 scholarships to talented Brazilian students and researchers to study fields of science, technology, engineering and mathematics at the world's top universities. In addition to promoting outbound mobility, the Science without Borders programme provides highly qualified researchers from overseas with grants to work with local researchers on joint projects (See box 8.3).

China, the country with the largest number of students living abroad, has seen a shift in its own policy on scientific mobility. For many years, the Chinese government fretted about brain drain. In 1992, the government began encouraging students who had settled abroad to return home for short visits to mainland China (see Box 23.2). In 2001, the government adopted a liberalized policy inviting the diaspora to contribute to modernizing the country without any obligation to move back to China (Zweig *et al.*, 2008). In the past decade, the government's ambition of increasing the number of world-class universities has spawned a rash of government scholarships for study abroad: from fewer than 3 000 in 2003 to over 13 000 in 2010 (British Council and DAAD, 2014).

Regional schemes in Europe and Asia promoting mobility

There are also regional policies promoting scientific mobility. Launched in 2000, the EU's European Research Area exemplifies this trend. To enhance the competitiveness of European research institutions, the European Commission has launched a range of programmes to facilitate researchers' international mobility and strengthen multilateral research co-operation within the EU. For instance, the EU's Marie Skłodowska-Curie actions programme provides researchers with grants to promote transnational, intersectorial and interdisciplinary mobility.

Another initiative that is influencing cross-border mobility is EU's requirement for publicly funded institutions to announce their vacancies internationally to provide an open labour market for researchers. Moreover, the 'scientific visa' package expedites administrative procedures for researchers applying from non-EU countries. Around 31% of post-doctoral researchers in the EU have worked abroad for over three months at least once in the past ten years (EU, 2014).

A similar initiative that is still in the early stages is the *Plan of Action on Science, Technology and Innovation, 2016–2020* (APASTI) adopted by the Association of Southeast Asian Nations. APASTI aims to strengthen scientific capacity in member states by fostering exchanges among researchers both within the region and beyond (see Chapter 27).

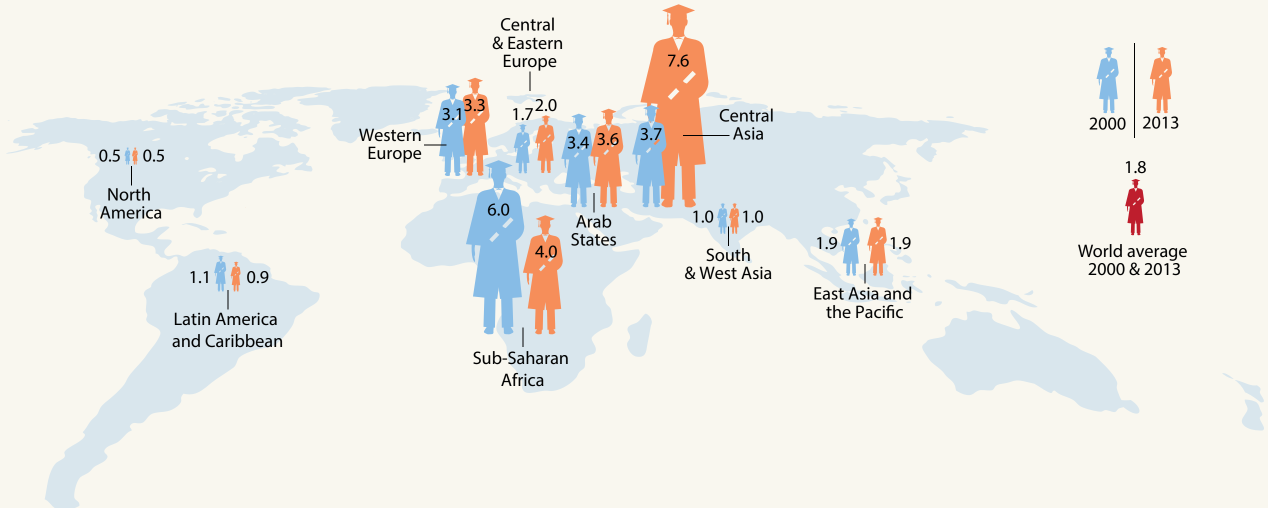
More international PhD students are studying science and engineering

Here, we shall be analysing trends in the cross-border migration of university students and doctorate-holders. Over the past two decades, the number of students pursuing higher education abroad has more than doubled from 1.7 million (1995) to 4.1 million (2013). Students from the Arab States, Central Asia, sub-Saharan African and Western Europe are more likely to study abroad than their peers from other regions (Figure 2.10).

The data used in the analysis on the following pages are drawn from the UNESCO Institute for Statistics' database; they are the fruit of joint data collections undertaken with the OECD and Eurostat annually for mobile students and every three years for PhD-holders. The survey excludes students on short-term exchange programmes. In 2014, more than 150 countries representing 96% of the world's tertiary student population reported data on international students. In addition, 25 mainly OECD countries have reported data on doctorate-holders for the years 2008 or 2009.

We can observe four distinct trends in the mobility of international students at doctoral level and among students enrolled in science and engineering programmes. Firstly, the latter two broad fields are the most popular educational programmes for international

Figure 2.10: **Outbound mobility ratio among doctoral students, 2000 and 2013**
By region of origin (%)

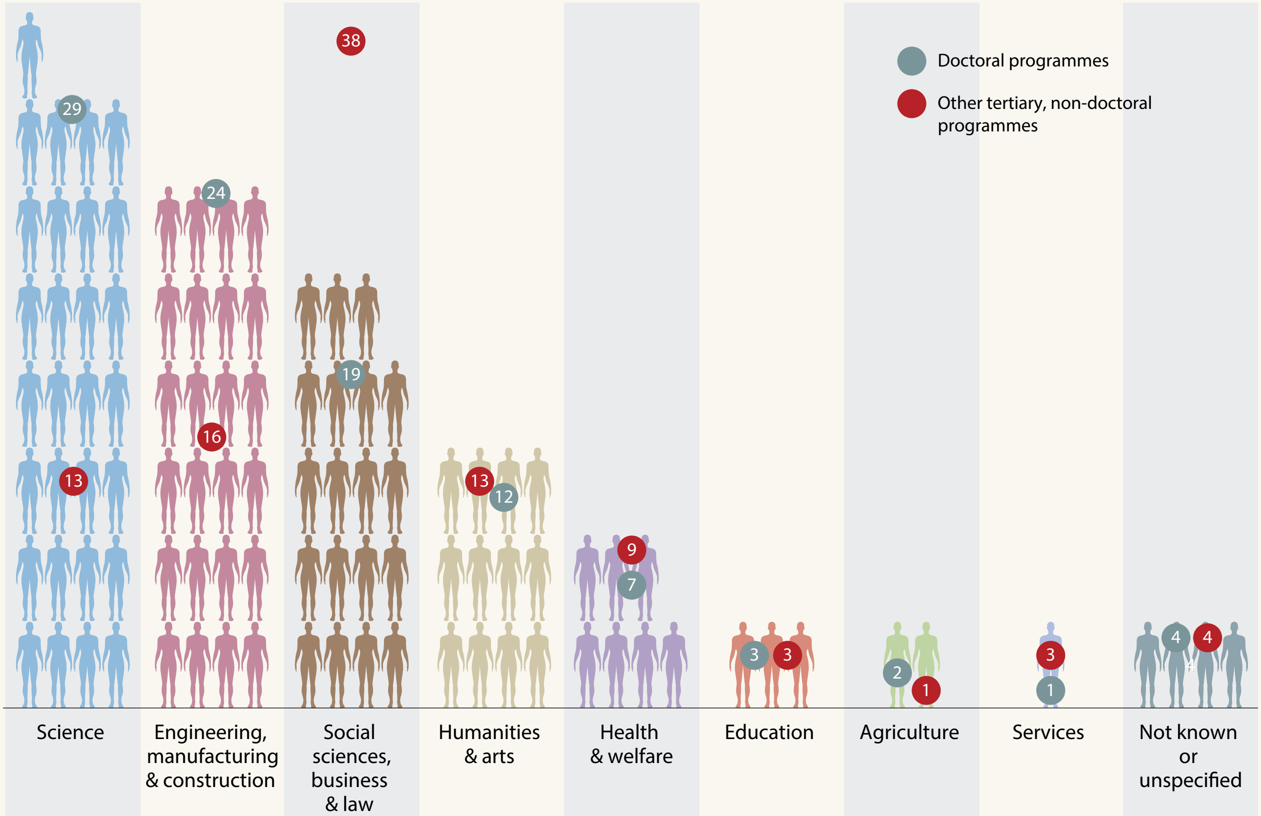


Note: The outbound mobility ratio is the number of students from a given country (or region) enrolled in tertiary programmes abroad, expressed as a percentage of total tertiary enrolment in that country (or region).

Source: UNESCO Institute for Statistics, June 2015

Figure 2.11: **Distribution of international students, 2012**

By type of programme and field of education (%)



Note: Data concern 3.1 million international students enrolled in 44 mainly OECD and/or EU countries.

Source: UNESCO Institute for Statistics, October 2014

doctoral students: out of a total of 359 000 international doctoral students in 2012, 29% were enrolled in science programmes and 24% in engineering, manufacturing and construction programmes (Figure 2.11). By comparison, in non-doctoral programmes, international students studying science and engineering constitute the second- and third-largest groups after social sciences, business and law. Among these students, a relatively large proportion comes from countries with a medium-level of technological capability, such as Brazil, Malaysia, Saudi Arabia, Thailand and Turkey (Chien, 2013).

There has been a notable shift in the profile of international doctoral students away from social sciences and business towards science and engineering programmes. Between 2005 and 2012, the number of international doctoral enrolments in science and engineering grew by 130%, compared to a rise of 120% reported in other fields.

The second distinctive trend is the concentration of international doctoral students in a smaller number of host countries than non-doctoral students. The USA (40.1%), UK (10.8%) and France (8.3%) host the bulk of international doctoral students. The USA hosts nearly half of doctoral students enrolled in S&T fields (Figure 2.12).

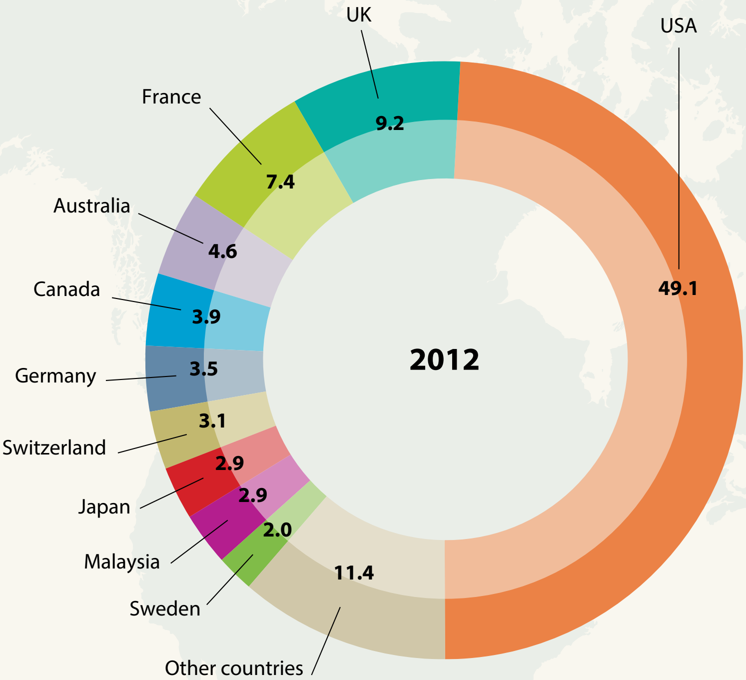
There is a marked variation in the inbound mobility rate of doctoral students: three in ten students in the USA are from overseas, compared to more than four in ten in the UK and France (Figure 2.12). The rate is even higher in Luxembourg, Liechtenstein and Switzerland, where more than half of doctoral students come from abroad.

Thirdly, the proportion of doctoral students pursuing a degree abroad varies greatly from one country to the next. The ratio of students from a given country enrolled in doctoral programmes abroad (or outbound mobility ratio) ranges from a low of 1.7% in the USA to a high of 109.3% in Saudi Arabia (Figure 2.12). Saudi Arabia thus has more doctoral students enrolled in programmes abroad than at home. This relatively high outbound mobility ratio is consistent with Saudi Arabia's long tradition of government sponsorship of its citizens' academic study abroad. Viet Nam had the next highest ratio of 78.1% in 2012, with approximately 4 900 enrolled abroad and 6 200 domestically. This high ratio is the result of the Vietnamese government's policy of sponsoring the doctoral training of its citizens overseas, in order to add 20 000 doctorate-holders to the faculty of Vietnamese universities by 2020 to improve its higher education system (British Council and DAAD, 2014).

Figure 2.12: **Preferred destinations of international doctoral students, 2012**

The USA alone hosts nearly half of international doctoral students enrolled in science and engineering fields

Distribution of international doctoral students in science and engineering programmes by host country, 2012 (%)



49.1%

Share of international doctoral students enrolled in science and engineering programmes in the USA

9.2%

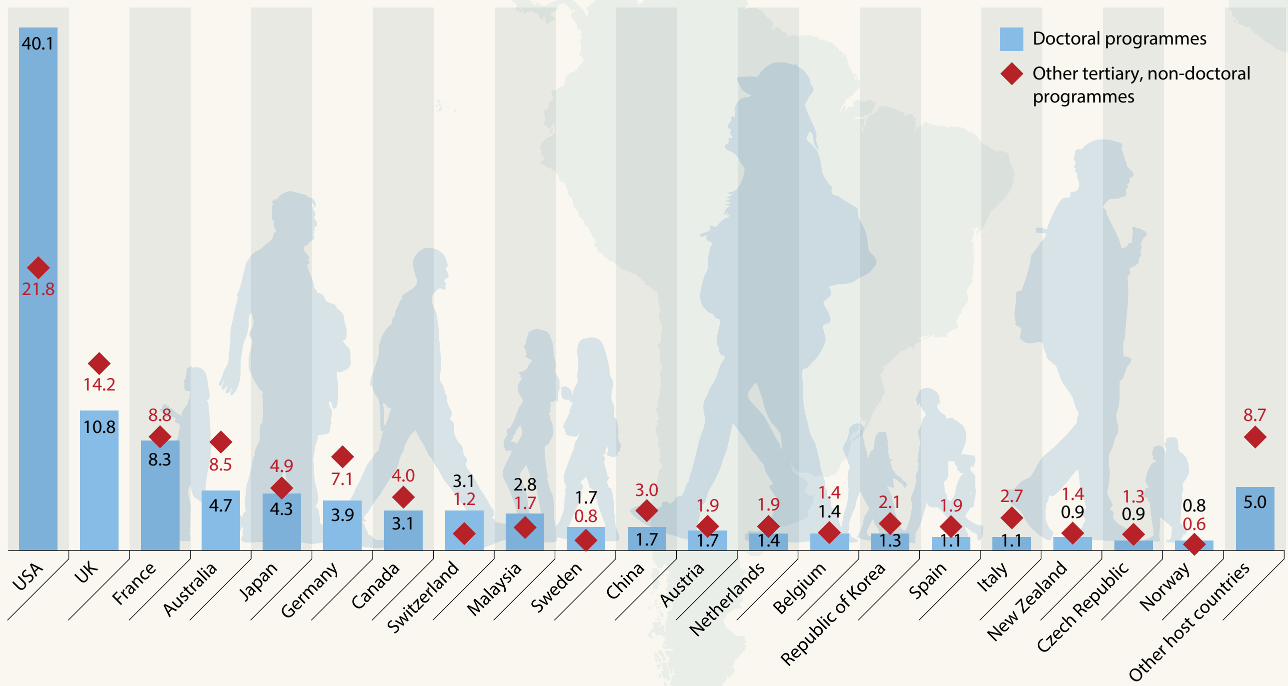
Share of international doctoral students enrolled in science and engineering programmes in the UK

7.4%

Share of international doctoral students enrolled in science and engineering programmes in France

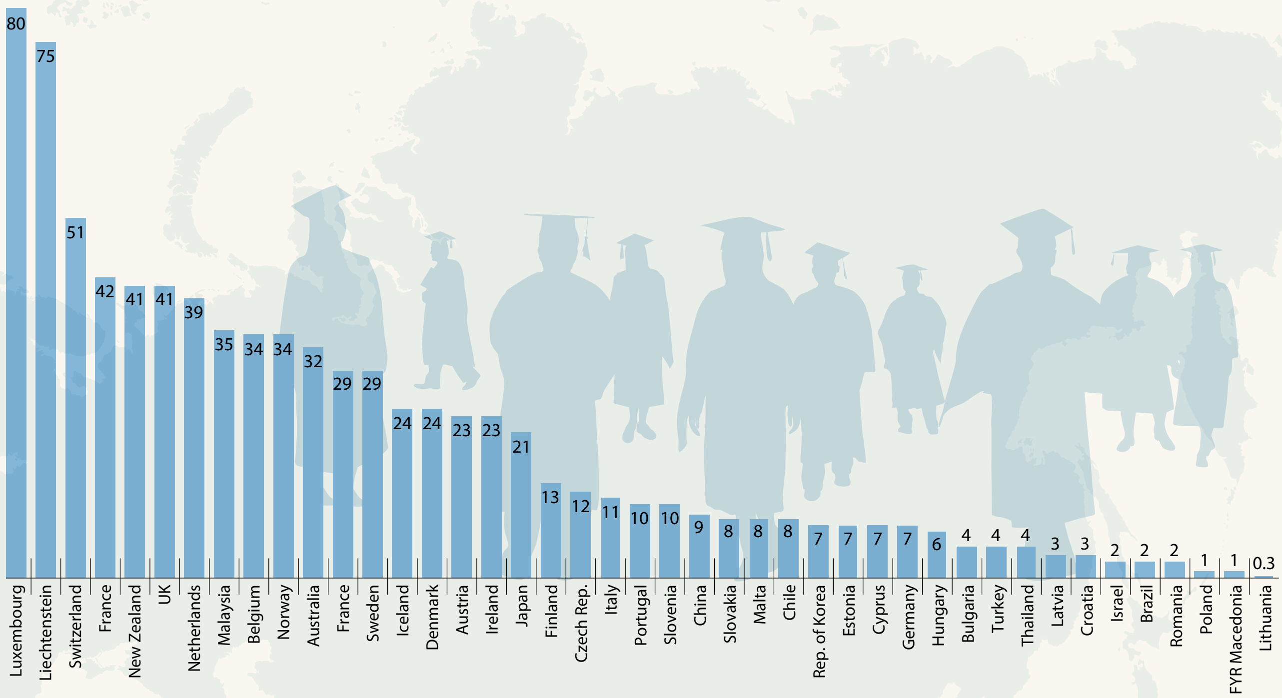
The USA hosts four out of ten international doctoral students

Share of international students by type of programme and host country, 2012 (%)



Most doctoral students in Luxembourg, Liechtenstein and Switzerland are international students

Share of international doctoral students in individual host countries, or inbound mobility rate, 2012 (%)



5 600 Number of Saudi doctoral students being trained overseas in 2012

5 200 Number of Saudi doctoral students being trained in Saudi Arabia in 2012

Saudi Arabia has more doctoral students enrolled in programmes abroad than at home

Countries with more than 4 000 doctoral students enrolled abroad in 2012

Country of origin	Number of outbound	Outbound mobility ratio*	Top destinations
China	58 492	22.1	USA, Japan, UK, Australia, France, Rep. of Korea, Canada, Sweden
India	30 291	35.0	USA, UK, Australia, Canada, France, Rep. of Korea, Switzerland, Sweden
Germany	13 606	7.0	Switzerland, Austria, UK, USA, Netherlands, France, Sweden, Australia
Iran	12 180	25.7	Malaysia, USA, Canada, Australia, UK, France, Sweden, Italy
Korea, Rep.	11 925	20.7	USA, Japan, UK, France, Canada, Australia, Switzerland, Austria
Italy	7 451	24.3	UK, France, Switzerland, USA, Austria, Netherlands, Spain, Sweden
Canada	6 542	18.0	USA, UK, Australia, France, Switzerland, New Zealand, Ireland, Japan
USA	5 929	1.7	UK, Canada, Australia, Switzerland, New Zealand, France, Rep. of Korea, Ireland
Saudi Arabia	5 668	109.3	USA, UK, Australia, Malaysia, Canada, France, Japan, New Zealand
Indonesia	5 109	13.7	Malaysia, Australia, Japan, USA, UK, Rep. of Korea, Netherlands, France
France	4 997	12.3	USA,UK, Malaysia, Switzerland, France, Japan, Germany, China
Viet Nam	4 867	78.1	France, U.S., Australia, Japan, Rep. of Korea, UK, New Zealand, Belgium
Turkey	4 579	9.2	USA, UK, France, Netherlands, Switzerland, Austria, Canada, Italy
Pakistan	4 145	18.0	UK, USA, Malaysia, France, Sweden, Australia, Rep. of Korea, New Zealand
Brazil	4 121	5.2	USA, Portugal, France, Spain, UK, Australia, Italy, Switzerland

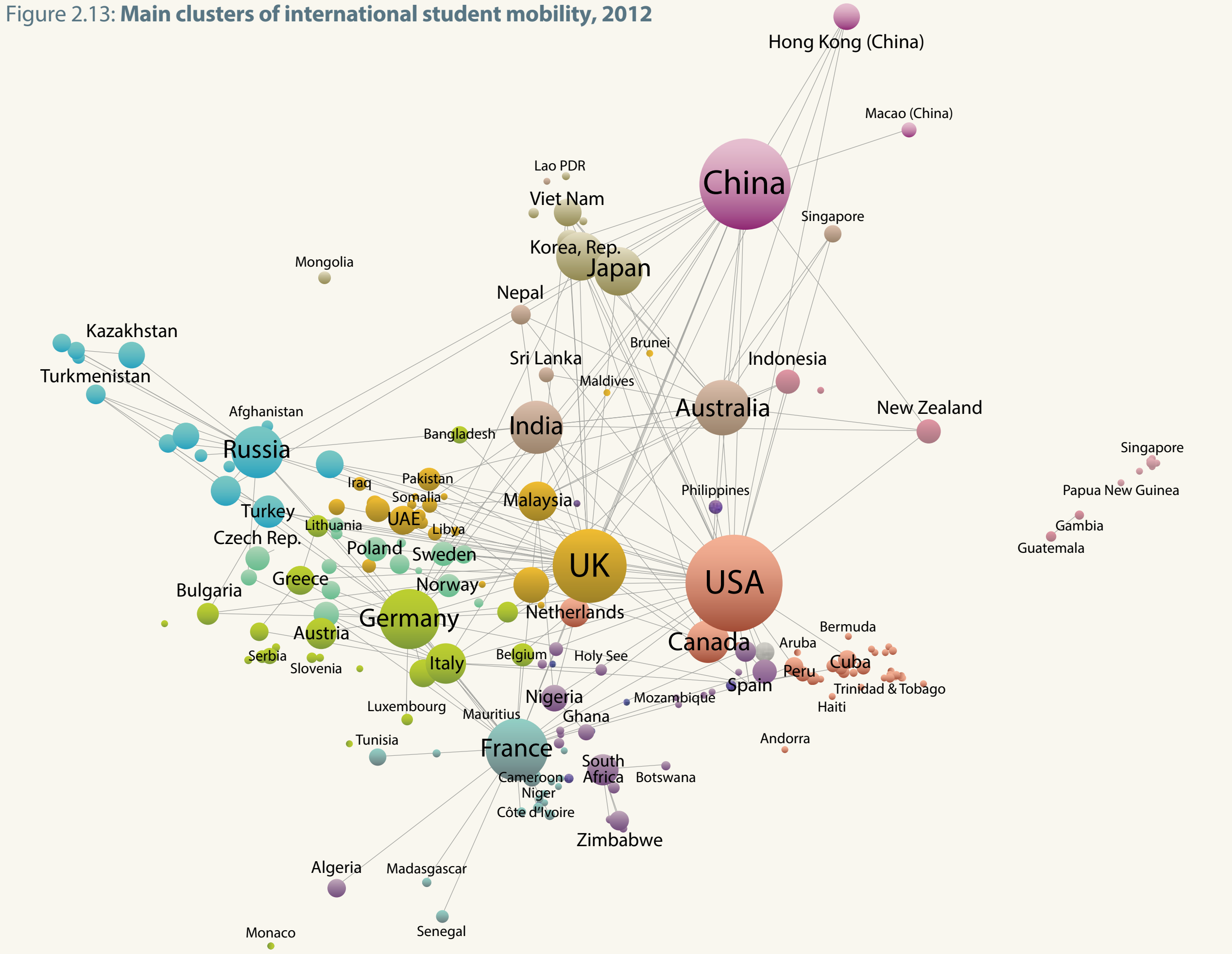
* The number of students from a given country enrolled in doctoral programmes abroad, expressed as a percentage of total doctoral enrolment in that country

Note: The UNESCO Institute for Statistics recognizes that Germany is a top destination for international doctoral students. However, due to data unavailability, Germany is absent from the top destinations listed here.

Note: Data for the tables and graphics in Figure 2.12 concern 3.1 million international students enrolled in 44 mainly OECD and/or EU countries.

Source: UNESCO Institute for Statistics, October 2014; Institute of International Education (2013) *Open Doors Report on International Educational Exchange*

Figure 2.13: **Main clusters of international student mobility, 2012**



Source: Data from UNESCO Institute for Statistics, October 2014; map created using VOSviewer

Fourthly, at least six noticeable networks (or clusters) of international student mobility can be identified (Figure 2.13). It should be noted that, although the flows of students are directional, the network shown in the map is undirected. Moreover, the distance between two countries approximately reflects the number of tertiary-level students migrating between the countries. A smaller distance indicates a stronger relation. The colours reflect the different clusters of the student mobility network. The size of the bubbles (countries) reflects the sum of student numbers from a given country who study abroad and the number of international students studying in that country. For instance, in 2012, approximately 694 400 Chinese students studied abroad and, the same year, China hosted 89 000 international students. The total number of international students originating from and flowing into China amounts to 783 400. By comparison, approximately 58 100 US students studied abroad in 2012 and, the same year, the USA hosted 740 500 international students. In total, there are 798 600 international students originating from and flowing into the USA. As a result, the sizes of the bubbles for China and the USA are comparable, even though the trends are reversed.

Bilateral ties between host and home countries in terms of geography, language and history shape these clusters to a certain extent. The USA cluster embraces Canada, several Latin American and Caribbean countries, the Netherlands and Spain. The UK cluster encompasses other European countries and its former colonies, such as Malaysia, Pakistan and the United Arab Emirates. India, a former colony of the UK, has maintained ties to the UK but is now also part of the cluster constituted by Australia, Japan and countries located in East Asia and the Pacific. Similarly, France leads its cluster, which consists of its former colonies in Africa. Another cluster groups mainly Western European countries. Additionally, the historical link between the Russian Federation and former Soviet states shapes a distinct cluster. Lastly, it is worth noting that South Africa plays an important role in the student mobility network in the southern part of Africa (see Chapter 20).

International mobility of doctorate-holders

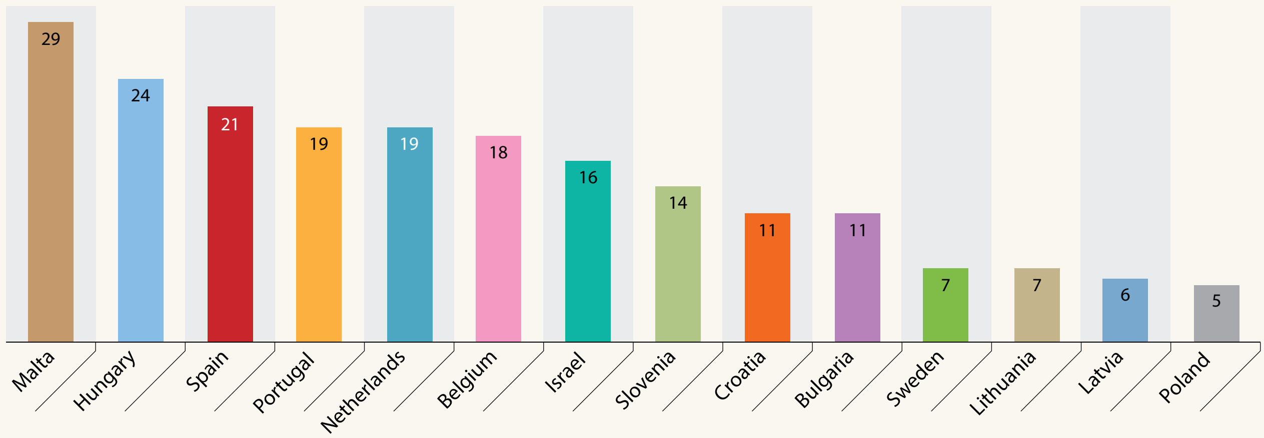
The careers of doctorate-holders survey reveals that, on average, between 5% and 29% of citizens with a doctorate have gained research experience abroad for three months or longer in the past 10 years (Figure 2.14). In Hungary, Malta and Spain, the proportion is over 20%, whereas in Latvia, Lithuania, Poland and Sweden, it is under 10%.

The main destinations for these mobile researchers' previous sojourn abroad were the USA, UK, France and Germany (Auriol *et al*., 2013). Studies conducted across Europe have shown that a high level of mobility by qualified personnel between sectors (such as universities and industries) and across countries contributes to the overall professionalism of the labour force, as well as to the innovative performance of the economy (EU, 2014).

Academic factors often lie behind the researcher's decision to uproot him- or herself. The move may offer better access to publishing opportunities, for instance, or enable the scientist to pursue a research direction that may not be possible at home. Other motivations include other job-related or economic factors and family or personal reasons (Auriol *et al*., 2013).

The presence of foreign doctorate-holders and researchers has long been acknowledged as adding cultural capital to the local community and expanding the talent pool of an economy (Iversen *et al.,* 2014). The careers of doctorate-holders survey reveals that Switzerland hosts the highest percentage (33.9%) of foreign doctorate-holders, followed by Norway (15.2%) and Sweden (15.1%) [Figure 2.15].

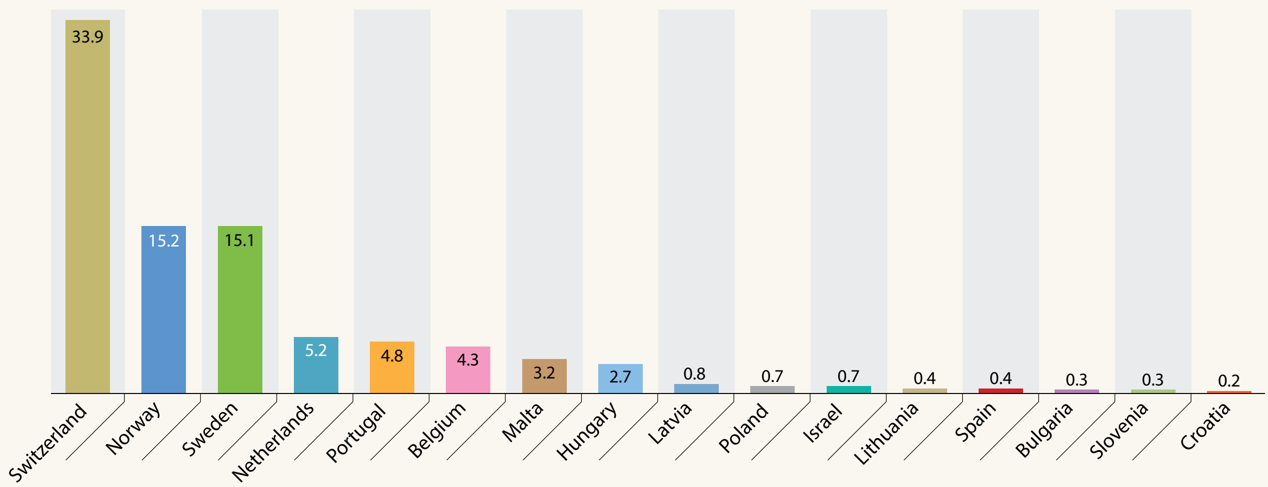
Figure 2.14: **Percentage of national citizens with a doctorate who lived abroad in the past ten years, 2009**



Note: The data cover sojourns of three months or more abroad. Data for Belgium, Hungary, the Netherlands and Spain refer to graduation years from 1990 onwards. For Spain, there is limited coverage of doctorate-holders for 2007–2009.

Source: UNESCO Institute for Statistics/OECD/Eurostat data collection on careers of doctorate-holders, 2010

Figure 2.15: **Percentage of foreign doctorate-holders in selected countries, 2009**



Source: UNESCO Institute for Statistics/OECD/ /Eurostat data collection on careers of doctorate-holders, 2010

CONCLUSION

Innovation is occurring in countries of all income levels

Although most R&D is taking place in high-income countries, innovation is pervasive and is occurring in countries across the full spectrum of income levels. Indeed, much innovation is occurring without any R&D activity at all; in the majority of countries surveyed in 2013, innovation unrelated to R&D implicated more than 50% of firms. R&D is a crucial component of the innovation process but innovation is a broader concept that goes beyond R&D alone.

Policy-makers should take note of this phenomenon and, accordingly, focus not just on designing incentives for firms to engage in R&D. They also need to facilitate non-research-related innovation, particularly in relation to technology transfer, since the acquisition of machinery, equipment and software is generally the most important activity tied to innovation.

In addition, the reliance of firms on market sources such as suppliers and clients to develop innovation highlights the important role played by external agents in the innovation process. One concern for policy-makers should be the low importance attached by most firms to maintaining linkages with universities and government research institutions, even though strengthening university–industry ties is often an important target of policy instruments.

International scientific mobility can nurture an innovative environment by enhancing skills, knowledge networks and scientific collaboration. International knowledge networks do not form naturally, however, and the potential benefits stemming from such networks are not automatic. Lessons learned from past and current success stories show that four main ingredients are required to sustain these international knowledge networks: firstly, a demand-driven approach; secondly, the presence of a local scientific community; thirdly, infrastructural support and committed leadership; and, lastly, quality higher education to upgrade the skills of the general population.

Over the past decade, there has been significant growth in cross-border scientific mobility, a trend that is showing no sign of letting up. Creating an enabling environment to facilitate cross-border mobility and collaboration is becoming a priority for national governments. To accompany this trend, governments need to introduce programmes which teach scientists and engineers to be sensitive to cultural differences in research, research management and leadership and to ensure research integrity across borders.

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