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Coordinated and guided by: Johan Stierna and Pierre Vigier

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The structure of the report is similar to that of the 2011 edition of the IUC report. The country profiles analysing individual EU Member States and Associated countries, included in the IUC 2011 report, are now published separately in the publication "Research and Innovation performance in EU Member States and Associated countries" (http://ec.europa.eu/research/innovation-union/index_en.cfm). The 2013 IUC report can also be found on the Europa website (http://ec.europa.eu/research/innovation-union/index_en.cfm?pg=keydocs), together with a full statistical annex. The cut-off date for Eurostat data was September 2013.

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EXECUTIVE SUMMARY

While world competition intensifies, Europe's knowledge base remains strong but needs a more strategic focus

- The EU is facing increasing world competition, in particular at the higher end of global value chains. In 2011, more than 70 % of the world's knowledge production was taking place outside the EU, and half of the world's scientists and engineers lived outside the triad[1]. Since 2008, developed Asian countries have gained increasing shares of global value chain income including income from medium-high and high-tech products.

- Europe remains however today the main knowledge production centre in the world, accounting for almost a third of the world's science and technology production. The EU has managed to maintain its competitive knowledge position to a greater degree than the United States and Japan and is making progress towards its R&D intensity target of 3 % by 2020. The EU also remains a very attractive location for R&D investment. In 2011, the EU was the main destination of FDI in the world, receiving around 30 % of FDI inflows worldwide, more than the United States or Japan.

- However, the US and Asian research and innovation efforts are often more strategically oriented. Science and technology development in Asia and the United States are more focused on transformative and pervasive technologies and more oriented towards emerging global markets. The United States is strengthening its profile as a world leading centre for science and technology in health, biotechnologies, nanotech and ICT. China is the world biggest producer of scientific publications in the fields of energy and ICT, while Japan has the highest rate of technology development in energy and in environmental technologies. In comparison, the EU is less focused on strategic areas and tends to scatter its efforts on a wider range of scientific fields and technologies, with the risk of dominating none.

A sustainable recovery requires structural change driven by innovation

- To stay competitive and enjoy sustained growth a knowledge economy must be based on high value added goods and services. The EU Member States that have been the most resilient to the current economic crisis, such as Germany and the Nordic countries have high R&D intensities and innovation dynamics. This corroborates new

[1] The EU, the United States and Japan

findings that R&D intensity is positively correlated with total factor productivity growth.

- Investment in R&D is highest in Israel, Finland and Sweden. Counter-cyclic efforts, in the form of resolute policies to protect or increase public R&D funding in spite of fiscal constraints, have been made in Malta, Luxembourg, Estonia, the Czech Republic, Denmark, Germany, Austria, Croatia, Slovenia and Poland, enabled by EU Structural Funds.

- Research excellence is highest in Switzerland, the Netherlands, Denmark, Sweden and Israel. Some European countries are strategically focused and very competitive in technologies for societal challenges and in key enabling technologies, in particular Sweden, the Netherlands, Germany, Finland, Switzerland, Israel and Austria.

- The most innovative economies are found in Sweden, Germany, Ireland, Luxembourg, Denmark, Finland, the United Kingdom and France according to the new innovation output indicator.[2] Hungary and Slovenia are the most innovative economies among the newer Member States. Eastern and Southern European countries appear to experiment a structural change underlined by the on-going upgrading of their economic structures over the last decade. This change is especially noticeable in Romania, Slovakia, Ireland, Norway, Cyprus, Spain, Lithuania and Denmark.

Six lessons for innovation-driven growth

- **Focus on the markets of the future**. Top innovation performers in the EU are characterised by open and very knowledge intensive manufacturing or services sectors, often coupled with strong firm dynamics in transformative technologies addressing global societal challenges. The confluence of different but related technologies is facilitated by Horizon 2020 and smart specialisation strategies. *Further policy integration between R&I and industrial policies would help in seizing this opportunity.*

- **Believe in High-growth firms**. Europe's firm structure is older and less knowledge-intensive than that in the United States. The R&D intensity gap is linked to the growth of firms in ICT and biotechnology in the United States over the last decade. However, several European countries show high dynamics of high-growth enterprises in innovative sectors which generate new jobs. Entrepreneurship is particularly strong in innovation-driven clusters. *Focus on framework conditions that generate high-growth*

[2] However, further refinements are needed to bring the indicator to its full potential.(see EC Communication "Measuring innovation output in Europe: towards a new indicator", 2013)

innovative enterprises, stimulated by innovation-driven clusters and by a culture of demanding customers leading to higher standards and lead markets.

- **Build on People**. In highly innovative economies, people are skilled, incentivised, enabled and demanding. Skilled labour, combining generic and sector-specific knowledge, is the engine for service innovation and for quality manufacturing. People are also in the centre for entrepreneurship and social innovation. Efficient public research organisations with performance-based institutional funding complemented with effective project-based funding provide staff with strong incentives to excel in education, research and technology transfer. *Research and innovation policies preparing the future should therefore consider emphasising strongly on incentives for researchers and inventors alongside skills uptake.*

- **Innovate in solutions**. Innovation is increasingly based on comprehensive solutions that integrate manufacturing and services. A large part of service innovation is linked to manufacturing. The development of high-tech knowledge-intensive services (e.g. connected objects, big data management, digital cities or engineering firms addressing societal challenges in health and environment) is a key factor of international competitiveness. *The cluster policies should encourage such integrated approaches as well as partnership between public and privates sectors, building on public sector innovation.*

- **Think Single Market**. While there is increasing knowledge circulation in Europe, Member States with lower absorptive capacity still have access to fewer knowledge channels. Lifting barriers such as high patent and licensing costs, information asymmetries, non-compete agreements and other barriers blocking the mobility of skilled labour would further stimulate knowledge circulation and enhance economic impact. Science and technology can also be better matched with industry needs, both at national and European levels. *Increasing the intensity and speed of the circulation of knowledge is therefore a key measurable objective of effective R&I policies.*

- **Build alliances and networks**. Innovation is increasingly international. The ability of a country to grow is enhanced through knowledge alliances. Full use of European Innovation Partnerships, Joint Technology Initiatives and other Public Private Partnerships is essential for innovation. Cooperation with international partners is positively correlated with research quality and there is a positive correlation between success in FP participation and scientific strengths. *Progress towards a European Research Area, improving transnational access to research infrastructure and a digital ERA are therefore essential. Integrated innovation/industrial policies for upgrading manufacturing industries must be differentiated by sector and adapt to the globalisation of production by focussing on vertical specialisation in manufacturing and service segments of global value chains.*

Europe's competitive position in research and innovation

Highlights

A growing number of countries in the world are upgrading their knowledge economies

The first decade of the 21st century has been characterised by an accelerated accumulation of knowledge. The world is endowed with an increasing amount of engineers, researchers, knowledge investment, scientific publications and technologies. This is partly linked to a widening of the geographical distribution of knowledge production, in particular in the rising Asian economies. While this growing world of knowledge opens up new opportunities to address major worldwide societal challenges, it also implies an intensification of competition at the higher ends of the value chains. Sustainable economic growth for Europe will increasingly require persistent investment in knowledge, reforms to deliver more effective research and innovation systems and determined action to transform the economy towards a more knowledge-intensive structure.

Despite the economic recession, Europe remains a major knowledge centre in the world

In this new world context, the EU has managed to maintain its competitive position more successfully than the United States. With almost 30 % of world knowledge production, Europe is today the main knowledge centre of the world. The continuing progress towards a fully-fledged European Research Area will further enhance Europe’s importance and attractiveness as a knowledge centre in a world of increasingly big players. Europe's scientific cooperation with all major world regions has intensified, adapting to the fact that 70 % of knowledge production takes place outside the EU.

Europe faces competitive pressure from the growing Asian economies, which are more focused on transformative technologies and new markets

There are however weaknesses in Europe's competitive position, which may threaten Europe's medium-term economic growth. Investment in knowledge is increasing faster in the Asian economies than in Europe. In 2014, China's R&D investment (expressed in purchasing power standards) may exceed that of all EU Member States together. At the same time, science and technology development in Asia and in the United States is often more strategic than in the EU. It is more focused on transformative and pervasive technologies oriented towards emerging global markets. The EU's technology assets are more focused on its established and traditional industries, while its scientific specialisation does not sufficiently back up technology strengths. Determined reforms are needed to overcome fragmentation and develop a common long-term strategic focus for Europe's knowledge profile. Despite regular improvements in the implementation of the Innovation Union, the economic effect of knowledge is hampered by weaker framework conditions for innovation, in particular for business R&D activity and entrepreneurship, when compared to the United States and several Asian economies.

Introduction

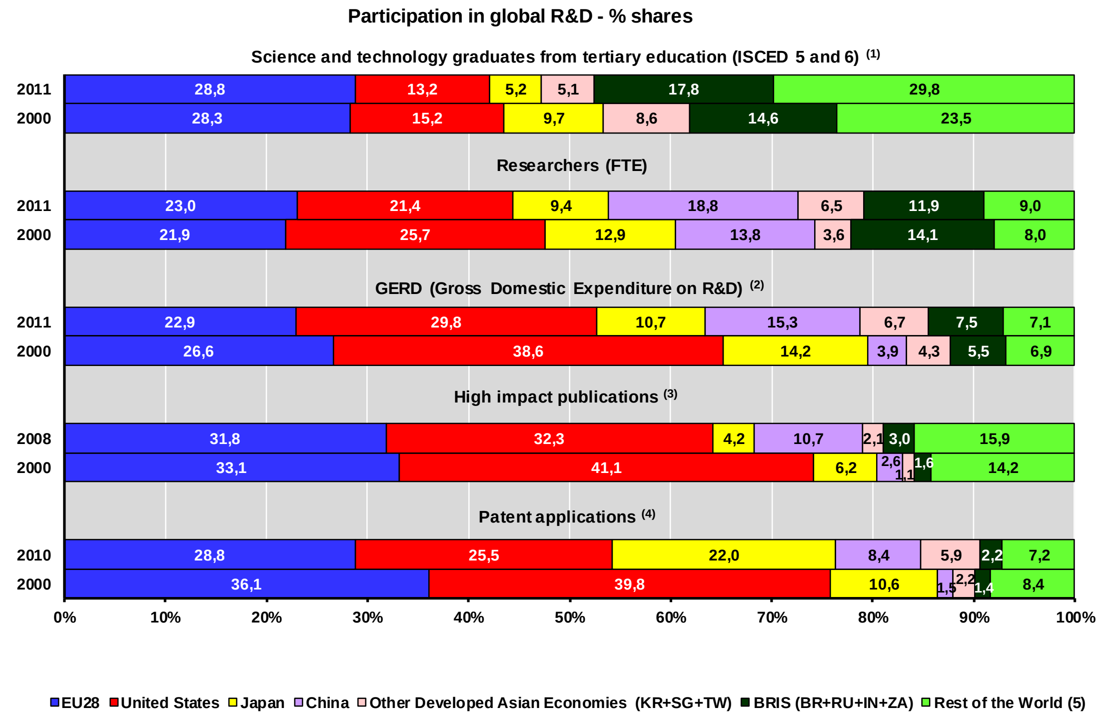
This chapter is an update and further development of the analysis of Europe's competitive position in research and innovation (R&I) published in the 2011 edition of the Innovation Union Competitiveness (IUC) report. Some structural long-term indicators have not been repeated although this edition goes deeper into a thematic breakdown of Europe's strengths in science and technology (S&T). Following a synthetic overview, the remaining chapter is structured around four main blocks covering the entire R&I system: investments in knowledge, science, technology and their economic impact.

1. Overall performance of the EU in science and technology

A rapidly growing amount of knowledge is more widely spread across the globe

The process of a broader geographic distribution of knowledge creation in the world continues. Emerging powers in science, technology and innovation, in particular China, the BRIS countries (Brazil, Russia, India, South Africa) and other developed Asian countries, are challenging the triad of the United States, the European Union (EU) and Japan. Today, 70 % or more of knowledge creation is found outside the EU, and around 50 % of the world's human resources for research and innovation live outside the triad. Figure 1 also illustrates that for science and engineering (S&E) graduates, the largest increase of the world share has been among the BRIS countries and in other world countries, possibly the first significant signs of the rising importance of these countries in the world R&I landscape.

Figure 1: World share of S&E graduates, researchers, GERD, high-impact publications and patent applications, 2000 and latest year



Source: DG Research and Innovation - Economic Analysis Unit — Innovation Union Competitiveness Report 2013
Data: Eurostat, OECD, UNESCO, Science Metrix / Scopus (Elsevier)
Notes: (1) Tertiary graduates in science and engineering : (i) Data are not available for China; (ii) Other Developed Asian Economies does not include SG and TW; (iii) BRIS does not include India and South Africa.
(2) GERD : Shares were calculated from values in current PPS€.
(3) (i) Top 10% most most cited publications - fractional counting method, scientific publications 2008: citation window 2008-2011; (ii) Other Developed Asian Economies does not include SG and TW; (iii) BRIS does not include South Africa.
(4) Patent applications under the PCT (Patent Cooperation Treaty), at international phase, designating the EPO by country of residence of the inventor(s).
(5) The coverage of the Rest of the World is not uniform for all indicators.
(6) Elements of estimation were involved in the compilation of the data.

At the same time, the total amount of knowledge produced every year has grown remarkably in the first decade of the 21st century. Comparing total expenditure on research and development (R&D) in purchasing power standards (PPS) in 2011 with the same investments in 2000 shows a 77 % increase in real terms. Total number of Patent Cooperation Treaty (PCT) patent applications in the world in 2010 was 57 % higher than in 2000, and the number of S&E graduates grew by 56 % from 2 430 000 in 2000 to 3 784 000 in 2011 ([3]). This opens up the way for new opportunities of international cooperation and for world progress in research and innovation addressing societal challenges. In economic terms, it also means stronger rationale for open innovation strategies in an environment of increased competition for knowledge-based goods and services.

[3] These data do not include China, as official international statistics on tertiary graduates in science and engineering is lacking for China.

The EU has been able to maintain its world share better than the United States and Japan. However, Asian economies are rapidly expanding their technology development

Although the EU's overall world share of knowledge creation continues to fall, its relative position compared to the other triad powers has been remarkably preserved over the last decade, particularly in comparison to the evolution of the US world share ([4]). It even managed to increase its share of world researchers.

In fact, Europe is now the largest producer of S&T in the world. The EU Member States and Associated countries in Europe produce more human resources, science and technology (HRST) than the United States. Around a third of the world's S&T is produced in these countries. The weaker dimensions in terms of evolution are R&D investments and PCT patent applications ([5]), as illustrated in Figure 1. The change in world shares of PCT patent development highlights in particular that both the EU and the United States are losing ground to the more dynamic Asian technology powers. The EU's world share of PCT patent applications has fallen by 20 %, which is clearly a stronger decrease than for the other dimensions of the R&I system. However, the US' world share of patent applications has fallen even more, by 36 %. The main expansion is found in Japan, China and other developed Asian economies.

2. Investing in knowledge, people and R&D

Investing in people is a key challenge for Europe in the years to come

Skilled labour is a key source for a competitive, knowledge-based economy. The level of knowledge and type of skills, as well as the quantity and mobility of highly skilled people, are key factors for matching supply and demand in the knowledge economy. Europe's competitiveness and potential to create growth and jobs depends on the availability of skills in line with labour market needs. However, new evidence on skills of Europe's working-age population (the PIAAC survey) shows that only few Member States (Finland, the Netherlands and Sweden) can match the performance of Japan, and many Member States display in international comparison skills levels below average. There are also significant disparities between Member States.

The lack of skills is aggravated by the fact that Europe's workforce has started shrinking. To stabilise growth, Europe therefore needs to up-skill its workers. However, low-skilled workers tend not to take part in re- and up-skilling programmes. The participation of adults in lifelong

[4] This finding is consistent with the results of the 2013 Innovation Union Scoreboard (IUS). Based on performance of the 24 indicators in the IUS, the EU has closed nearly half of its gap with the United States and Japan since 2008. The EU annual average growth rate for innovation performance, according to the IUS, was 1.6 % in the 5-year period 2008–2012.

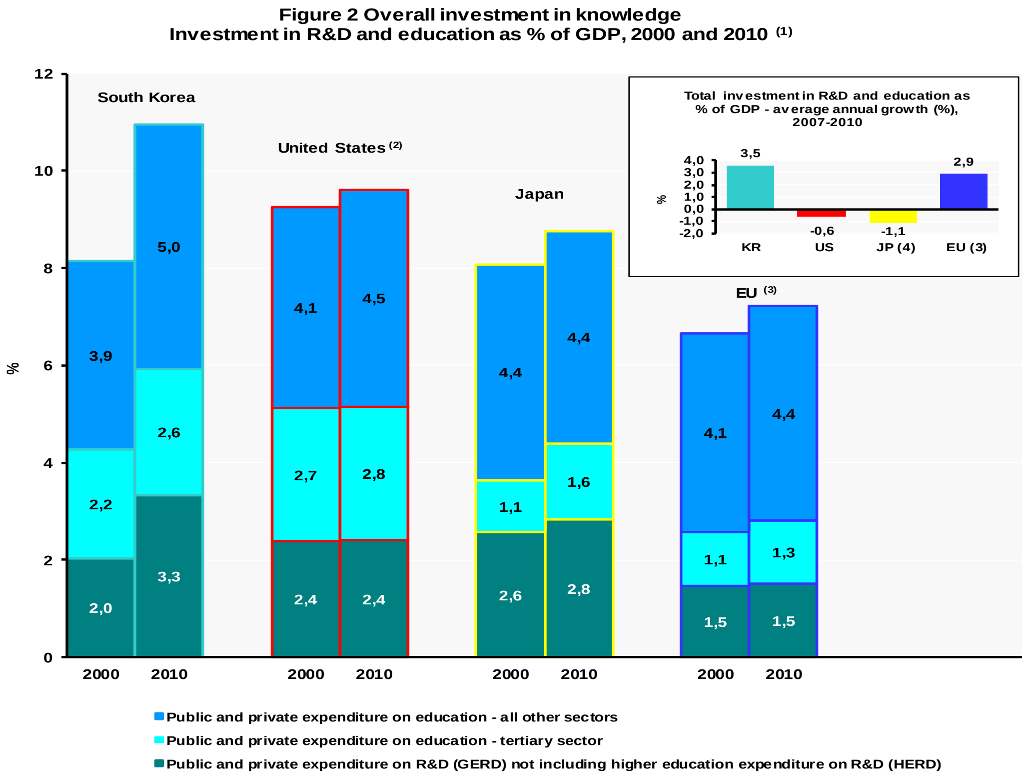
[5] PCT: Patent Cooperation Treaty. 'International' patent application seeking patent protection for an invention in several countries.

learning has actually been stagnating for years (in 2012, it stood at 9% and is still far from the European benchmark of 15%). There is an urgent need to break up this "low-skills trap", considering the trend of labour markets to request increasingly higher skills levels (the demand for low-skilled workers is forecast to drop by 20% between 2010 and 2020).

Despite its world lead, Europe still faces a particular challenge because of its ageing population, with shrinking youth cohorts entering the labour market ([6]). A comparison of Figure 2 and Figure 1 indicates that the capacity of the EU to preserve its world share of researchers and graduates in S&E may be undermined by persistent lower investments in education and research compared to competing knowledge economies.

Overcoming the lack of skills in Europe will require substantial and efficient investment to enhance quality of provision and prevent educational failure. The Commission's Communication of May 2013 "*Moving Europe beyond the Crisis*", stressed that the necessary investment in education and skills have not been made during and prior to the crisis.

Figure 2: Overall investment in knowledge

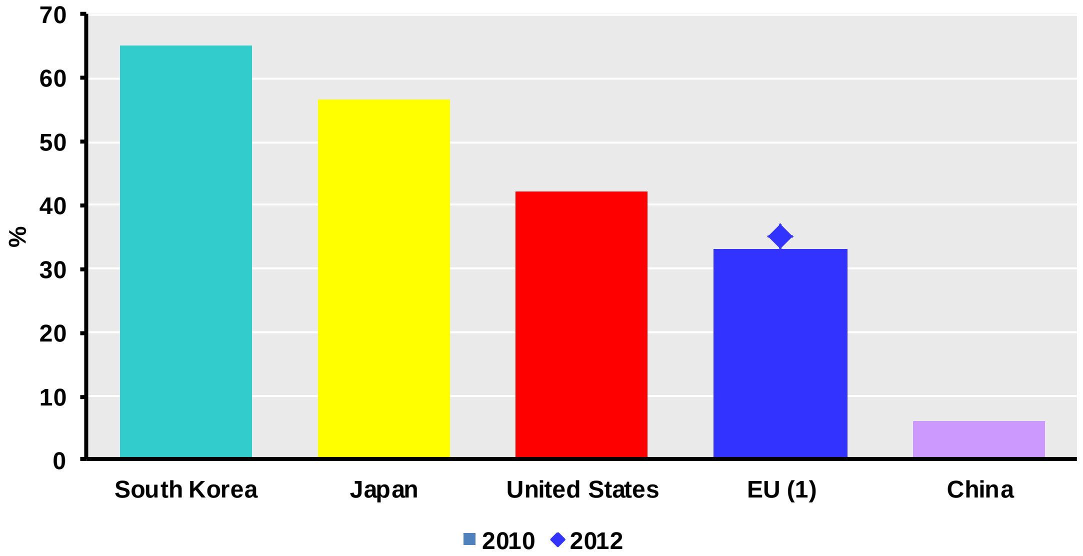


Source: DG Research and Innovation - Economic Analysis Unit
Innovation Union Competitiveness report 2013
Data: Eurostat, OECD
Notes: (1) KR, US, JP: There are breaks in series between 2010 and 2000.
(2) US: GERD not including HERD does not include most or all capital expenditure.
(3) EU:Croatia is not included.
(4) JP: Average annual growth refers to 2008 -2010.

[6] For a more detailed analysis of highly skilled labour and researchers in Europe, see Chapters I.4 and I.5.

Figure 2 presents overall investment in knowledge for which the public policymakers are accountable. Data are available for the large knowledge-intensive countries, except for China. The figure shows that in terms of its economy the EU invests less not only in R&D but also in higher education. Even in compulsory basic education, the EU invests a lower share of its economy than the United States. There has been a slight increase in the EU's investments over the last decade while there has been a negative growth is smaller in the United States and Japan. However, focussing on the growth in the period of economic crisis (small box in the graph), the EU has achieved higher growth than Japan, even if the gap with the United States and South Korea is still growing. The EU is not closing its overall knowledge investment gap. The challenge of developing highly skilled people in the EU in the years to come is confirmed by the data on tertiary education attainment, as illustrated in Figure 3. With a slight increase in 2009–2011, the EU's performance is still significantly lower than that of the United States and Japan.

Figure 3 Education - share of population aged 25-34 with tertiary education attainment (%)



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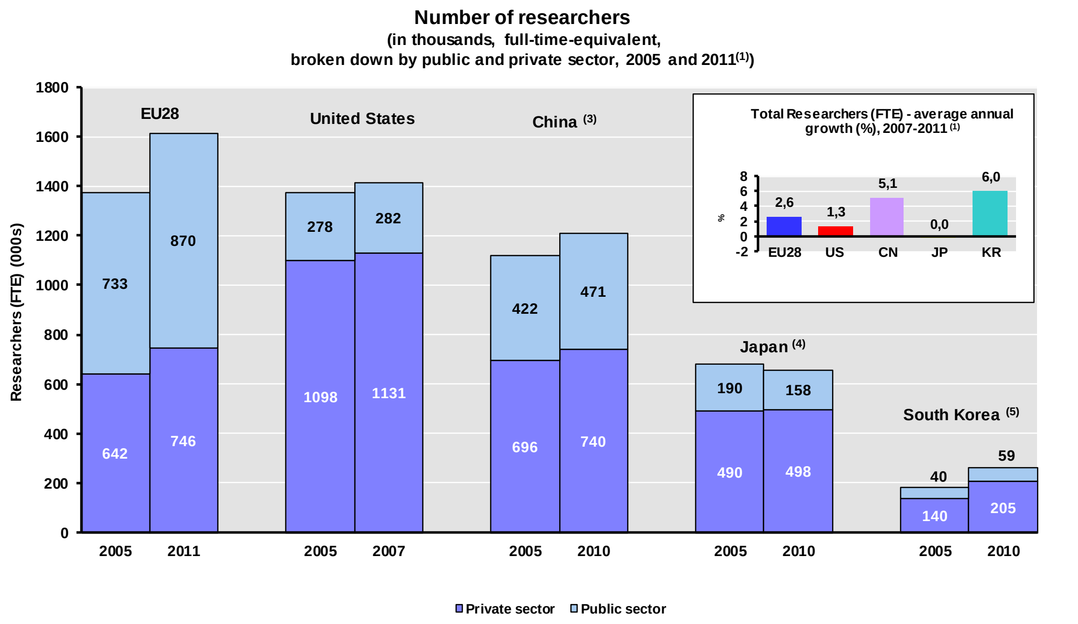
Source: DG Research and Innovation - Economic Analysis Unit
Data: Eurostat, OECD
Note : (1) Data for 2012 are available only for the EU.

The United States has reached tertiary education attainment of over 40 %, while more mature knowledge-intensive countries in Asia, such as Japan and South Korea, have rates of over 50 % of the population aged 25–34 years. These findings have to be considered with some care. More is not always better in terms of tertiary education graduates and variables concerning skills profiles are also highly relevant (see Chapter I.5).

However, having such an obviously lower share of tertiary graduates in Europe is a threat to Europe's future competitiveness in the high value-added products and services sectors. This is partly the result of lower levels of investment in knowledge (both higher education and research expenditure). But today, when knowledge is globally mobile, growing is not enough; Europe must grow faster than other key knowledge centres to catch up in the knowledge economy. In the medium term, this trend may affect the number of researchers in the EU, as well as the share of highly skilled labour in the work force.

Figure 4 presents the total number of full-time equivalent (FTE) researchers in the EU compared to other large knowledge economies. Official statistics on the number of researchers have been revised in China (a break in series) with a resulting downward revision of the total Chinese research population ([7]). Figure 4 also illustrates the place of employment of the researchers.

Figure 4: Number of FTE researchers private and public



Source: DG Research and Innovation - Economic Analysis Unit
Data: Eurostat, OECD
Notes: (1) US: 2007; JP, CN, KR: 2010.
(2) US: 2005-2007; KR: 2007-2010; JP: 2008-2010; CN: 2009-2010.
(3) CN: There is a break in series between 2009 and the previous years.
(4) JP: There is a break in series between 2008 and the previous years.
(5) KR: There is a break in series between 2007 and the previous years.

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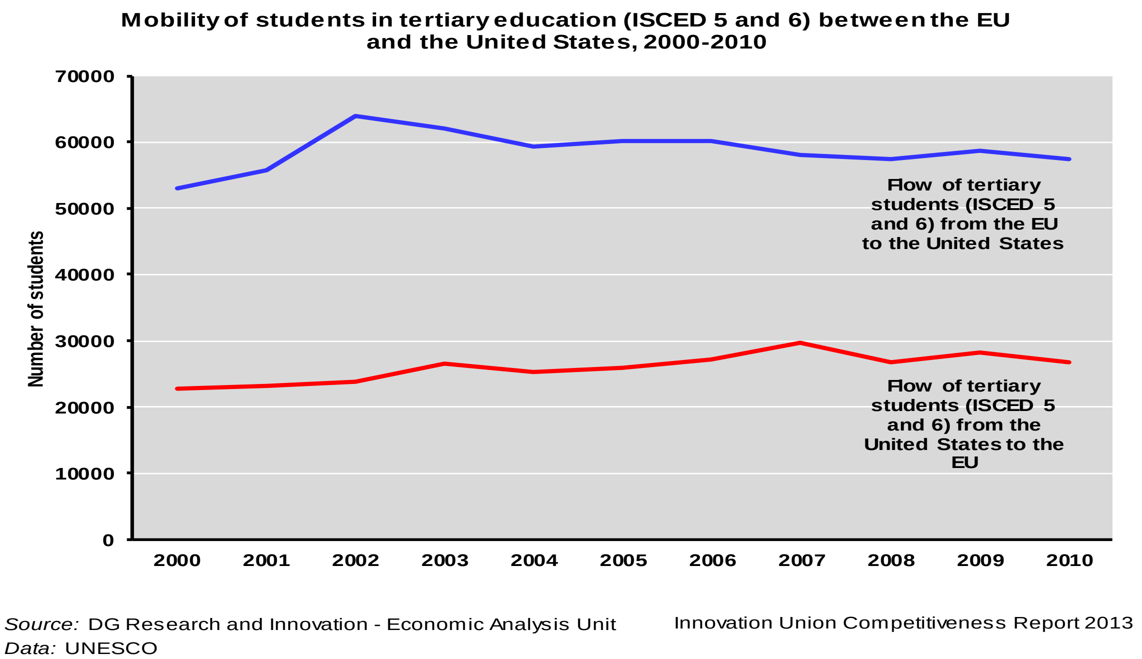
[7] In the Innovation Union Competitiveness report 2011, based on the previous official statistics for China. China had overtaken both the United States and the EU in number of FTE researchers. Latest Organisation for Economic Co-operation and Development (OECD) data for China show that there is a major break in series between data from 2009 onwards and the previous years. Total researchers in 2009 following the break in series equals 1 152 311, compared to a value of 1 592 420 in 2008 — a decrease of 28 %.

The EU has the largest number of researchers in the world, but they are concentrated in the public sector. All world competitors have much higher shares of researchers in the private sector, although the EU has managed to increase its numbers of business enterprise researchers since 2005. This structural difference in R&D production is also visible in R&D investments, where the EU has a much lower share of R&D investments in the private sector. Considering each EU Member State, this proportion varies with the most knowledge-intensive countries having shares of business R&D and researchers similar to that of the United States ([8]).

There are indications of a persistent 'brain drain' from the EU to the United States

Beyond the challenge of investing in people, Europe faces a structural deficit in the mobility flows of scientists across the Atlantic. Scientific cooperation is based on intensive mobility of research students and scientists, ranging from participation in international scientific conferences to longer visits to research centres in other countries. This mobility is positive when it is balanced and includes return of the researcher, enriched with knowledge spillover, career development, networking and a higher quality of research. International knowledge flows benefit both host and home institutions. However, when the international mobility of researchers is unbalanced, with consistent 'brain drain' dynamics from certain countries and limited knowledge flows in return, the mobility of researchers may in fact damage a country's knowledge accumulation. Given the increasing international competition for highly skilled workers, these risks may also have significant economic consequences.

Figure 5: Mobility of students (ISCED 5 and 6) between the EU and the United States



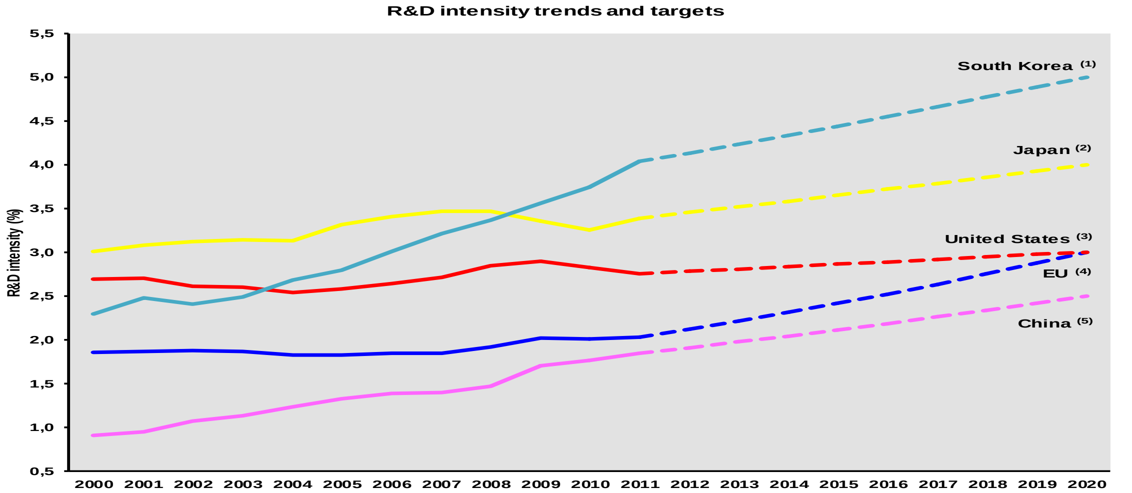
[8] A more detailed analysis is available in Chapter I.3.

Figure 5 reveals that the flow of tertiary education and doctoral students from the EU to the United States is persistently higher than the reverse. Over the last decade, this gap has slightly decreased (it was widest in 2002) but it remained important in 2009-2010. In 2010, 57 433 students left the EU-28 for graduate or doctoral studies in the United States, while less than half as many, 26 782, left the United states for studies in the EU. The gap is the largest for eastern European countries, but also for most Mediterranean countries. On the other hand, the United Kingdom and Ireland have a positive student flow balance with the United States. In 2009, half of the US students coming to the EU, 14 300, went to UK universities, while 8 500 left the United Kingdom for studies in the United States. Currently, there are no full datasets on the international mobility of researchers or on flows of students between the EU and other world regions. However, surveys on subpopulations of researchers indicate that the largest direction of researcher mobility is still between the EU and the United States. The main reasons noted by EU researchers for moving to the United States are better job opportunities, educational choices, and the existence of scientific or professional infrastructure.

While China and South Korea boost investments in R&D, a moderate growth in the EU indicates resilience in times of crisis

Knowledge creation requires funding and investments that have large potential for positive externalities. Consistent with the data in Figure 1, Figure 6 illustrates a rising investment trend in China and South Korea, a slight fall in the United States and Japan, and modest growth in the EU, albeit from a lower level. China's R&D intensity is closing the gap with the EU. In contrast, investments in the United States and Japan have slowed down following the economic crisis. In other words, up until 2011, the EU's investments in R&D were more resilient to the economic crisis than those of the United States and Japan (a trend also visible in Figure 7). If current trends were to continue, pushed by policy efforts in the Europe 2020 strategy, the EU will have closed its R&D intensity gap with the United States by 2020. However, for this to happen, the European economy would need to speed up its structural change towards more knowledge-intensive manufacturing and services.

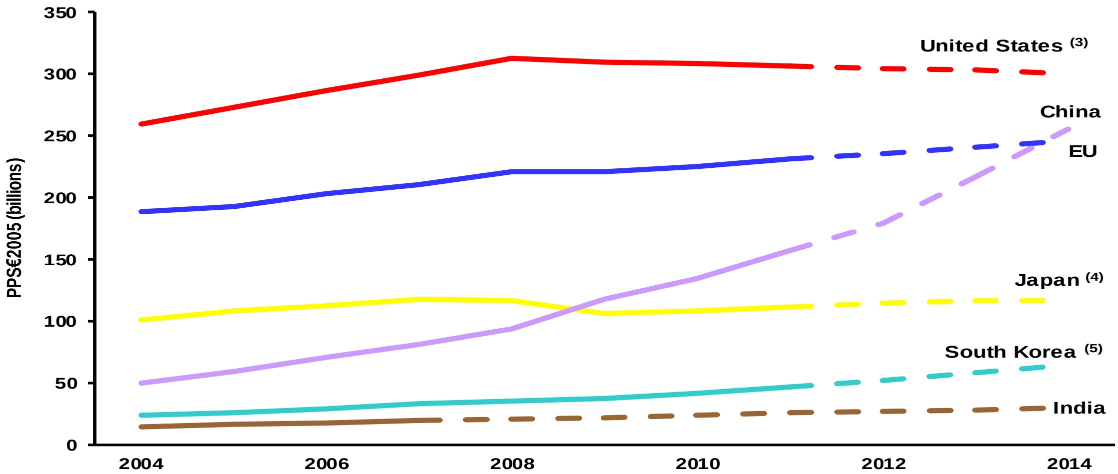
Figure 6: R&D investment trends as share of the economy (GDP)



Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness Report 2013
Data: DG Research and Innovation, Eurostat, OECD
Notes: (1) South Korea: (i) The projection is based on an R&D intensity target of 5,0% for 2020; (ii) There is a break in series between 2007 and the previous years.
(2) Japan: (i) The projection is based on an R&D intensity target of 4,0% for 2020; (ii) There is a break in series between 2008 and the previous years.
(3) United States: (i) The projection is based on an R&D intensity target of 3.0% for 2020; (ii) R&D expenditure does not include most or all capital expenditure (iii) There is a break in series between 2006 and the previous years.
(4) EU: The projection is based on an R&D intensity target of 3.0% for 2020.
(5) China: The projection is based on an R&D intensity target of 2,5% for 2020.

Currently, EU R&D intensity growth is linked to the shrinking economy following the crisis. On average, over the crisis period 2008–2011, the EU has achieved a positive and counter-cyclic trend in its R&D investments. The EU's R&D investments in real terms have grown over this period, slightly closing the gap with the United States.

Figure 7 Evolution of world R&D expenditure in real terms (1), 2004-2014 (2)

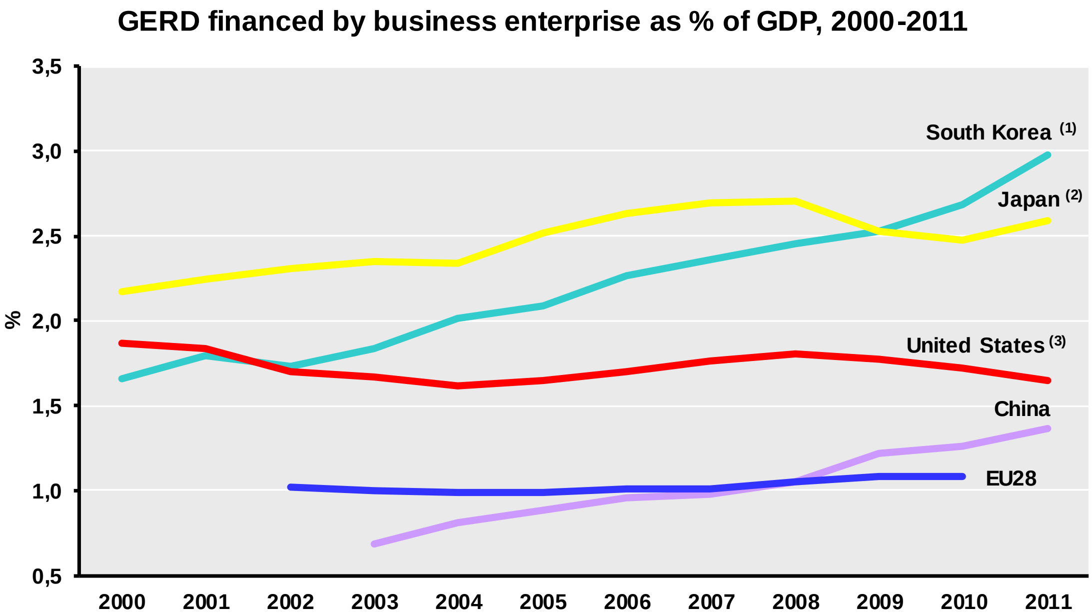


Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Eurostat, OECD
Notes: (1) Billions of PPS€ at 2005 prices and exchange rates.
(2) The values for 2012, 2013 and 2014 were estimated from the trends over the previous three years except in the case of India.
(3) US: There is a break in series between 2006 and the previous years; (ii) Most or all capital expenditure is not included.
(4) JP: There is a break in series between 2008 and the previous years.
(5) KR: There is a break in series between 2007 and the previous years.

Figure 7 also illustrates the fast and consistent growth of China's R&D investments, reflecting its determination to compete in the higher end of the global value chains ([9]). Most likely, in 2014 China will invest more in R&D in real terms (in PPS) than the EU-28 together, reaching an investment level close to that of the United States.

As visible in Figure 8, in the EU it is mainly the business sector that invests less in R&D. Over the period 2002–2010, there has only been a very slight increase of business R&D investments in the EU, which contrasts with the strong increase in the most knowledge-intensive Asian countries. Japan and the United States have been most affected by the economic crisis.

Figure 8: Business enterprises investments in R&D



Source: DG Research and Innovation - Economic Analysis Unit   Innovation Union Competitiveness Report 2013
Data: Eurostat, OECD
Notes: (1) KR: There is a break in series between 2007 and the previous years.
(2) JP: There is a break in series between 2008 and the previous years.
(3) US: (i) There is a break in series between 2006 and the previous years;
(ii) GERD financed by business enterprise does not include most or all capital expenditure.

[9] See also Chapters I.3 and III.4.

3. The EU's competitive position in science

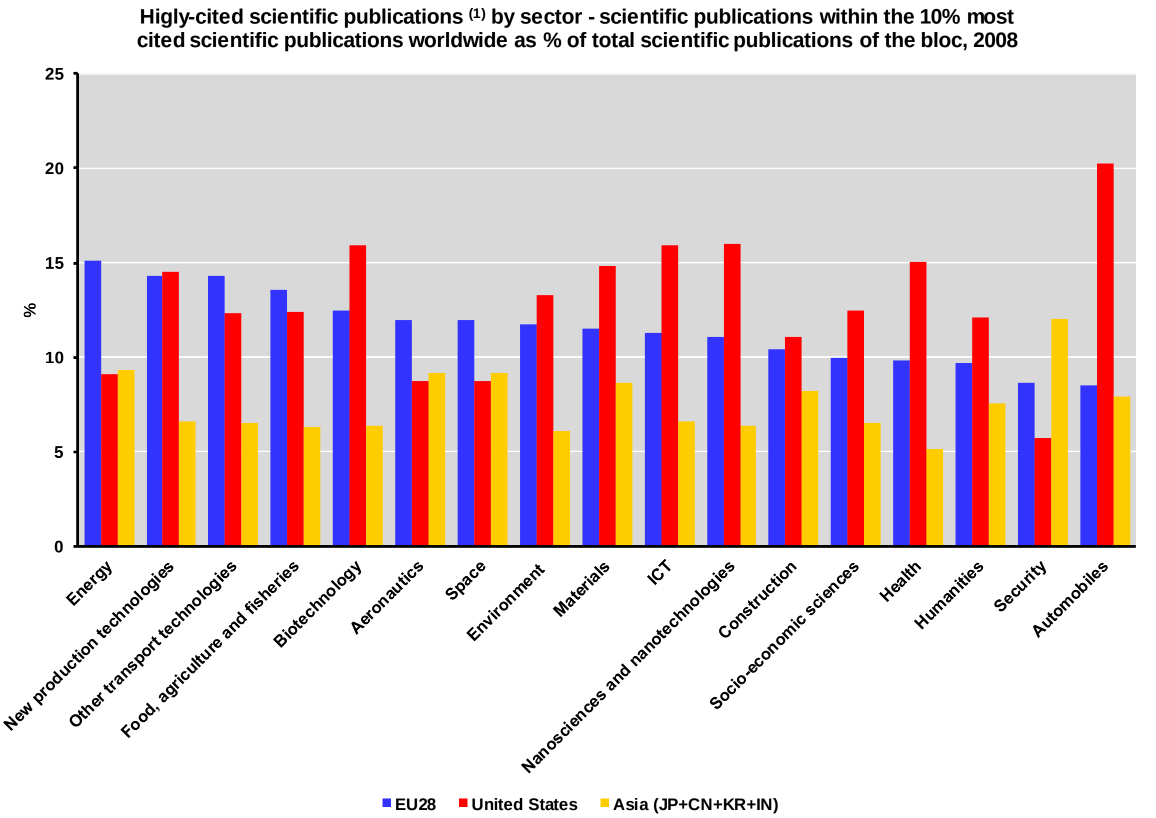
The growing geographic distribution of knowledge creation in the world, coupled with the continuous accumulation of the total knowledge assets available globally, push international competition towards an increasing specialisation. It is more and more difficult to be among the world leaders in a broad array of S&T areas. In addition, the growing global flows of R&D investments, foreign direct investment (FDI) ([10]) and a highly skilled work force are attracted by sector-specific competence centres. The EU's competitive position in research and innovation is therefore forcefully and increasingly dependent on its capacity to focus its science and technology in relevant fields.

The EU leads scientific excellence in several fields but lags behind in strategic areas

A comparison of overall research excellence in the world — highly cited publications, university performance and PCT patent development (see Chapter II.1.) — reveals that the United States outperforms the EU, but that several European countries score considerably higher than the United States. Figure 9 compares the EU with the United States and leading Asian countries in respect to one of these indicators, high-quality scientific production, by scientific field. The classification is based on the same themes as the EU Framework Programme (FP), although the data covers scientific publications in Scopus.

[10] In 2008, EU firms' FDI fell sharply. Since then, there has been a progressive increase in FDI outflows, both within the EU and to countries outside the EU. In 2011, the decreasing trend has been reversed with extra–EU FDI outflows reaching EUR 365 billion. Although the level is below the peak of 2007, outward direct investments have returned to their pre-crises values. A considerable part of this FDI was invested in research and innovation activities. In 2010, the EU-27 invested over EUR 50 million in professional, scientific and technical activities in extra–EU countries, which represents 17 % of all extra EU-27 FDI. In 2011, EUR 242 billion FDIs were made in the EU from non-EU firms.

Figure 9: Number of Top-10 % Most Highly Cited Publications (FRAC), 2008 (citation window 2008-2011)



Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness Report 2013
Data: Science Metrix
Note: (1) Fractional counting method, scientific publications 2008: citation window 2008-2011.

According to the bibliometric data presented in figure 9, based on Scopus database, the EU has a world scientific lead (in terms of high-impact) in energy, science for transport technologies (other than automobiles)[11], aeronautics, space, and the combined area of food, agriculture and fisheries. In the field of environment and science for new production technologies and for construction, the scientific quality in the EU is almost on a par with that in the world-leading United States.

However, for most scientific fields the United States is the leading world hub in terms of quality (scientific impact), and the EU is lagging behind. This includes several strategic science areas such as health and biotechnology, information and communications technology (ICT), nanoscience, materials and science for new production technologies. The most striking differences are the areas of biotechnology and automobiles (the latter being a stronghold for European industry). World scientific excellence in security is found in Japan, with the EU as follower.

[11] 'Other transport technologie's refer to all areas of transport except automobiles, aeronautics and space.

The EU is reinforcing its scientific strengths in the scientific fields where it has a leading world position — but is falling further behind in health and ICT

Figure 10 presents an overview of the evolution of the EU's scientific production and quality in each scientific field. The table presents several quality factors for measuring scientific quality. Apart from the 10 % most cited publications, the table also shows other indicators on scientific quality, such as the Average of Relative Citations (ARC) and the Average of Relative Impact Factors (ARIF). These measures broadly point in the same direction.

Figure 10: Scientific production and performance of the EU by scientific fields

EU Publications indexed in Scopus by FP7 thematic priorities, 2000-2010

	Pubs (FULL)	Pubs (FRAC)	Pub Trend	Growth Index	CI	SI	ARC	ARIF	% in top 10% most
Total	3.769.431	3.326.352		1,34 ▬	n.a. ▼	1,01 ▬	1,06 ▬	1,03 ▬	10,7%
Health	2.163.762	1.911.495		1,18 ▬	n.a. ▼	1,14 ▲	1,01 ▬	0,99 ▬	10,1%
Food, Agriculture and Fisheries	160.099	141.435		1,26 ▬	n.a. ▼	0,97 ▬	1,18 ▲	1,13 ▲	12,7%
Biotechnology	45.915	39.794		1,53 ▼	n.a. ▼	0,80 ▼	1,14 ▲	1,15 ▲	12,1%
ICT	367.331	327.818		2,21 ▬	n.a. ▼	0,89 ▼	1,07 ▬	1,01 ▬	10,9%
Nanosciences & Nanotechnologies	26.251	22.389		1,85 ▼	n.a. ▼	0,79 ▼	1,12 ▲	1,12 ▲	11,0%
Materials	152.008	132.245		1,07 ▼	n.a. ▼	0,72 ▼	1,19 ▲	1,21 ▲	12,3%
New Production Technologies	73.181	64.303		1,66 ▼	n.a. ▼	0,73 ▼	1,17 ▲	1,20 ▲	12,2%
Construction and Construction Technologies	33.257	30.262		1,49 ▬	n.a. ▼	1,04 ▬	1,05 ▬	1,02 ▬	10,8%
Energy	84.448	73.026		1,50 ▬	n.a. ▼	0,68 ▼	1,38 ▲	1,34 ▲	14,5%
Environment	225.914	188.716		1,31 ▬	n.a. ▼	0,97 ▬	1,18 ▲	1,12 ▲	12,2%
Aeronautics or Space	19.741	8.075		1,40 ▼	n.a. ▼	0,62 ▼	1,23 ▲	1,30 ▲	12,9%
Automobiles	7.159	6.565		1,14 ▬	n.a. ▼	1,07 ▬	0,98 ▬	0,89 ▼	9,7%
Other transport technologies	71.326	63.604		1,45 ▬	n.a. ▼	0,64 ▼	1,29 ▲	1,35 ▲	14,0%
Socio-economic sciences	220.774	199.104		1,79 ▬	n.a. ▼	1,01 ▬	1,00 ▬	0,96 ▬	9,8%
Humanities	102.936	95.729		1,62 ▬	n.a. ▼	1,33 ▲	0,95 ▬	0,93 ▬	9,6%
Security	15.329	13.716		2,10 ▲	n.a. ▼	0,77 ▼	1,18 ▲	1,11 ▲	11,8%

Source: DG Research and Innovation - Economic Analysis Unit

Data: Science Matrix - Canada, based on Scopus data

Notes: FULL=full counting; FRAC=fractional counting; CI=citation index; SI=specialisation index;

ARC=Average of Relative Citations; ARIF=Average of Relative Impact Factors

A general conclusion from Figure 10 is that the EU is reinforcing its scientific strengths in the science fields where it has excellent quality or a world-leading position, namely in energy and science for other transport technologies, aeronautics, space, and in food, agriculture and fisheries. A very positive sign is the clear improvement in terms of scientific quality in some strategic fields where the EU has achieved high quality, although it still lags behind the United States.These include the environment, nanosciences, materials, and science for both new production technologies and biotechnologies.

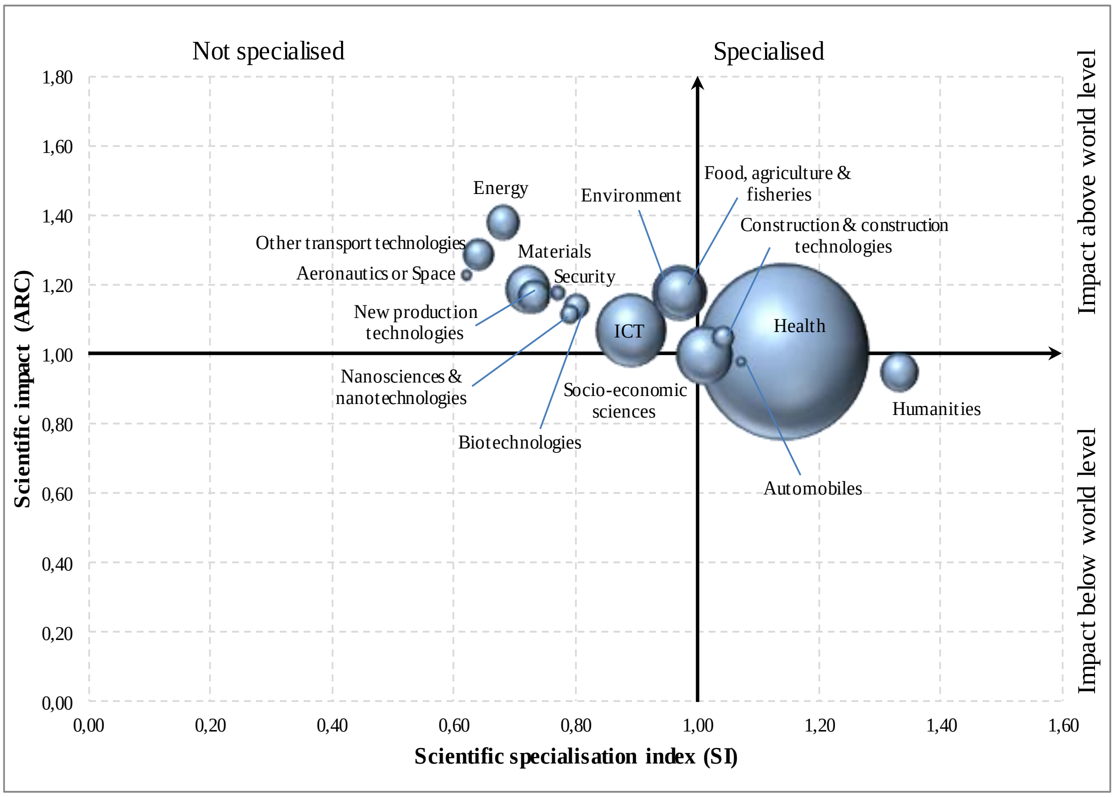
A worrying sign is the lower and stagnant scientific quality in health and ICT, fields where the EU has the largest number of scientific publications. Despite the high and increasing number of scientific papers published on health (the EU counts a higher number of scientific publications than the United States) and the strong increase in scientific publications in ICT, scientific quality in these fields remains in line with the world average and has not significantly improved over the last decade. The EU's other major publication fields are materials, environment and socioeconomic sciences. The trend is an increase up to the economic crisis, since which scientific production is most areas has stagnated.

The EU is not specialised in the scientific fields where it has a higher quality

Figure 11 correlates the scientific quality in the EU with its scientific specialisation. The size of each bubble represents the number of total scientific publications in that field.[12]

Figure 11: EU's scientific specialisation and quality, 2000–2010

Positional analysis of EU publications in Scopus by FP7 (specialisation versus impact), 2000-2010



Source: DG Research and Innovation - Economic Analysis Unit

Data: Science Metrix - Canada, based on Scopus

Notes: Scientific specialisation include 2000-2010 data; the impact is calculated for publications of 2000-2006, citation window 2007-2009

Figure 11 shows that the scientific specialisation in the EU does not coincide with the fields in which quality is highest. Scientific production in the EU is instead concentrated in health, humanities, science for construction technologies, automobiles and socioeconomic sciences, all of which are fields in which the EU is lagging behind the United States in terms of quality, and where no clear quality progress has taken place over the last decade.

[12] The y-axis measures scientific impact. It should be considered that there may be a certain bias between scientific fields in what concerns citations. Some disciplines, such as health science, tend to use more citations than other disciplines.

In contrast, the United States achieves a combination of high scientific output, specialisation and impact in several scientific fields ([13]). More specifically, the United States achieves high levels of output, specialisation and scientific impact in health, environment, socioeconomic sciences and the humanities. In some scientific fields the United States is facing a similar challenge to the EU, with a lower level of specialisation in areas where scientific quality is high and the country is recognised as a world leader, namely ICT, biotechnology, new production technologies and materials (excluding nanotechnology). China and Japan systematically receive fewer citations in most research areas although they are much more specialised in several areas. There is one exception: Japan performs strongly in energy research, combining a high level of specialisation with a high impact score.

Health research constitutes the largest area of scientific production in all regions/countries considered. While European countries dominate in terms of quantity of publications in this area, the United States shows a higher level of quality and specialisation. Both Japan and China have a smaller output in health research than European countries and the United States, and they are cited less frequently than the world average in this area. In the longer term, the strategy of greater Chinese and Japanese specialisation in strategic fields such as energy, materials, new production technologies, and for China, in ICT and other transport technologies, may bear its fruits in terms of increased quantity and quality in science.

These findings also provide guidance for international scientific cooperation. In particular, the EU has a particular interest in scientific cooperation with the United States and Asia in areas where these regions have higher scientific quality than the EU, while the EU is relatively attractive for inward mobility and investments in the scientific fields where it is a world leader.

The EU is enlarging and intensifying its international scientific cooperation

The evolution towards more geographically distributed scientific production, coupled with growing overall production and pressure for reviewed specialisation strategies, goes hand in hand with an increase in international scientific cooperation. Given that today over 70 % of knowledge production takes place outside the EU, reinforced international cooperation in science is of utmost relevance. Almost one third (30 %) of the EU's overall scientific production is achieved through cooperation among researchers from different countries, a trend which has grown constantly (8 % annual average growth) over the last decade. As shown in Figure 12, all countries have increased their international scientific cooperation, with growth rates ranging from 8 % to 22 %.

In this context, it is relevant to monitor the extent to which European researchers cooperate with colleagues from countries outside Europe more closely, in particular with peers in the United States and in the rising S&T centres in Asia and Latin America. Figure 12 provides an overview of the scientific cooperation in the world.

[13] For full data, see Statistical annex.

Figure 12: Scientific co-publications between the EU and world partners, 2000–2011.

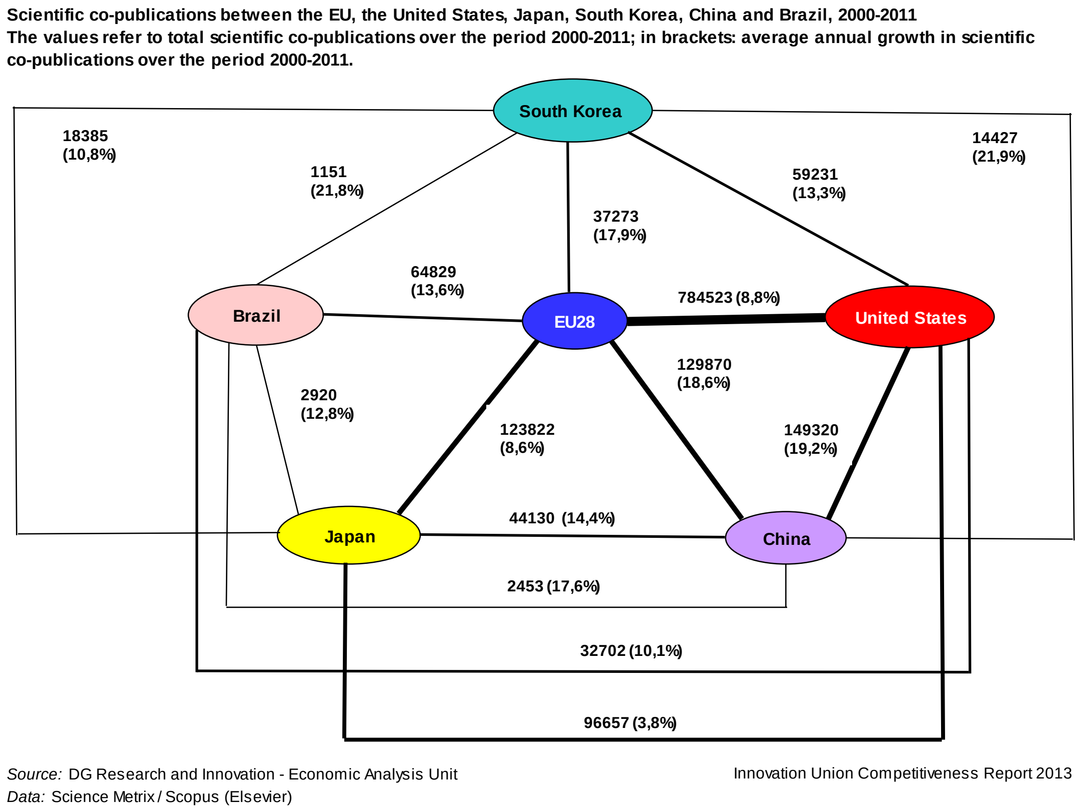


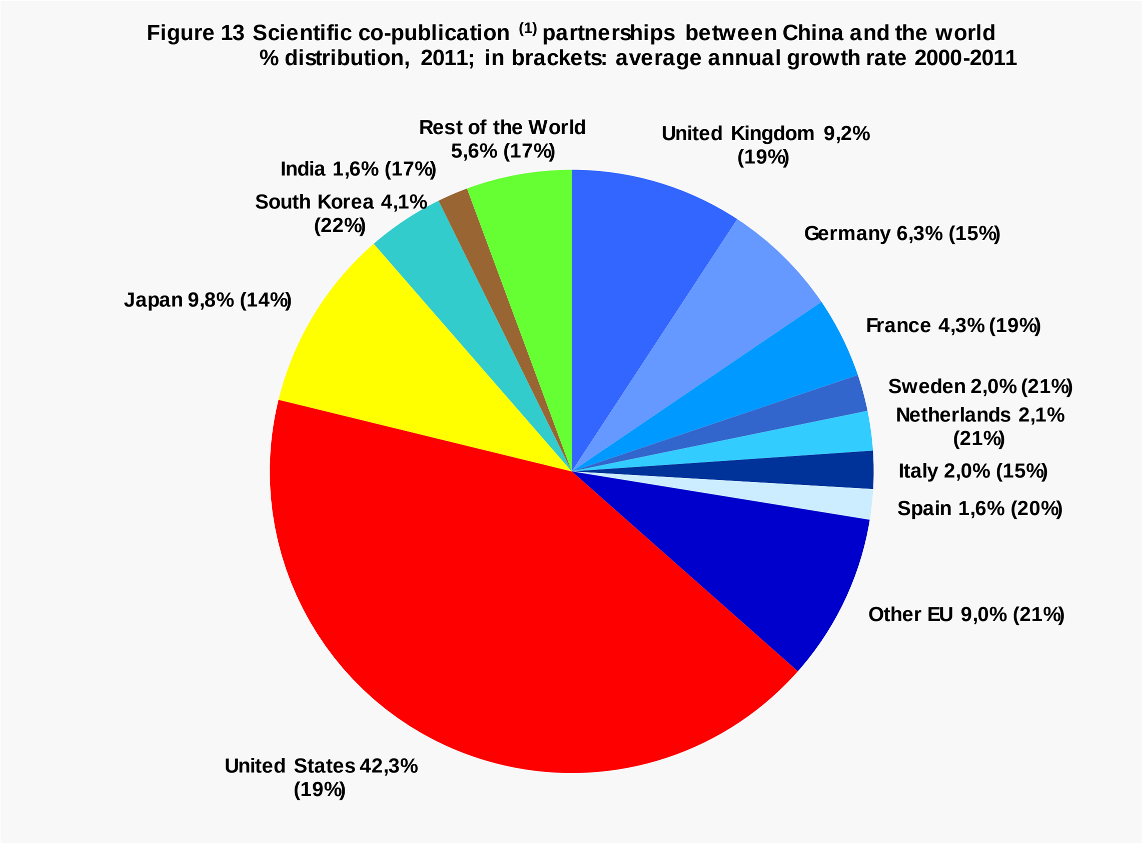
Figure 12 shows that the major part of international scientific cooperation still takes place between the EU and the United States. The United States cooperates more closely than the EU with China and South Korea, while the EU boasts more intensive scientific cooperation with Japan and Brazil. The EU is slowly catching up in its scientific cooperation with South Korea, but is still losing ground in cooperation with China. At world level, the largest growth in scientific cooperation is centred on China with growth rates of up to 21.9 % (Chinese–South Korean cooperation).

Given the large scale of the international science and technology, individual EU Member States alone have less relative weight

The process towards more distributed science and technology reinforces the importance of visibility and scale for international cooperation. This mainly has an impact at the country level, in particular in the case where larger countries such as China and India are moving up to a prominent position in S&T. In this context, each EU Member State has become smaller in relative terms, even though every country has managed to increase its individual scientific cooperation with China. As illustrated in Figure 13, even larger scientific producers among the EU Member States represent only 10 % or less of China's international scientific cooperation, and most Member States represent less than 1.5 % of Chinese international co-publications. However, taken as a block, the EU does have a critical mass and impact on China's international scientific cooperation. The EU as a whole corresponds to over one third

(36 %) of China's scientific cooperation with other world partners, the second world scientific partner after the United States (42 %). This calls for increased scientific coordination within Europe around the European Research Area policy.

Figure 13: Scientific co-publication partnerships between China and the world



Source: DG Research and Innovation - Economic Analysis Unit   Innovation Union Competitiveness report 2013

Data: Science Metrix / Scopus (Elsevier)

Note: (1) Full counting method.

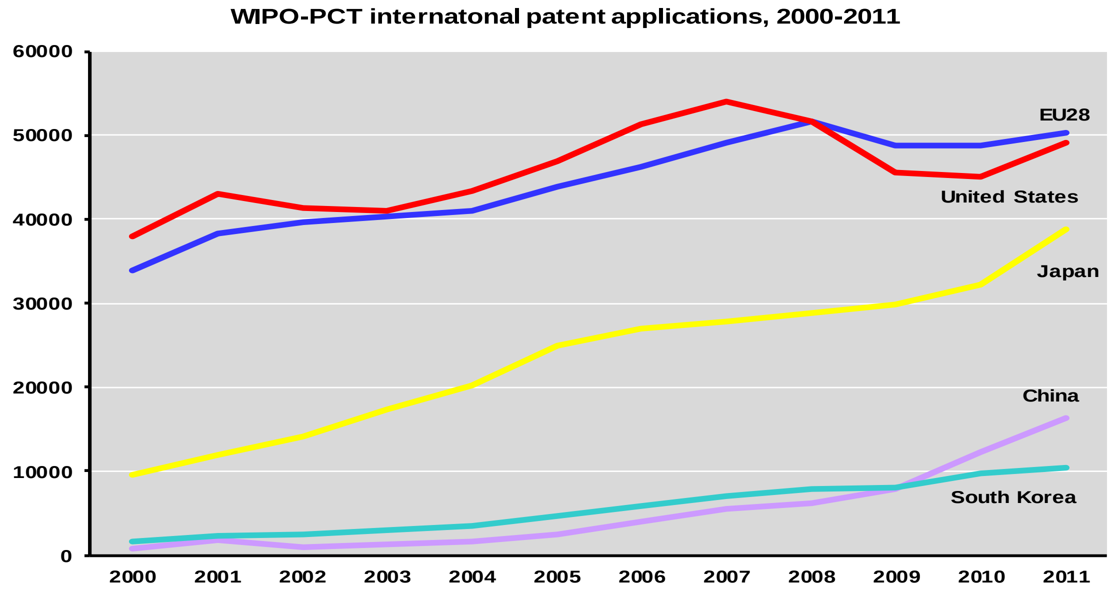
4. The EU's competitive position in technology development

This section presents the world position and sector profile of the EU in technology production, complementing the previous sections on human resources, investments and science.

While the EU and the United States are reinvigorating their technology development and recovering from the effects of the crisis, the major Asian economies are catching up quickly

Figure 14 illustrates the overall trend in world technology production, also visible in Figure 1. The main data are derived from PATSTAT and the World Intellectual Property Organization (WIPO)–PCT patent application statistics, allowing for international comparability and avoiding home bias. These are the most recent patent data available. Even though this is an indicator of the quantity of applications, there is overall a high statistical correspondence between PCT patent applications and triadic patent applications, indicating a possible relevance for the quality of the technology developed ([14]).

Figure 14: Total WIPO–PCT patent application by priority year 2000–2011



Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness Report 2013
Data: WIPO

As in science, the EU broadly maintains its dynamism in patent production, even surpassing the United States since the economic crisis. There was a slight fall following the crisis in 2007, but recovery from 2010 onwards. Technology production in the United States has

[14] See Directorate-General Joint Research Centre (JRC) Ispra, final report on research excellence. Project co-financed by DG Research and Innovation, 2013.

declined more, although there has also been a clear recovery trend since 2010. Even though both the EU and the United States have increased their PCT patent applications, the main change over the last decade has been in Asia, with the continued rise of Japan and South Korea and the acceleration of China's growth from 2009 onwards. Figure 15 presents a sector breakdown of PCT patent applications in terms of world shares and change over time (2008 to latest available year for sector-specific PCT data). In the table, the world technology production is divided into the three major blocks of countries: the EU, North America (including the United States and Canada) and Asia (including Japan, China and South Korea).

Figure 15: PCT applications, World shares; absolute numbers in major world regions

	EU-27		North America		Asia	
	2000	2008	2000	2008	2000	2008
Health	32.7% 6015	30.9% 7207	49.4% 9068	47.9% 11 172	14.5% 2661	17.3% 4035
Biotechnology	28.0% 2787	32.0% 2415	49.0% 4885	44.4% 3346	20.7% 2068	20.8% 1566
ICT	37.7% 8354	25.8% 9960	40.0% 8864	35.0% 13 486	20.5% 4552	37.9% 14 613
Energy	29.8% 1624	31.6% 1744	48.2% 2467	46.9% 2591	19.7% 1007	19.2% 1059
Green energy	32.7% 3196	33.3% 3806	43.6% 4258	32.5% 3687	21.2% 2075	31.7% 3624
Environment	34.7% 3970	34.5% 4839	42.0% 4815	31.8% 4456	20.8% 2386	31.1% 4363
Nanotechnology	31.5% 256	34.1% 478	45.6% 371	37.0% 552	19.8% 161	26.5% 389
Materials	41.7% 7091	35.5% 8070	34.4% 5850	29.4% 6691	21.0% 3566	32.1% 7296
New Prod. techn.	36.0% 4978	36.8% 5664	45.1% 6236	36.33% 5596	15.8% 2185	23.8% 3670
Security	38.7% 2200	34.8% 2934	45.5% 2585	37.6% 3171	12.6% 717	24.9% 2098
Automobiles	60.0% 1642	50.2% 2213	24.5% 670	17.3% 763	14.3% 391	31.2% 1378
Other Transport	58.0% 449	47.5% 625	25.6% 198	22.3% 294	9.8% 76	24.2% 318
Aeronautics	42.8% 112	65.7% 460	50.0% 131	26.7% 187	5.0% 13	6.1% 43
Space	27.7% 28	35.4% 28	50.5% 51	34.2% 27	18.8% 19	30.4% 24
Construction	54.8% 1532	44.2% 2183	28.2% 787	35.6% 1757	11.0% 307	15.4% 759
Food, Agriculture Fishery	43.4% 1641	36.8% 1902	36.0% 1362	37.7% 1949	15.4% 582	21.1% 1091

Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: WIPO PCT applications; data processed by the University of Bocconi, Italy.

Figure 15 presents a very tight and even distribution of strengths in several technology areas, after the clear rise of Asia in all categories. Consistent with the findings from Figure 1, it has been mainly North America that has lost shares and Asia that has gained. The EU has in broad terms kept its world technology share in most areas.

Technology-intensive countries in North America and Asia are more strategic than the EU, focussing on key enabling technologies and transformative technologies linked to societal challenges

Another important finding from Figure 15 is the differences in technology profiles between the three major blocks of countries. Countries in North America and Asia seem to be more strategic and selective in their approach, orienting technology development to key enabling technologies and transformative technologies linked to societal challenges. North America, headed by the United States, stands out in technologies for health, biotechnology, energy and security; Asia takes the lead in ICT. This evolution is partly linked to FDI. Asia has reached a technology position on a par with the western blocks in green energy, environmental technologies, materials and space. For the EU's capacity to transform its economy through more radical innovations, the exceptions are environmental technologies and green energy, materials, new production technologies and aeronautics, where the EU held a world lead in 2008. But Asia is catching up rapidly in these fields as well as in automobiles and other transport technologies. The EU presents a broader but less specialised technology profile, keeping its strengths in more traditional and established industry sectors (automobiles, transport, construction, food and agriculture). However, also in these sectors, with the rise of Asia, the EU is losing world shares.

Comparing the technology strengths of the EU to its world position in various scientific fields (see Figure 9) highlights several interesting findings. Overall, the EU's world competitive positions in science and in technology match to a certain extent. As in science, the EU submits the largest share of PCT patent applications in aeronautics, space and other transport technologies, in environment and in green energy, and it is almost on a par with North America in technologies for food, agriculture and fisheries. Similarly, as in science, the EU is clearly behind North America in health, biotechnology and ICT patent applications, with a decreasing world share in health technologies and ICT. In contrast with its scientific performance, the EU is world leader in technologies for automobiles, construction, materials and new production technologies, the former three being areas where there has been a clear improvement in scientific quality in the EU as well. On the other hand, the EU’s scientific lead in energy and security has not been transformed into leading positions for technology.

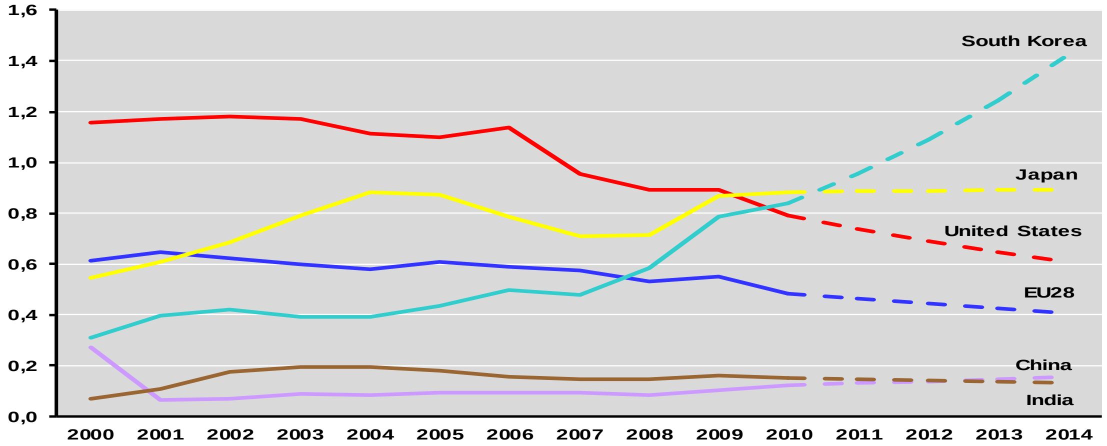
Economic transformation addressing societal challenges may come from Asia

Figures 16 and 17 highlight the accelerating progress of Asia in transformative technologies linked to major societal challenges and expanding world markets. Contrasting with the slow move from the traditional technology leaders of the United States and the EU, Figures 16 and

17 outline a major geographic strategic shift in the world's knowledge economy in the decade to come.

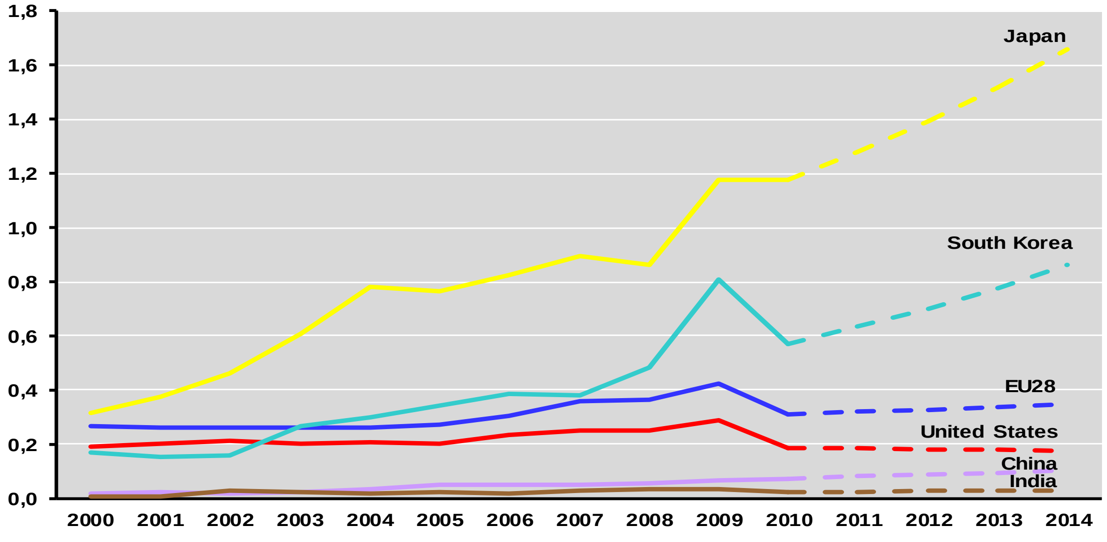
Figures 16 and 17: PCT patent applications in areas addressing societal challenges

Figure 16 Health-related technologies - PCT patent applications (1) per billion GDP (PPS€), 2000-2014 (2)



Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness Report 2013
Data: Eurostat, OECD
Notes: (1) Patent applications under the PCT (Patent Cooperation Treaty), at international phase, designating the EPO by country of residence of the inventor(s).
(2) The values for 2011-2014 were estimated on the basis of the average annual growth over the period 2005-2010.

Figure 17 Environment-related technologies - PCT patent applications (1) per billion GDP (PPS€), 2000-2014 (2)



Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness Report 2013
Data: Eurostat, OECD
Notes: (1) Patent applications under the PCT (Patent Cooperation Treaty), at international phase, designating the EPO by country of residence of the inventor(s).
(2) The values for 2011-2014 were estimated on the basis of the average annual growth over the period 2005-2010.

The United States and Asia are specialised in transformative and pervasive technologies, while the EU's technology development is focused on its established industries

The previous analysis of the EU's scientific production revealed a mismatch between the specialisation and, on the other hand, quality and world-relative strength (compare Figures 11 and 9). The major technological areas of specialisation and de-specialisation of Europe can be illustrated through the Revealed Technological Advantage (RTA), which compares the relative importance of a given technological area in patent production throughout Europe ([15]) to the relative importance of this technological area in worldwide patent production ([16]). Figure 18 provides an overview of the technology specialisation (RTA index) of the EU, the United States and the major Asian technology powers. The arrows indicate the trend over the period 2000–2010 and the colour green indicates areas of technology specialisation.

Figure 18: RTA index, WIPO by applicants, 2000–2010

Thematic priority	EU-27	United States	ASIA
Health	0.9 ⇓	1.25 ⇑	0.61 ⇑
Biotechnology	0.94 ⇑	1.20 ⇓	0.71 ⇑
ICT	0.84 ⇓	1.04 ⇓	1.29 ⇑
Energy	1.15 ⇓	0.74 ⇓	1.22 ⇑
Environment	1.04 ⇓	0.88 ⇓	1.15 ⇑
Nanotechnologies	0.83 ⇓	1.16 ⇓	1.07 ⇑
Materials	1.05 ⇓	0.86 ⇓	1.16 ⇑
New Production techn.	1.02 ⇑	1.10 ⇓	0.78 ⇑
Security	0.97 ⇓	1.09 ⇓	0.81 ⇑
Automobiles	1.59 ⇑	0.54 ⇓	0.96 ⇑
Other Transport techn.	1.45 ⇓	0.70 ⇑	0.69 ⇑
Aeronautics	1.52 ⇑	1.03 ⇓	0.21 ⇑
Space	1.02 ⇑	1.25 ⇓	0.64 ⇑
Construction technologies	1.40 ⇓	0.82 ⇑	0.53 ⇑
Food and Agriculture	1.12 ⇓	0.91 ⇑	0.81 ⇑

Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: WIPO PCT applications; data processed by the University of Bocconi, Italy.

The broad diversification within the EU's technology profile contrasts with the highly specialised technology portfolio of Asian countries. The United States is in a somewhat intermediate position. The EU is characterised by its technology specialisation on established industries such as aeronautics, automobiles, other transport technologies and construction

[15] The EU and Associated Countries.

[16] Four patent systems are considered: European Patent Office (EPO) patent applications, United States Patent and Trademark Office (USPTO) grants, PCT patent applications and triadic patents.

technologies. The specialisation profile in the United States and even more so in Asia is quite the opposite. They have a much clearer specialisation profile in transformative and pervasive technologies. The United States is positioning itself in health, biotechnology and nanotechnologies, while Asia has already achieved technological advantage in ICT, nanotechnologies, materials, energy and environment technologies. Overall, Asia is expanding its relative strengths in all technology areas.

The EU is not focussing on these transformative technologies. The trend is instead to reinforce technologies in its established transport and production sectors while simultaneously losing ground in all branches of transformative and pervasive technologies, including technologies addressing societal challenges, which have a potential for transformative structural change.

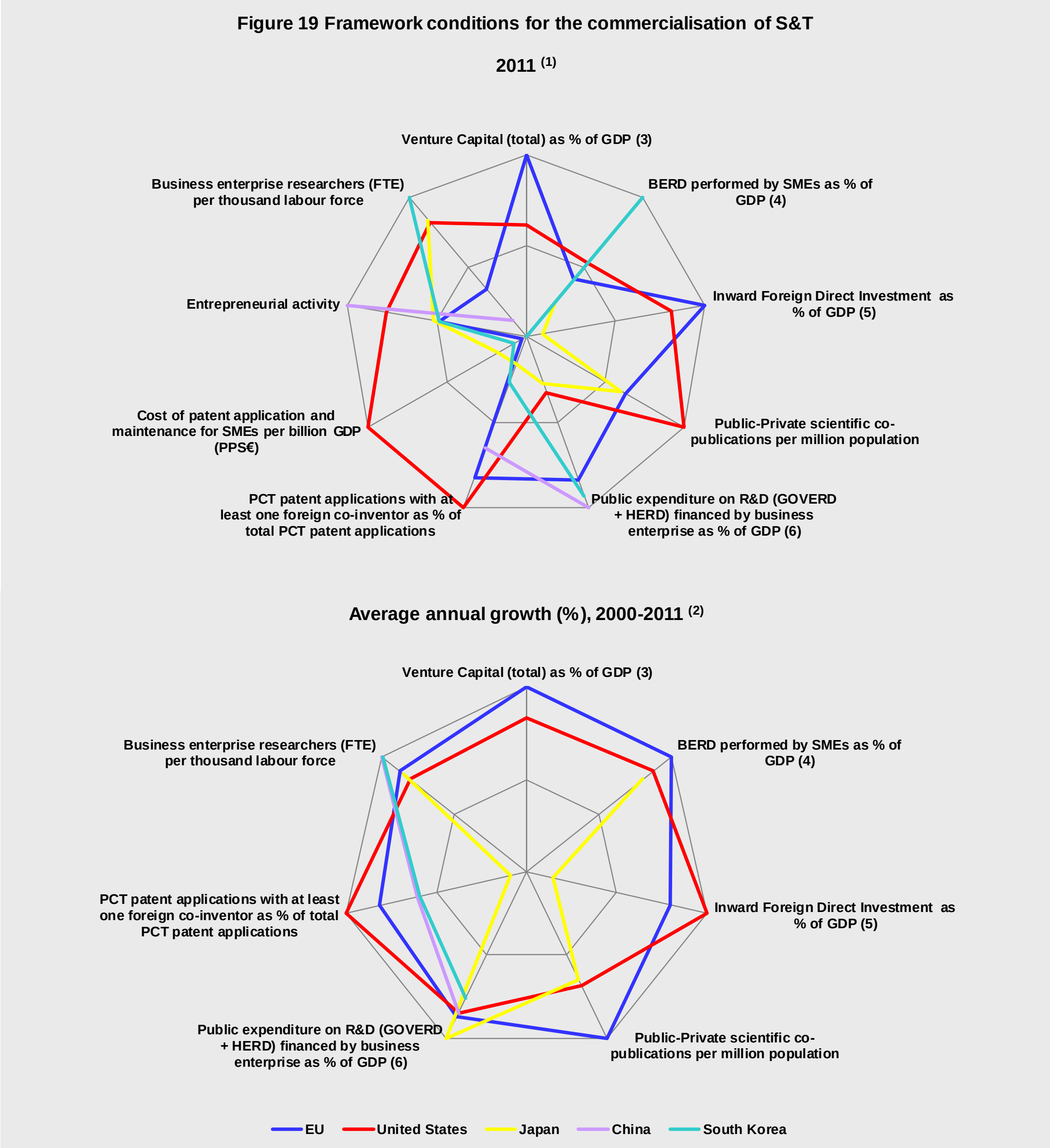
Comparing the EU's technology specialisation profile (Figure 18) with its technology strengths at the world level (Figure 15), a clearer match emerges than during the comparison with the EU’s scientific production profile. The specialisation in transport and construction reflects the technology areas where the EU has the largest world shares of PCT patent applications. At the other end of the scale, the lower and falling world technology shares in health and ICT match the low and decreasing RTA index for these areas. The mismatch between world position and specialisation efforts occurs for only a few technology areas. The lower and decreasing specialisation in energy, environment and materials may in the medium term endanger the EU’s lead in these areas, if it has not done so already (the latest patent statistics only go up to 2008). This would also create a mismatch between the EU's scientific strengths in these areas and its technology position.

5. Innovation and economic impact for a knowledge-intensive economy

Knowledge in the form of human capital, science and technology requires a vigorous innovation system if it is to have a real economic impact. A well balanced intellectual property rights (IPR) system, risk capital, finance ventures, entrepreneurship, knowledge flows and business absorptive capacity are all essential building blocks in a systemic approach to innovation.

Figure 19 illustrates the EU's relative strengths in these framework conditions for innovation, and shows the dynamics over the period 2000–2011. Overall, the EU benefits from more finance to innovation in the form of venture capital and inwards FDI, and it has achieved a considerable average annual growth in knowledge transfer and R&D activity in small and medium-sized enterprises (SMEs). However, the EU suffers from higher patent costs, lower entrepreneurial activity and less research activity in the business sector compared to Asian countries and the United States. Data on framework conditions for China, South Korea and Japan are lacking for some indicators.

Figures 19: Framework conditions for commercialisation of S&T



Source: DG Research and Innovation - Economic Analysis Unit

Innovation Union Competitiveness Report 2013

Data: Eurostat, OECD, Innovation Union Scoreboard, Eurobarometer, PriceWaterhouseCoopers - NVCA Money Tree Report

Notes: (1) The values refer to 2011 or to the latest available year.

(2) Growth rates which do not refer to 2000-2011 refer to growth between the earliest available year and the latest available year over the period 2000-2011.

(3) EU does not include BG, EE, HR, CY, LV, LT, LU, MT, SI and SK.

(4) (i) US: BERD does not include most or all capital expenditure; (ii) JP: BERD by size class is underestimated.

(5) (i) The values refer to the average over the period 2008-2011 and average annual growth refers to the growth between 2004-2007 and 2008-2011; (ii) EU refers to extra-EU.

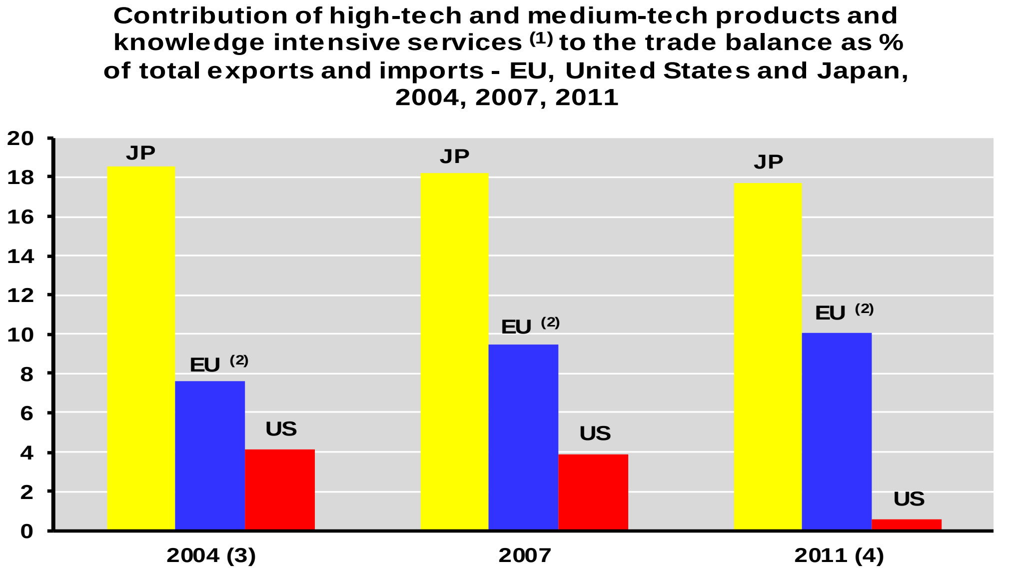
(6) US: (i) GOVERD refers to federal or central government expenditure only; (ii) HERD does not include most or all capital expenditure.

(7) Elements of estimation were involved in the compilation of the data.

The EU is increasing its contribution of high-tech products, medium-tech products and knowledge-intensive services to the trade balance

The share of trade in knowledge-intensive goods and services reflects a country's level of competitiveness and its capacity to compete in the higher end of global production chains ([17]). While reflecting the economic structure, it also provides an indication on the effectiveness of the innovation system.

Figure 20: Contribution of knowledge-intensive goods and services to trade balance



Innovation Union Competitiveness Report 2013

Source: DG Research and Innovation - Economic Analysis Unit
Data: Eurostat, COMTRADE
Notes: (1) US, JP: Data were not available for all knowledge intensive sectors for all years.
(2) Extra-EU27.
(3) US, JP: 2005.
(4) US: 2010.

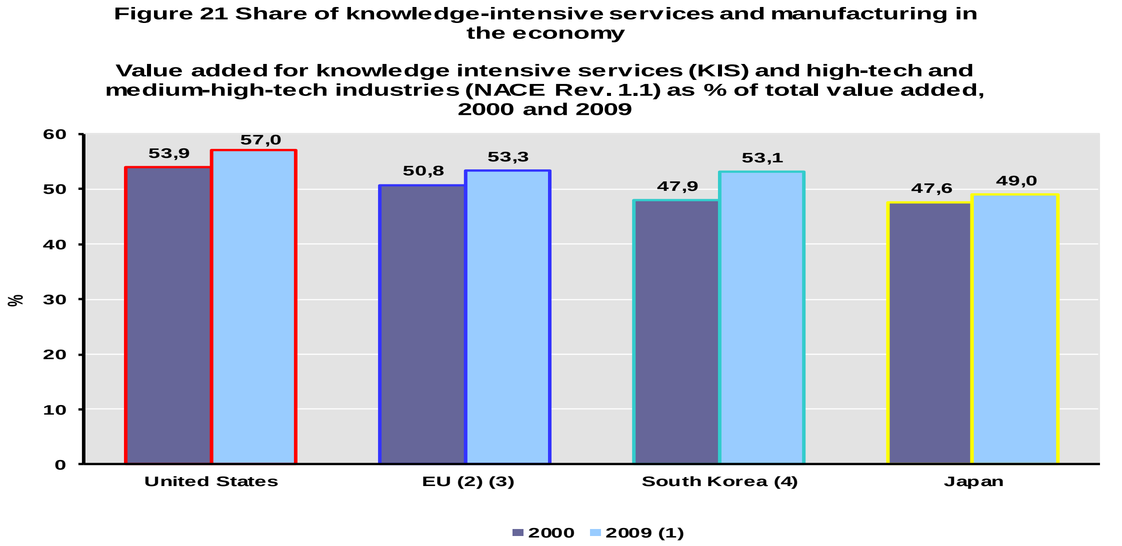
As represented in Figure 20, the EU has increased its contribution of high-tech products, medium-tech products and knowledge-intensive services (KISs) to the overall trade balance (progressing from 7.6 % to 10 % in 2011). It is worth noting that in the same period, both the United States and Japan experienced falling knowledge intensity in their trade balance, albeit departing from very different situations: while the knowledge-intensive trade balance in Japan fell slightly from 18.5 % in 2004 to 17.7 % in 2011, that of the United States passed from a balance of 4.1 % in 2004 to a surprisingly low level of 0.6 % in 2011. More relevant is the breakdown of the evolution for the three competitors: while in the EU the growth over the period is explained by positive balances in all three categories (high-tech products, medium-

[17] Chapter III.4 presents the most updated data on global value chain income, showing that the EU still represents the highest world share of global value chain income, although with a decreasing evolution since 2008. The EU remains competitive in medium-tech and high-tech products, as well as in business and other market services. However, it is losing competitiveness in low-tech and medium-low–tech products.

tech products and KISs), the slightly reduced contribution in Japan is due exclusively to an inversion of the contribution of knowledge-intensive services (KISs) to the trade balance (over the period, the trade balance of Japan in high-tech and medium-tech products remained stable). For the United States, the shrinking contribution of knowledge-intensive goods and services to the trade balance is linked to a clear reduction of high-tech and medium-tech products falling from 7.7 % contribution in 2004 to 2.4 % in 2011. The United States also suffered from a slight decrease in the contribution of KISs to the trade balance.

While data on the trade balance provide a good proxy for international competitive advantages in knowledge-intensive goods and services, they do not depict the overall knowledge intensity of the economy. This remains an essential factor for the long-term sustainability of high-income economies.

Figure 21: Share of knowledge-intensive services and manufacturing in the economy



Source: DG Research and Innovation - Economic Analysis Unit   Innovation Union Competitiveness report 2013
Data: Eurostat, OECD
Notes: (1) JP: 2008.
(2) EU does not include Croatia.
(3) EU: Building and repairing of ships (low-tech) is included.
(4) KR: Water transport and air transport are not included.

Figure 21 shows that knowledge intensity has increased in all developed economies. This is a general trend, reflecting the growing knowledge accumulation in the world. The United States remains the most knowledge-intensive economy with a strong positive evolution. The EU is moving in the right direction but the upgrading of its economy must be accelerated to catch up and close its gap with the United States. Overall, Figures 20 and 21 reflect the positive picture of the EU's competitive position in research and innovation ([18]). Maintaining this position depends on the capacity of Europe to upgrade and position itself in the knowledge economy of tomorrow.

[18] For a more detailed analysis of structural change in the EU, see Part III of this report.

I. Invest:

Knowledge-driven competitiveness

1. R&D intensity in Europe

Highlights

The EU's R&D intensity is growing coupled with a catching-up within Europe

The European Union (EU) is making progress towards its research and development (R&D) intensity target of 3 % in 2020. After several years of stagnation at around 1.85 % of gross domestic product (GDP), the EU's R&D intensity has been progressing steadily since 2007 to reach 2.02 % of GDP in 2011. Internationally, R&D intensity in the United States is on a downward trend, while South Korea and China have achieved an extremely rapid and sustained R&D intensity growth. R&D intensity in Japan increased between 2010 and 2011 following a decline between 2008 and 2010.

Some EU Member States achieved even higher rates of growth in R&D intensity than China over the period 2007–2011. This is the case for Estonia, Slovenia, Slovakia, Poland and Ireland, Poland and Ireland in all of which countries R&D intensity grew by between 34 % and 120 % compared to 32 % in China. Since 2007, R&D intensity has increased in all EU Member States, except in Luxembourg, Sweden, Romania and Croatia (data are not available for Greece).

However, business as usual is not sufficient to reach the 2020 target

If the EU 3 % target is to be achieved by 2020, much more rapid progress is needed in most Member States. If progress made over the period 2000–2011 is replicated over 2011–2020, only 8 Member States are likely to reach their 2020 targets: Germany, Estonia, Ireland, Cyprus, Hungary and Finland (as well as Denmark and Malta, which have already reached their R&D intensity targets). However, if the trend over 2007–2011 is maintained, 11 Member States will reach their 2020 targets.

Progress at the EU level depends to a large degree on the evolution in the biggest Member States, which either remain far from their targets or have set targets that could be increased. The lack of progress towards individual R&D intensity targets reveals the need for structural change in the sectoral composition of Europe's economy.

The decrease in the EU's world share in R&D expenditure due to the rise of China has slowed down during the crisis

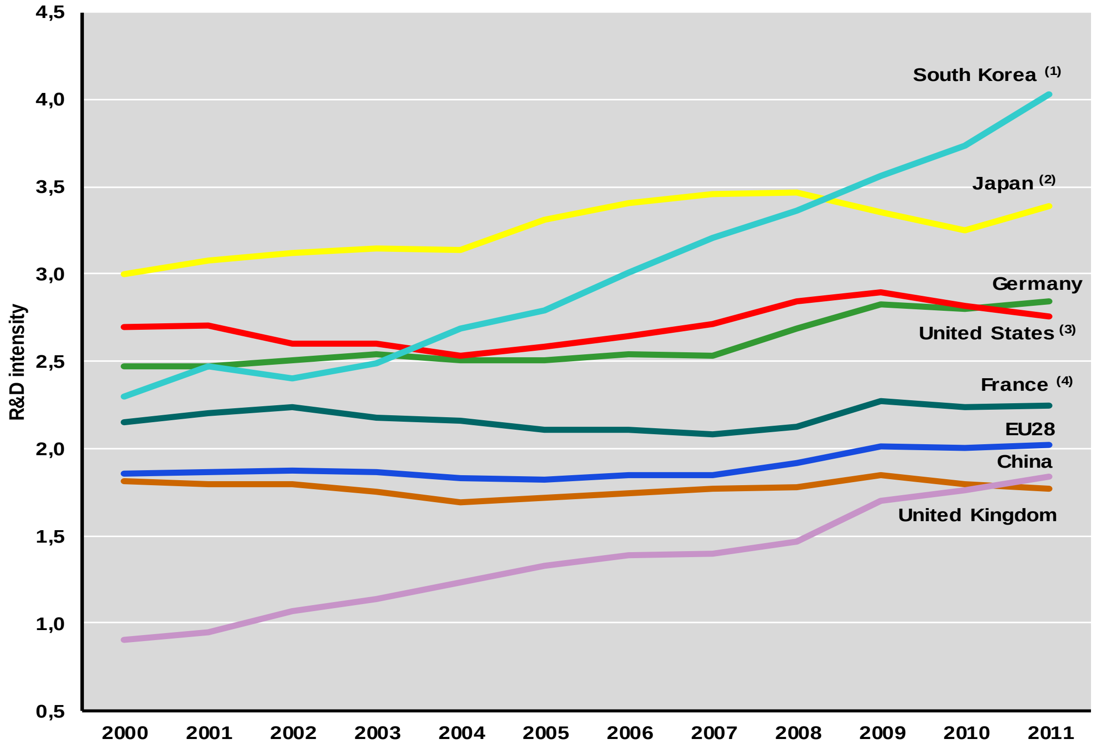
In 2011, the EU represented 22.8% of total R&D expenditure in the world, measured in PPS€ at 2005 prices and exchange rates, down from 26.7% in 2000 (Figure I.1.1). The continuously decreasing share of the EU in world R&D expenditure is mainly due to the rapid rise of China. However, this decrease of the EU's share has decelerated during the crisis (-1.1

percentage points, from 23.9% in 2007 to 22.8% in 2011) compared to the years before the crisis (-2.8 percentage points, from 26.7% in 2000 to 23.9% in 2007). The decrease of the US share since 2000 has been even more pronounced than that of the EU, from 38.6% to 30.2% in 2011, while the share of the developed Asian economies has eroded from 18.3% in 2000 to 18.0% in 2011 after rising to 19.1% just before the crisis; in this group of economies, the decrease of Japan's share has been partly compensated by the increase of South Korea's share. The rest of the world's share has been relatively stable at around 7%. The main change is that of China whose share has increased almost fourfold from 3.9% in 2000 to 15.2% in 2011, with an acceleration after 2008, to the detriment of the shares of the United States and the developed Asian economies.

The EU's R&D intensity has been slowly progressing since 2007

After seven years of relative stagnation at around 1.85 % of GDP between 2000 and 2007, the R&D intensity (R&D expenditure over GDP) of the EU has been slowly progressing since 2007, reaching 2.02 % of GDP in 2011 (see Figure I.1.2). This positive evolution contrasts with the downward trend observed in the United States and Japan, albeit at a much higher level. What stands out, however, is the extremely rapid and sustained R&D intensity growth in South Korea and China, driven to a large extent by the business sector. This means extremely high annual growth rates in R&D expenditure in a context of high GDP growth in these two countries, in particular in China (see also Chapter I.3).

Figure I.1.2 Evolution of R&D intensity, 2000-2011



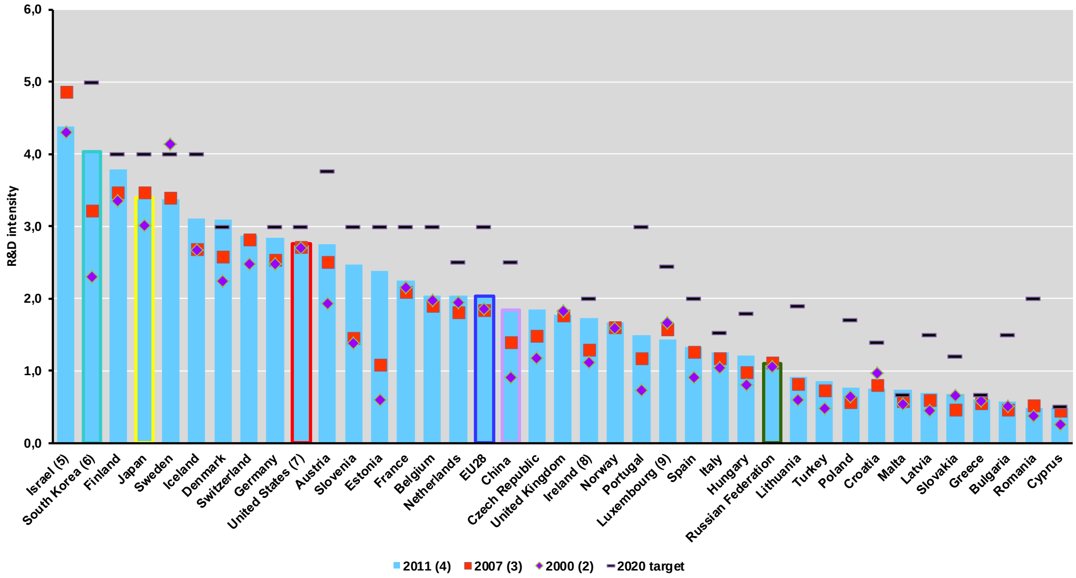
Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Eurostat, OECD
Notes : (1) KR: (i) GERD for 2000-2006 (inclusive) does not include R&D in the social sciences and humanities.
(ii) There is a break in series between 2007 and the previous years.
(2) JP: There is a break in series between 2008 and the previous years.
(3) US: (i) GERD does not include most or all capital expenditure;
(ii) There is a break in series between 2006 and the previous years.
(4) FR: There are a breaks in series between 2004 and the previous years and 2010 and the previous years.

Some EU Member States have experienced higher R&D intensity growth rates than China since 2007, but for the EU average much more rapid progress than during the last decade is needed to reach the 3 % target in 2020

Since 2007, among EU Member States, R&D intensity has decreased in Luxembourg, and has very slightly decreased in Sweden, Romania and Croatia. R&D intensity has progressed in all other Member States (see Figure I.1.3). Progress has been particularly rapid in Estonia (+ 120 % between 2007 and 2011), Slovenia (+ 71 %), Slovakia (+ 47 %), Poland (+ 35 %) and Ireland (+ 34 %). These R&D intensity growth rates are larger than that of China (+ 26 % between 2007 and 2010).

If progress made over the 2000–2010 decade is replicated during the 2010–2020 decade, the following Member States are likely to reach their 2020 targets: Finland, Denmark (already attained), Germany, Austria, Slovenia, Estonia, Cyprus, Hungary, Ireland and Malta (already attained). For all other Member States and for the EU average, more rapid progress than during the last decade is required to reach their respective targets in 2020. The pace of progress for the EU average is to a large extent determined by the progress of the large Member States, which are still far from their targets ([19]). This progress in turn is to a large extent linked to the evolution of the sectoral composition of these economies, which largely determines the overall evolution of business R&D intensity ([20]).

Figure I.1.3 R&D intensity 2000, 2007, 2011 and 2020 target (1)



Source: DG Research and Innovation - Economic Analysis Unit

Innovation Union Competitiveness report 2013

Data: Eurostat, OECD

Notes: (1) CZ, UK, NO, CH, TR, IL, RU: R&D intensity targets are not available.

(2) EL, SE, NO: 2001; HR: 2002, MT: 2004.

(3) EL, CH: 2004.

(4) EL: 2007; CH: 2008; IS: 2009.

(5) IL: GERD does not include defence.

(6) KR: The R&D Intensity target refers to 2012.

(7) US: (i) GERD does not include most or all capital expenditure; (ii) The R&D intensity target of 3,0% does not have a deadline.

(8) IE: The R&D intensity target is 2.5% of GNP which is estimated to be equivalent to 2.0% of GDP.

(9) LU: The R&D intensity target is between 2.30% and 2.60% (2.45% was assumed).

(10) DK, FR, HU, NL, PT, SI, SE, US, JP, KR: Breaks in series occur between 2000 and 2011.

[19] 'Science, Technology and Competitiveness Key Figures Report 2008/2009', p. 26.

[20] 'Innovation Union Competitiveness report 2011', Sections 5.3 and 5.4, pp. 121–126.

2. Public investments in R&D

Highlights

In spite of the economic crisis, some European countries have made determined efforts to protect or increase public R&D funding, backed up by EU funding

Half of all EU Member States have been able to ensure smart fiscal consolidation, with higher levels of real growth in government R&D budgets than in GDP. Many 'catching-up economies', such as Slovenia, Estonia, the Czech Republic, Croatia and Malta have managed to increase their public R&D budgets, for most of them backed up and supported by EU Structural Funds and by competitive R&D funding in the Seventh Framework Programme (FP7). As a result of these counter-cyclical efforts, public R&D intensity in the EU has increased during the crisis period.

Public R&D investment, in Germany, Austria and the Nordic countries grew annually in real terms over the period 2008–2012 in contrast to France, the United Kingdom, Italy and Spain, which showed decreases, partly compensated for by the foregone tax revenues supporting fiscal incentives for R&D.

Public budgetary efforts for research and innovation increasingly include tax incentives for business R&D

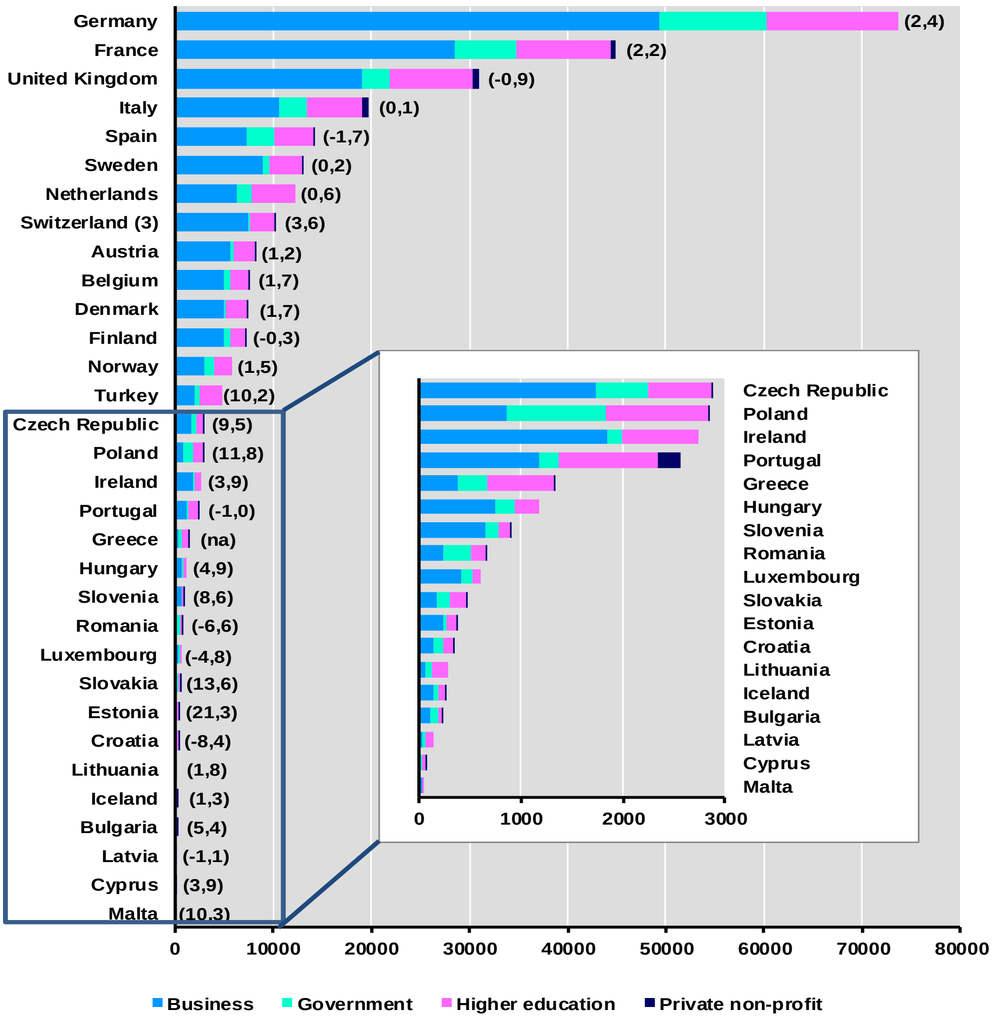
Public budgetary measures for research and innovation (R&I) include growing indirect support for R&D, predominantly through tax incentives. This indirect support is not visible in the R&D intensity data, although R&D tax incentives have become the main channel of government support for business R&D in some Member States (France, the Netherlands and Portugal). Over the period 2007–2011, most Member States substantially increased their indirect support for R&D.

2.1. Government direct support for research and development

Total domestic R&D expenditure in Germany, France and the United Kingdom together amounted to about EUR 150 billion in 2011, close to 60 % of total domestic R&D expenditure in the EU. Figure I.2.1 shows that in most European countries, the business sector performs the largest part of domestic R&D expenditure. In some countries (e.g. Poland, Romania, Slovakia, Croatia, Lithuania, Bulgaria and Latvia), however, R&D effort is predominantly ensured by the public sector (higher education and government), a sign that conditions for business R&D investment are still insufficiently attractive, and that supporting specialisation with a view to establishing more knowledge-based business activities is still proving difficult.

Overall R&D investment, measured in gross domestic expenditure on R&D (GERD), grew in most EU Member States and Associated countries, as visible in Figure I.2.1. (in parentheses). Estonia, Slovakia, Poland and Turkey all had average annual real growth above 10 % over the 2008–2011 period. The only countries with a negative average annual growth in real terms are Croatia, Romania, Luxembourg, Spain, Latvia, Portugal, the United Kingdom and Finland. The two largest Member States in terms of total R&D budget, Germany and France, experienced moderate average annual real growth of 2.4 % and 2.2 %, respectively.

Figure I.2.1. Gross domestic expenditure on R&D (GERD) by sectors of performance, in millions of euro, 2011 (1)
in brackets: average annual real growth (%) in total GERD, 2008-2011 (2)



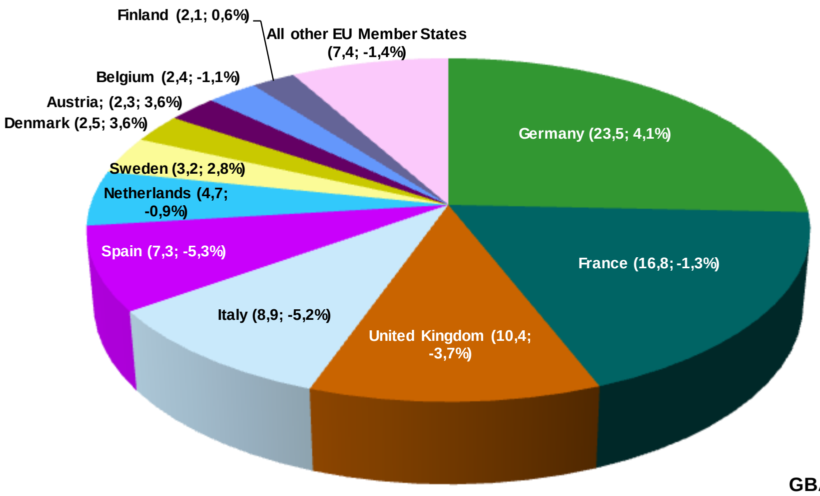
Source: DG Research and Innovation - Economic Analysis Unit   Innovation Union Competitiveness report 2013
Data: Eurostat, OECD
Notes: (1) EL: 2007; CH: 2008; IS: 2009.
(2) IS: 2006-2009; NL, SE: 2007-2010; SI: 2008-2010; FR: 2010-2011.
(3) CH: Government refers to federal or central government only.

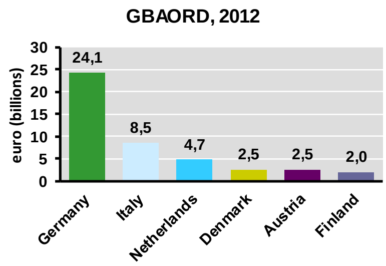
While public R&D investments are increasing in Germany and the Nordic countries, they are decreasing in other larger EU economies (France, the United Kingdom, Italy and Spain)

The most recent data from Eurostat on government budget appropriations or outlays for R&D (GBAORD) are from 2011 (2012 data is currently only available for some Member States). Germany, France and the United Kingdom together make up more than 50 % of the total public R&D budget (GBAORD) of the EU (see Figure I.2.2). The total R&D budget of the EU-15 Member States reached EUR 87.6 billion, which represents 96 % of the total R&D budget of the EU Member States.

Figure I.2.2. also shows that Germany, Denmark, Austria and Sweden increased their public R&D budget by an average annual real growth of between 3 % and 4 % (Germany and Austria further increased their public R&D budget in 2012). On the other hand, Spain, Italy, the United Kingdom, France, the Netherlands and Belgium presented negative average annual real growth in their public R&D budgets from the crisis period of 2008–2011.

FIGURE I.2.2 Government budget appropriations or outlays for R&D (GBAORD) (1)**, 2011**
(in brackets: total GBAORD in billions of euro, and average annual real growth (%), 2008-2011 (2)**)**





Source: DG Research and Innovation - Economic Analysis Unit
Data: Eurostat
Notes: (1) GBAORD does not include EU Structural Funds or R&D tax incentives.
(2) DK, DE, NL, AT, FI: 2008-2012.

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The decrease in public R&D investments for many EU Member States, as visible in Figure I.2.2 (as well as the decrease in the total R&D budgets shown in Figure I.2.1), has to be interpreted in the context of a shrinking economy over the period 2008–2011 coupled with the sovereign debt crisis in many countries. This is the reason why R&D intensity has grown in most EU Member States and in the EU as a whole.

More than half of EU Member States have been able to preserve the government R&D budget in relative terms during the crisis, achieving a smart fiscal consolidation

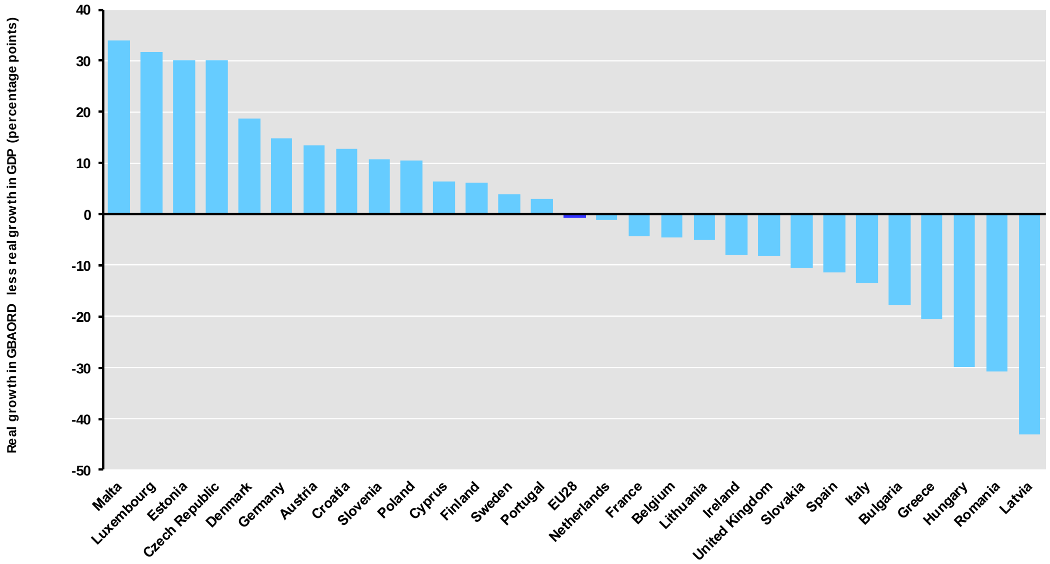
The sovereign debt crisis in Europe has imposed harsh constraints on national government budgets in recent years. How have governments' R&D budgets (GBAORD) evolved in EU Member States in that context?

Figure I.2.3 shows that in about half of the EU Member States, government R&D budget grew faster (or decreased less) than GDP during the crisis. This means that these Member States have been able to protect government efforts in R&D relatively to GDP despite severe budgetary constraints.[21] If the indirect efforts in the form of tax incentives are added (e.g. the Netherlands has opted for a large increase of tax incentives for R&D), an even larger number of Member States would achieve genuine smart fiscal consolidation (compare with Figure I.2.8).

In the last third of Member States, real growth of government R&D budgets was far below that of GDP. These are mostly Member States with low government R&D budgets. The trend is therefore that of an increase of the R&D divide in the EU during the crisis.

[21] Investment in R&D is of course not the only factor improving productivity. A recent IMF study presented the role of improved Total Factor Productivity in the economic adjustment process.(Blanchard, Griffith, Gruss, IMF, 2013)

Figure I.2.3 Government investment in the future
The difference in percentage points between real growth (1) in government budget appropriations or outlays for R&D (GBAORD (2)) and real growth (1) in GDP, 2008-2012 (3)(4)

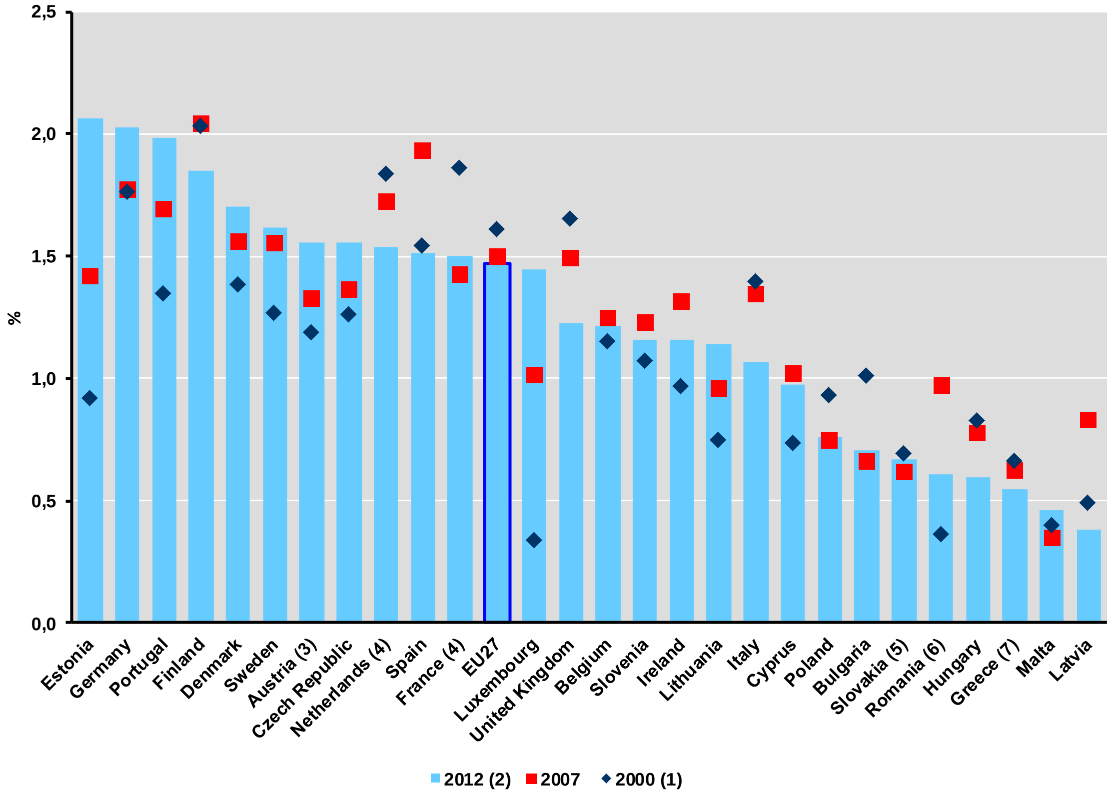


Source: DG Research and Innovation - Economic Analysis Unit — Innovation Union Competitiveness Report 2013
Data: Eurostat
Notes: (1) Real growth was calculated from values in PPS€ at constant 2005 prices and exchange rates.
(2) Foregone tax revenues resulting from R&D tax incentives are not included.
(3) PL: 2008-2009; BE, BG, ES, FR, HR, CY, LV, LT, HU, RO, SE, UK, EU28: 2008-2011.
(4) Data for 2012 are provisional.

In 2011, the government R&D budget represented slightly less than 1.5 % of total government expenditure on average in the EU, about the same level as before the crisis in 2007 (Figure I.2.4). Therefore, on average, Member States have not sacrificed the R&D budget to the benefit of other government expenditure during the crisis. In that sense, Member States have on average managed to achieve smart fiscal consolidation, preserving R&D investment ([22]). However, R&D represents a smaller share in government expenditure than in 2000 (1.6 %) and the situation differs widely across Member States. Estonia, Slovakia, Luxembourg, Portugal and Germany are the Member States where the share of R&D in government expenditure has progressed the most since 2007.

[22] For an overview of public education expenditure in the crisis period, see Chapter I.4.

Figure I.2.4 GBAORD [(1)] as % of general government expenditure, 2000, 2007, 2012



Source: DG Research and Innovation - Economic Analysis Unit

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Data: Eurostat

Notes: (1) DK, UK: 2001; CY, MT: 2004; HU: 2005.
(2) PL: 2009; BE, BG, ES, FR, CY, LV, LT, HU, SE, UK, EU27: 2011.
(3) AT: Federal or central government only.
(4) FR, NL : Break in series between 2006 and the previous years.
(5) SK: Break in series between 2002 and the previous years.
(6) RO: Break in series between 2012 and the previous years.
(7) EL: Break in series between 2008 and the previous years.

2.2. Funding for research and innovation from the EU Community budget

A government budget for R&D does not represent all national public investment in R&D. EU Structural Funds have allowed the level of public investment in R&D to be maintained in countries with low and decreasing levels of government R&D budget (see Figure I.2.5). Also, indirect support to R&D through R&D tax incentives constitutes a large and growing part of government support to R&D in some Member States (see Figure I.2.8). This indirect support is not included in the government R&D budget figures that account for direct government funding only. Finally, extra–budgetary government support for R&D (e.g. *Investissements d'Avenir* in France) is by definition not accounted for in the R&D budget.

EU Structural Funds significantly contribute to finance R&D and innovation expenditure in Member States

In the nomenclature of Structural Funds 2007–2013, research, technological development and innovation (RTDI) refers to research and technological development (RTD) activities in research centres, RTD infrastructures and centres of competence, technology transfer, assistance to RTD, particularly in SMEs, and investment in firms directly linked to research and innovation ([23]).

Structural Funds financing RTDI projects represent a very significant part of public support to RTDI in many Member States. In some, in particular in EU-13 Member States, Structural Funds for RTDI are of the same order of magnitude as the national budget for civil R&D, so that Structural Funds roughly double (or more than triple in the case of Latvia) the volume of government funding to R&D in the country. In EU-15 Member States, Structural Funds for RTDI are more modest compared to the national civil R&D budget (1 % to 5 %) but still substantial, in particular in Portugal, Spain and Italy.

[23] See Methodological annex for the complete list of categories of projects belonging to research, technological development and innovation in this nomenclature.

Figure I.2.5 Structural Funds 2007-2013 for RTDI (1) - amounts allcocated and implementation rate and as % of civil GBAORD

	Structural Funds 2007-2013 for RTDI			Civil GBAORD 2007-2011		
	Allocation euro (millions) (1)	Implementation (2) euro (millions) (2)	Implementation rate % (2) as % of (1)	Total euro (millions) (3)	Allocation as % of total (1) as % of (3)	Implementation as % of total (2) as % of (3)
Belgium	253	248	98,2	11402	2,2	2,2
Bulgaria	242	173	71,4	495	48,9	34,9
Czech Republic	3556	2988	84,0	4277	83,1	69,9
Denmark	159	138	86,8	10686	1,5	1,3
Germany	4647	3923	84,4	101013	4,6	3,9
Estonia	604	516	85,4	503	120,2	102,6
Ireland	155	558	359,3	4411	3,5	12,6
Greece	2168	1146	52,8	3497	62,0	32,8
Spain	5302	3628	68,4	39755	13,3	9,1
France	2183	1671	76,5	66704	3,3	2,5
Italy	5451	4542	83,3	47326	11,5	9,6
Cyprus	37	43	115,8	385	9,5	11,1
Latvia	637	615	96,6	226	282,5	272,8
Lithuania	899	752	83,7	641	140,1	117,3
Luxembourg	16	13	84,3	990	1,6	1,3
Hungary	1488	959	64,4	1909	78,0	50,2
Malta	68	54	79,3	56	121,3	96,2
Netherlands	288	368	127,7	23558	1,2	1,6
Austria	359	234	65,2	10507	3,4	2,2
Poland	8700	7475	85,9	:	:	:
Portugal	3534	3606	102,0	8095	43,7	44,5
Romania	843	690	81,9	2034	41,4	33,9
Slovenia	859	723	84,1	1004	85,5	72,0
Slovakia	1215	738	60,7	1066	113,9	69,2
Finland	444	395	89,0	9387	4,7	4,2
Sweden	405	388	96,0	12820	3,2	3,0
United Kingdom	1888	1431	75,8	46430	4,1	3,1

Source: DG Research and Innovation - Economic Analysis Unit   Innovation Union Competitiveness Report 2013
Data: Eurostat, DG REGIO
Notes: (1) RTDI includes the following sectors: (01) RTD activities in research centres, (02) RTD infrastructures and centres of competence (03) Technology transfer and improvement of cooperation of networks, (04) Assistance to RTD, particularly in SMEs (and RTD services in research centres), (06) Assistance to SMEs for the promotion of environmentally-friendly products and processes, (07) Investment in firms directly linked to research and innovation, (09) Other methods to stimulate research and innovation and entrepreneurship in SMEs, (74) Developing human potential in the field of research and innovation.
(2) Date of data extraction: 23 August, 2013.

R&D funding from the EU Framework Programme constitutes an important top-up investment for many European countries, in particular for catching-up countries

In addition to the national and regional public budgets for R&D, EU Member States and Associated Countries have been eligible for competitive funding for R&D projects from the European Community budget, channelled through the Seventh Framework Programme. The larger Member States, with more research teams, have in total received a higher European Community financial contribution and have seen more applicants retained from their countries, as is visible in Figure I.2.6. The success rate has also been very high in France and

Germany, but smaller countries such as Switzerland, the Netherlands, Belgium and Denmark have achieved similar or higher success rates. Comparing total R&D investment in individual countries (GERD), Figure I.2.6 shows that catching-up countries, in particular eastern European countries, have higher proportions of Framework Programme (FP) funding, indicating the relative importance of FP funding for these countries.

Figure I.2.6 FP7 funding - EC contribution and success rate of applicants, 2008-2012

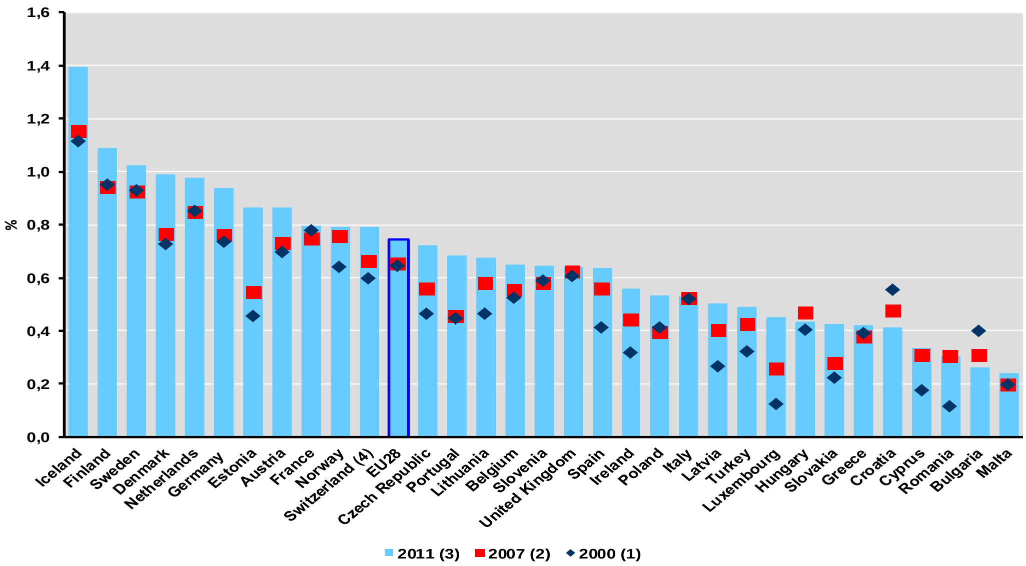
	EC financial contribution in retained proposals euro (millions)	FP funding received as % of GERD 2011 (1)	Financial success rate (%)	Number of applicants in retained proposals
Belgium	1595	21,1	23,8	5184
Bulgaria	93	42,4	10,7	662
Czech Republic	224	7,8	14,9	1233
Denmark	861	11,6	22,6	2397
Germany	6028	8,2	23,0	15522
Estonia	78	20,5	15,6	480
Ireland	489	17,8	18,0	1781
Greece	863	64,3	13,4	3302
Spain	2624	18,5	16,2	9603
France	3879	8,6	24,0	10703
Croatia	67	20,0	11,0	377
Italy	3071	15,5	15,1	10229
Cyprus	75	86,6	10,9	427
Latvia	34	24,0	11,7	292
Lithuania	53	18,8	14,5	400
Luxembourg	35	5,7	13,1	183
Hungary	242	20,1	14,8	1422
Malta	17	36,1	10,6	177
Netherlands	2615	21,3	23,3	6972
Austria	961	11,6	20,6	3002
Poland	374	13,2	12,2	2054
Portugal	427	16,7	13,5	2055
Romania	138	21,0	9,0	964
Slovenia	146	16,4	11,1	821
Slovakia	69	14,7	12,0	453
Finland	800	11,2	17,0	2296
Sweden	1410	10,8	20,1	3951
United Kingdom	5223	16,9	20,2	15199
Iceland	56	20,7	17,2	251
Norway	666	11,2	19,6	1995
Switzerland	1561	15,2	24,7	3860
Macedonia (2)	12	87,8	8,4	94
Turkey	155	3,3	7,2	1085
Israel	634	8,3	16,2	1723

Source: DG Research and Innovation - Economic Analysis Unit   Innovation Union Competitiveness report 2013
Data: DG Research and Innovation, Eurostat, OECD
Notes: (1) EL:2007; CH:2008; IS: 2009; MK: 2010.
(2) Former Yugoslav Republic of Macedonia.

As a result of Member States' budgetary efforts and Structural Funds support, public R&D intensity in the EU has progressed during the crisis

Public R&D intensity (R&D expenditure in the government and higher education sectors as percentage of GDP) has increased or remained stable since 2007 in all Member States, except Hungary, Bulgaria and Croatia (see Figure I.2.7). It is above 1 % in Finland and Sweden (as well as in Iceland) and close to 1 % in Denmark, the Netherlands and Germany. Spectacular progress occurred in Estonia, where public R&D intensity increased by more than 60 % between 2007 and 2011 to reach almost 0.9 % of GDP. Progress since 2007 is also noticeable in Luxembourg, Slovakia and the Czech Republic. On average, public R&D intensity in the EU increased by 13.6 % between 2007 and 2011, from 0.66 % of GDP to 0.75 % of GDP.

Figure I.2.7 Public (government and higher education) R&D expenditure as % of GDP, 2000, 2007, 2011



Source: DG Research and Innovation - Economic Analysis Unit

Innovation Union Competitiveness Report 2013

Data: Eurostat

Notes: (1) EL, SE, NO: 2001; HR, MT, AT: 2002.
(2) EL: 2004.
(3) EL: 2007; IS: 2009; CH: 2010.
(4) CH: Government expenditure refers to federal or central government only.
(5) DK, FR, IT, LU, NL, PT, SI, SE, UK, NO: Breaks in series occur between 2000 and 2011.

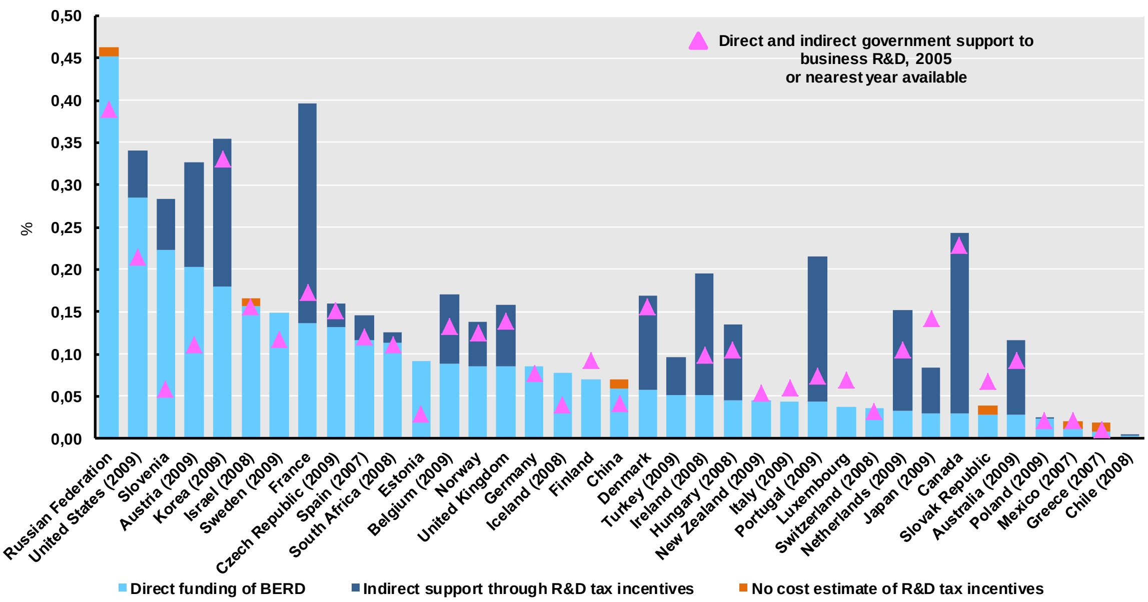
2.3. Indirect funding for research and innovation through tax incentives to business R&D

In addition to budgetary efforts for R&D, indirect government support for R&D has significantly increased through R&D tax incentives in a number of Member States since 2007

In some Member States (France, the Netherlands and Portugal), R&D tax incentives have become the main channel of government support for business R&D, ahead of direct funding for business R&D (see Figure I.2.8). Foregone tax revenue due to R&D tax incentives has substantially increased between 2007 and 2010, in particular in France, Portugal, Ireland, the Netherlands, Austria and Denmark ([24]) and has appeared in Italy and Slovakia. This has been achieved in addition to the R&D budgetary efforts depicted in Figures I.2.3 and I.2.4. Since then, 13 Member States reported having introduced new R&D tax incentives or increased the level of existing ones in 2012: Belgium, the Czech Republic, Denmark, Finland, Germany, Italy, the Netherlands, Poland, Romania, Slovenia, Spain, Sweden and the United Kingdom[25].

Government tax incentives for R&D include R&D tax credits, R&D allowances, reductions in R&D workers' wage taxes and social contributions, as well as accelerated depreciation of capital used for R&D ([26]). Countries' schemes differ in that they use either one instrument or the other, or they combine them. There is no clear relationship across countries between the level of total (direct and indirect) government support for business R&D and the level of business R&D intensity.

Figure I.2.8 Direct government funding of business R&D and tax incentives for R&D, 2010



Source: DG Research and Innovation - Economic Analysis Unit
Data: OECD Science, Technology and Industry Outlook 2012

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A full picture of EU Member States' public efforts to enhance the knowledge intensity of their economy also requires an overview of the evolution of public investments in education, and in particular in higher education. These statistics are presented in Chapter I.4.

[24] For the 2007 level of foregone tax revenues due to R&D tax incentives, see the figure on p. 77 in Chapter 4.1 in 'Measuring Innovation: a New Perspective', OECD, 2010. Only EU Member States that are members of the OECD are covered (19 Member States).

[25] European Commission, survey of the European Research Area Committee (ERAC), 2012.

[26] OECD Science, Technology and Industry Scoreboard 2011.

3. Business enterprise investments in R&D

Highlights

Business R&D investment is still growing in the EU, although at a slower pace

Business expenditure on R&D continued to increase in the EU between 2007 and 2011, although at a slower pace than between 2000 and 2007 (2.3 % average annual growth over 2007–2011 compared to a 4 % growth in the pre-crisis period). A catching-up process has been particularly evident in smaller eastern European countries, both in terms of nominal growth and in terms of business R&D intensity. However, in a small number of Member States, nominal business expenditure on R&D has decreased, and overall EU business R&D intensity remains much lower than that of the United States, Japan, South Korea and now also China, which has experienced exceptional growth in business R&D expenditure since 2000. In addition to R&D investment, businesses invest in other knowledge-based capital for innovation. In general, countries whose firms include R&D in their growth strategies also mobilise larger business investments in knowledge-based capital.

Europe maintains attractive for business R&D investment, although for some industries business R&D investment is increasingly moving outside Europe

Business R&D investment is increasingly integrated in strategies intended to internationalise business innovation. This process is likely to expand, with EU firms expecting their worldwide investments in R&D to grow by 4 % annually over the period 2012–2014. This is partly a sector-specific dynamic, highest in the pharmaceutical, machinery, electrical and optical equipment (including computers and communication equipment), motor vehicles and other transport equipment sectors. The level of R&D internationalisation, inflows as well as outflows, is highest in smaller, R&D-intensive countries, such as Austria, Belgium, Ireland, Sweden, Switzerland and the Netherlands. But it is also very high in the United Kingdom. The internationalisation of R&D has led to strong integration of business R&D within Europe.

FDI in research and innovation is an integral part of Europe's innovation fabric; however, outsourcing trends are worrying

Intra–EU R&D flows account for almost half of the total R&D expenditure of foreign-owned firms in EU Member States. In 2007, the largest flows of international business R&D investment took place between the United States and Europe, and within Europe, including Switzerland. In recent years, China, India, Singapore, Taiwan and Malaysia have emerged as new locations for R&D by foreign-owned firms, but the EU remains attractive for foreign overseas R&D investment (R&D investment in the EU by the United States more than doubled between 1994 and 2008). The attractiveness of the EU as an investment location is underlined by the foreign direct investment (FDI) data, which show that the EU is the main investment destination in the world, accounting for around 30 % of FDI inflows worldwide in 2011. However, after 2007 a new trend is visible in the FDI flows, with decreasing intra–EU flows coupled with growing FDI flows to and from China and India.

3.1. Business enterprise investments in research and development in EU Member States and Associated Countries

In nominal terms, business expenditure on R&D has continued to increase in the EU between 2007 and 2011, although at a slower pace than between 2000 and 2007

Business expenditure on R&D progressed by more than 20 % in nominal terms in all European countries between 2000 and 2007, except in Sweden and Slovakia, where the growth was more modest (see Figure I.3.1) ([27]). In 10 Member States (8 EU-13 Member States, plus Portugal and Spain), business expenditure on R&D more than doubled over this period. These spectacular increases correspond to a catching-up phase starting from very low values, in particular in small eastern European countries.

Over the period 2007–2011, the pace of nominal growth in business R&D expenditure slowed down in 16 Member States but further accelerated in 10 Member States (see Figure I.3.1). Over this period, the nominal amount of business R&D expenditure decreased only in Spain, Cyprus, Latvia, Luxembourg, Romania and the United Kingdom. Overall, the annual average rate of growth in business R&D expenditure in the EU remained positive during the crisis (+ 2.3 % annually on average over 2007–2011, which results in a total increase of almost 10 % over this period), but was smaller than during the pre-crisis period (+ 4 % annually on average over 2000–2007).

[27] *Stricto sensu* it is not possible to calculate any growth rate over a period of time including a break in series. Breaks in series are specified in the footnotes of Figure I.3.1.

Figure I.3.1 Business Enterprise Expenditure on R&D (BERD), 2000 (1), 2007 (2), 2011 (3) and average annual growth rate (4) (5) (%), 2000-2007 (6) and 2007-2011 (7)

	BERD (millions of euro)			Average annual growth rate (%)	
	2000 (1)	2007 (2)	2011 (3)	2000-2007 (6)	2007-2011 (7)
Belgium	3589	4420	*5073*	3,0	*3,5*
Bulgaria	15	43	*117*	16,2	*28,0*
Czech Republic	446	1211	1735	11,3	6,1
Denmark	2596	4102	*5025*	5,7	*5,2*
Germany	35600	43034	*49342*	2,7	*3,5*
Estonia	8	82	*237*	38,6	*30,5*
Ireland	842	1603	*1855*	9,6	*3,7*
Greece	202	384	:	9,6	:
Spain	3069	7454	7396	13,7	-2,9
France	19348	24753	28497	2,1	3,6
Croatia	115	141	150	3,9	1,9
Italy	6239	9455	*10700*	6,1	*3,1*
Cyprus	5	16	*14*	17,4	*-4,0*
Latvia	15	41	*39*	19,0	*-0,9*
Lithuania	16	66	*74*	21,7	*2,6*
Luxembourg	337	495	*416*	5,6	*-4,2*
Hungary	180	492	752	14,9	14,2
Malta	16	21	*32*	9,5	*10,9*
Netherlands	4458	5495	*6416*	3,0	-1,7
Austria	3131	4846	*5626*	9,1	*3,8*
Poland	432	535	855	2,3	14,8
Portugal	258	1011	*1174*	*21,6*	*3,8*
Romania	103	272	237	23,6	2,6
Slovenia	167	299	*660*	8,7	12,7
Slovakia	94	100	174	0,8	15,0
Finland	3136	4513	5047	5,3	2,8
Sweden	8118	8343	*9062*	-2,4	*1,5*
United Kingdom	18884	22842	*19051*	*4,5*	*1,4*
EU	*110648*	146083	*160126*	*4,0*	*2,3*
Iceland	*142*	219	142	*9,3*	13,3
Norway	1814	2410	3042	4,8	5,3
Switzerland	5065	6257	7547	*5,2*	5,5
Turkey	465	1407	2061	37,8	17,7

Innovation Union Competitiveness report 2013

Source: DG Research and Innovation - Economic Analysis Unit
Data: Eurostat, OECD
Notes : (1) SE, NO: 2001; AT, HR: 2002, MT: 2004.
(2) CH: 2004.
(3) CH: 2008; IS: 2009.
(4) Average annual growth rates are calculated from values in euro for euro area countries and from values in national currency for all other countries and takes into account breaks in series (see notes (5), (6) and (7)).
(5) DK, ES, FR, NL, SI, SE, UK: Breaks in series occur between 2000 and 2011.
(6) CH: 2000-2004; DK: 2000-2006; FR: 2001-2003; SE: 2001-2004; UK, NO: 2001-2007; ES, HR, AT: 2002-2007; MT: 2004-2007.
(7) CH: 2004-2008; IS: 2007-2009; NL: 2007-2010; SI: 2008-2010; ES: 2008-2011.
(8) Values in italics are estimated or provisional.

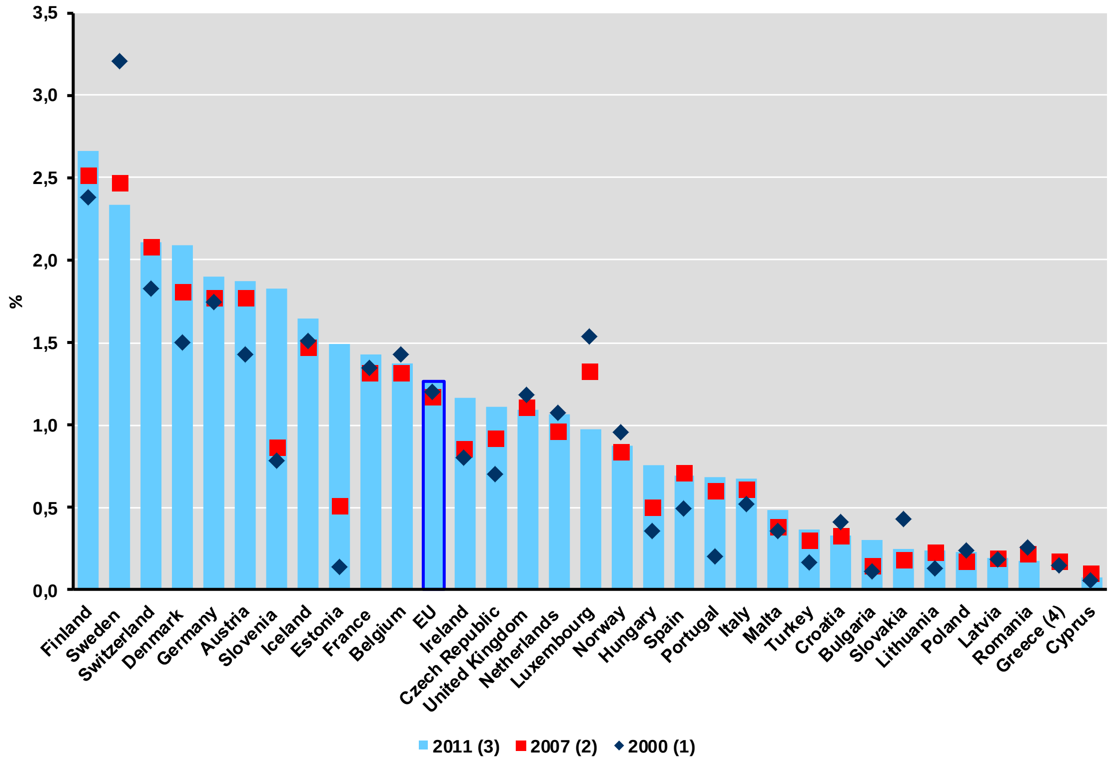
In terms of GDP, business expenditure on R&D in the EU progressed over the period 2007–2011, after a period of stagnation between 2000 and 2007

Business R&D intensity (business R&D expenditure as a percentage of GDP) progressed or remained roughly unchanged in almost all Member States between 2007 and 2011, except in

Sweden and Luxembourg where it decreased (see Figure I.3.2) ([28]). In these two countries, the decrease is even more marked in comparison to 2000. Business R&D intensity progressed the most in Estonia, Slovakia, Ireland, Hungary, the Czech Republic and Bulgaria between 2007 and 2011 relative to the 2007 level.

On average in the EU, business R&D intensity increased by 6.8 % between 2007 and 2011 (from 1.18 % to 1.26 % of GDP). This level is, however, far below that of South Korea (2.99 %, 2010), Japan (2.54 %, 2009) and the United States (2.02 %, 2009). It is also below the level of China (1.25 % in 2009; i.e. probably more than 1.4 % in 2011). As analysed in the Innovation Union Competitiveness (IUC) report 2011 ([29]), the lower business R&D intensity in the EU is to a large extent due to the sectoral composition of the EU's economy, where the more R&D-intensive sectors (in particular high-technology manufacturing sectors) account for a smaller share than in the United States, Japan and South Korea.

Figure I.3.2 Business R&D intensity (BERD as % of GDP), 2000, 2007, 2011



Source: DG Research and Innovation - Economic Analysis Unit — Innovation Union Competitiveness report 2013
Data: Eurostat, OECD
Notes: (1) SE, NO: 2001; AT, HR: 2002, MT: 2004.
(2) CH: 2004.
(3) CH: 2008; IS: 2009.
(4) EL: 2007 is the latest available year.
(5) DK, ES, FR, NL, SI, SE, UK: Breaks in series occur between 2000 and 2011.

[28] *Stricto sensu* it is not possible to calculate any growth rate over a period of time including a break in series. Breaks in series are specified in the footnotes of Figure I.3.2.
[29] See Chapter I.5.

Exceptional growth in business R&D expenditure has been pursued in China and South Korea since 2000

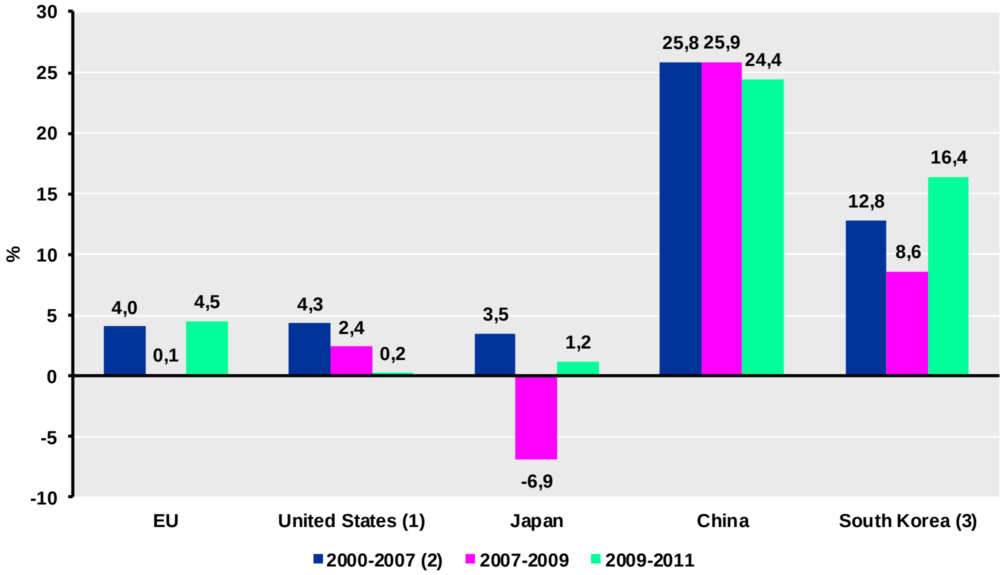
Since 2000, nominal growth in domestic business expenditure on R&D in the EU, the United States and Japan has been largely outpaced by that of South Korea and China (see Figure I.3.3). In China, business expenditure on R&D multiplied by 5 in nominal terms between 2000 and 2007, and further increased by 58 % between 2007 and 2009. In South Korea, business expenditure on R&D multiplied by 2.3 in nominal terms between 2000 and 2007, and further increased by 37 % between 2007 and 2011.

The growth in business R&D expenditure in South Korea and China is much higher than the GDP growth in these countries and has not slowed down during the crisis. As a result, in terms of GDP, business R&D expenditure increased by 0.62 percentage points in South Korea between 2000 and 2007 and a further 0.44% between 2009 and 2011 (see Figure I.3.4). China's business R&D intensity more than doubled between 2001 and 2009, from 0.57 % of GDP to 1.25 % of GDP, at the same level as the EU already in 2009.

The rapid increase in business R&D expenditure in South Korea occurred in most economic sectors except construction. It occurred mostly in the manufacturing sector, in particular in radio, TV and communications, which now represents close to half of total business R&D expenditure in South Korea, as well as in motor vehicles, machinery and equipment, chemicals and pharmaceuticals, which represent, respectively, on the order of 17 %, 8 %, 6 % and 3 % of total business R&D expenditure in South Korea. The share of these sectors in total business R&D expenditure in South Korea has been rising since 2000 ([30]).

[30] Based on data from the study 'Internationalisation of business investments in R&D and analysis of their economic impact', European Commission, 2012, on the basis of Eurostat and OECD data.

Figure I.3.3 Business enterprise expenditure on R&D (BERD) - nominal average annual growth rate (%)



Source: DG Research and Innovation - Economic Analysis Unit
Data: Eurostat, OECD
Notes: (1) US: Most or all capital expenditure is not included.
(2) KR: 2000-2006.
(3) KR: Break in series between 2007 and the prevous years.

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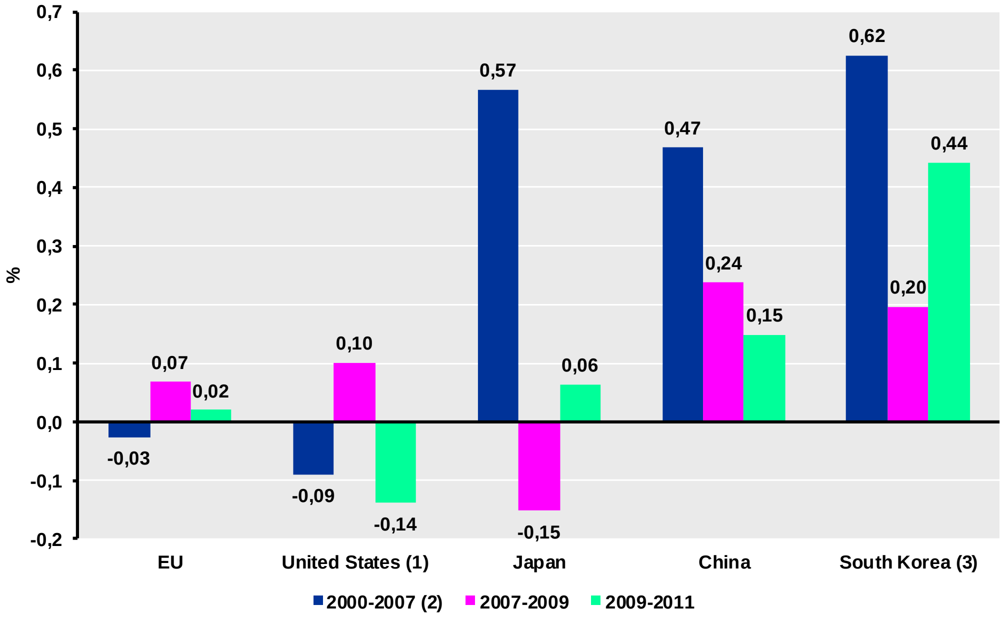
Figure I.3.4 Business R&D intensity - change in percentage points



Source: DG Research and Innovation - Economic Analysis Unit
Data: Eurostat, OECD
Notes: (1) US: Most or all capital expenditure is not included.
(2) KR: 2000-2006.
(3) KR: Break in series between 2007 and the prevous years.

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3.2. Attractiveness for foreign investments in R&D

Firms increasingly perform R&D at locations outside their home countries. This development is referred to as the internationalisation of business R&D. The internationalisation of R&D has become an important trend, shaping the national innovation systems of all EU and Organisation for Economic Co-operation and Development (OECD) countries ([31]).

Which countries are attracting foreign-owned firms' R&D?

These changes are measured by comparing the R&D expenditure of foreign-owned firms in a particular country to total R&D expenditure in the business sector of the country (see Figure I.3.5). The level of R&D internationalisation is highest in small countries such as Austria, Belgium or Ireland. In some of these countries, R&D expenditure of foreign-owned firms is even higher than that of domestic firms. Smaller countries also exhibit a higher degree of openness in trade and FDI. In addition, it only takes a handful of multinational firms and their R&D investments to substantially raise overall R&D expenditure in a small country.

Large and medium-sized countries, in contrast, have considerably lower levels of R&D internationalisation. In the United States, only around 15 % of all business R&D expenditure comes from foreign-owned firms. The share of foreign-owned firms is around 25 % in Germany. Japan is considerably below the US value.

But there are also exceptions to this rule. The United Kingdom and Canada, on the one hand, have high levels of R&D internationalisation compared to other countries of a similar size. The United Kingdom benefits from its role as the preferred location for the European headquarters of US, Asian and other non-European firms. Canada owes its high degree of R&D internationalisation to its strong economic ties with the United States.

On the other hand, Finland, Switzerland and Denmark have a surprisingly low number of foreign-owned firms investing in R&D. While these are all small countries, size is clearly not a determining factor as the situation is very different in. Determining factors are highly country-specific and include the amount of R&D performed by domestic firms, the attractiveness of the market, but also geography and cultural factors.

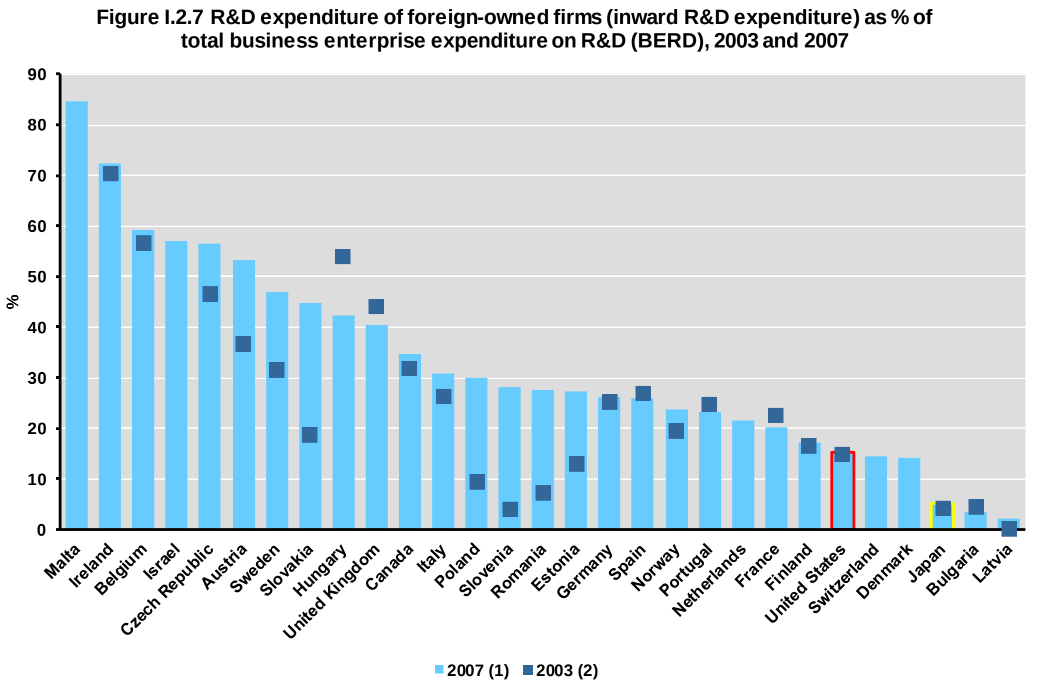
Large countries may have a low degree of internationalisation in relative terms; in absolute terms, however, the United States, Germany, the United Kingdom, Japan and France are by far the most important host countries for the R&D activities of foreign-owned firms. In 2007, foreign-owned firms in the United States spent around EUR 30 billion on R&D. The

[31] This section is based on the results of the study 'Internationalisation of business investments in R&D and analysis of their economic impact', European Commission, 2012 (http://ec.europa.eu/research/innovation-union/index_en.cfm?pg=other-studies).

corresponding amount for Germany is EUR 11 billion, while it is EUR 9 billion for the United Kingdom, EUR 4.8 billion for France and EUR 4.4 billion for Japan.

There is no official figure for the R&D expenditure of foreign-owned firms in the whole of the EU. Data from EU Member States suggest however that it can be estimated at more than EUR 42.6 billion in 2007. Around half of this sum can be attributed to foreign-owned firms from non-EU countries, mostly US and Swiss firms.

Figure I.3.5: R&D expenditure of foreign-owned firms (inward R&D expenditure) as share of total business R&D expenditure, 2003 and 2007



Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: 'Internationalisation of business investments in R&D' study (2012), based on data from Eurostat, OECD and national statistical offices.
Notes: (1) PL, FI, CA: 2006; MT, CH: 2008.
(2) RO, FI: 2004.
(3) DK, MT, NL, CH, IL: Data are not available for 2003.

Globally, the internationalisation of business R&D is the result of relations between a small number of countries

Figure I.3.6 illustrates relationships within the manufacturing sectors of the EU, the United States, Japan, China and Switzerland. The services sector is excluded due to missing data. The size of the pie chart for each country indicates the total amount of R&D expenditure of foreign-owned firms in this country, while the pie slices represent the R&D expenditure of foreign-owned firms from one particular country.

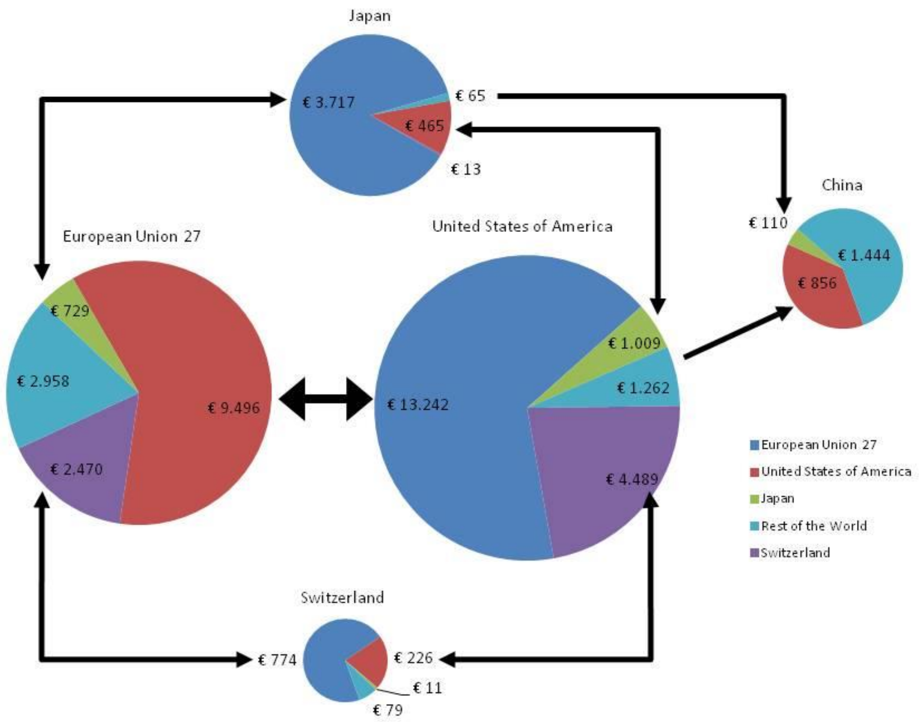
The figure reveals the outstanding importance of the relationship between the US and the EU. R&D expenditure by US firms in the EU and by EU firms in the United States taken together account for two thirds of the R&D expenditure by foreign-owned firms in manufacturing worldwide ([32]). The United States is also the largest investing country in the majority of the EU Member States. EU firms account for more than 65 % of the total manufacturing R&D expenditure of foreign-owned firms in the United States, or more than 90 % once other European countries that are not members of the EU (mainly Switzerland and Norway) are added.

In recent years, China has emerged as a new location for foreign-owned firms' R&D activities. However, Chinese data is incomplete and plagued by some methodological issues that render a comparison with data from OECD countries difficult. Figures I.3.6 and I.3.7 include the R&D expenditure of wholly foreign-owned companies. In China (see Figure I.3.6) this was EUR 2.4 billion for the year 2007. A breakdown of this amount into different countries of origin is not available.

[32] The EU is considered as one entity, and intra–EU relationships (for example R&D of German firms in France) are not taken into account.

Figure I.3.6: Overseas business R&D expenditure in manufacturing between the EU, the United States, Japan, China and Switzerland, 2007

Figure I.2.8 Flows of overseas business R&D expenditure in manufacturing (millions of euro) between the EU [(1)], the United States, Japan, China and Switzerland, 2007

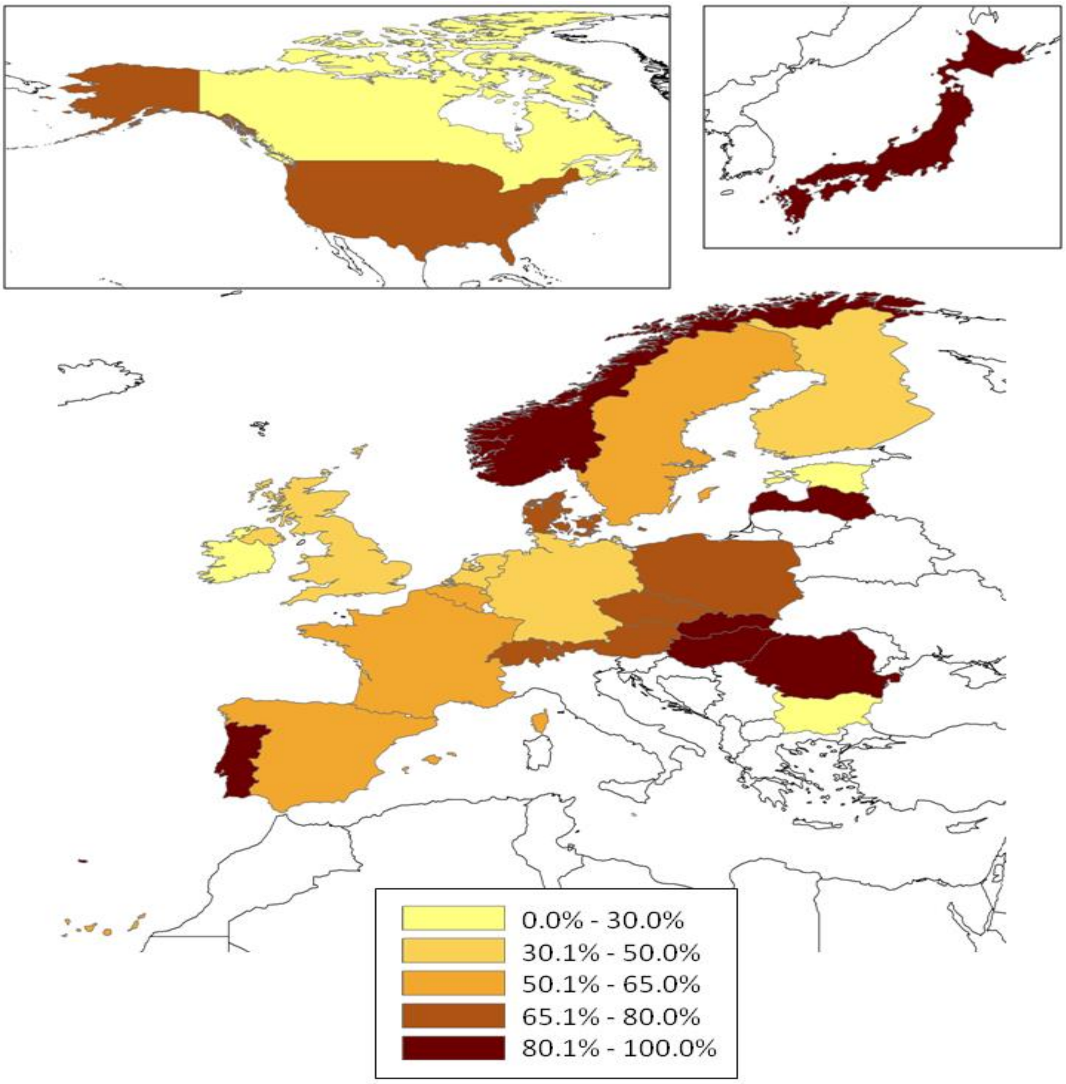


Source: DG Research and Innovation - Economic Analysis Unit — Innovation Union Competitiveness report 2013
Data: 'Internationalisation of business investments in R&D' study (2012), based on data from Eurostat, OECD and national statistical offices.
Notes: (1) EU does not include Croatia.
(2) CN: Data were estimated from national data sources and from outward data for the United States and Japan.
(3) CH: The services sector is included.
(4) Reading note: EU [(1)] firms spent 774 million euro on R&D in Switzerland in 2007; Swiss firms spent 2470 million euro on R&D in the EU [(1)].

The internationalisation of R&D has led to strong integration of business R&D within Europe

In 2007, EU Member States, as can be seen in Figure I.3.7, accounted for the largest share of R&D expenditure by foreign-owned firms in almost all European countries. Moreover, the EU was the largest investor in Japan and the United States. Figure I.3.7 also confirms the finding that the internationalisation of R&D is still mostly intra-European, not global integration.

Figure I.3.7: R&D expenditure of foreign-owned firms: Share of EU countries as country of origin (2007)



Source: DG Research and Innovation

Data: 'Internationalisation of business investments in R&D' study (2012), based on OECD, Eurostat, national statistical offices

Notes: Malta and Switzerland 2008; Ireland 2005, Canada 2003; only manufacturing included in Belgium, Canada, France, Germany, Ireland, Japan, Norway and the United States of America

Intra–EU R&D internationalisation (foreign-owned firms from one EU Member State performing R&D in other Member States) amounts to around EUR 19 billion in 2007. This is almost half of the total R&D expenditure of foreign-owned firms in EU Member States (EUR 42.6 billion). Thus, the internationalisation of business R&D is also contributing to the completion of the European Research Area (ERA) ([33]). Despite strong ties between

[33] However, more recent data on FDI flows indicate a decrease of the intra–EU FDI flows following the economic crisis period from 2007 onwards. On the contrary, extra–EU FDI flows have grown faster, in particular

neighbouring countries, there are no cohesive sub-groups in the network, i.e. groups of countries that are strongly connected with each other, but have only weak links to the rest of Europe.

The internationalisation of R&D is, to a considerable degree, sector specific

A high sectoral R&D intensity is a necessary precondition for the internationalisation of R&D. In most countries, R&D expenditure by foreign-owned firms is therefore concentrated on R&D-intensive, high-tech or medium-high–tech sectors. Moreover, some sectors offer better preconditions for the decentralised organisation of R&D because their knowledge base is less cumulative, allowing an easier exchange of knowledge, or because there are only few size advantages in R&D that would favour centralisation.

These factors help demonstrate why the internationalisation of R&D predominantly takes place in pharmaceuticals, machinery and equipment, electrical and optical equipment (including computers, communication equipment and instruments), motor vehicles and other transport equipment, including the aerospace sector. Each of these sectors accounted for between EUR 5.2 billion (machinery and equipment) and EUR 16.4 billion (pharmaceuticals) of R&D expenditure by foreign-owned firms worldwide in 2007. The highest degree of internationalisation is found in pharmaceuticals, where 30 % of total R&D expenditure in the United States and Europe comes from foreign-owned firms. Motor vehicles and other transport equipment follow. The only noteworthy non-manufacturing sector is business services, which is important in Israel, Estonia and the United Kingdom in particular. In most of these sectors, the United States attracts the largest amount of R&D of foreign-owned firms, followed by Germany ([34]).

The lowest degrees of R&D internationalisation are found in low- and medium-low–tech sectors such as textiles and clothing, wood, paper, rubber and plastics, or basic metals and metal products. An exception is the food and beverage industry, which shows high levels of R&D internationalisation due to the presence of a number of multinationals with widely decentralised R&D networks. Though data is scarce, evidence suggests that service industries tend to be characterised by lower levels of R&D internationalisation compared to manufacturing industries.

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to China. See 'Innovation Union Competitiveness papers', 2013/3.(http://ec.europa.eu/research/innovation-union/index_en.cfm?pg=other-studies)

[34] A broader analysis of the globalisation of production is presented in Chapter III.4.

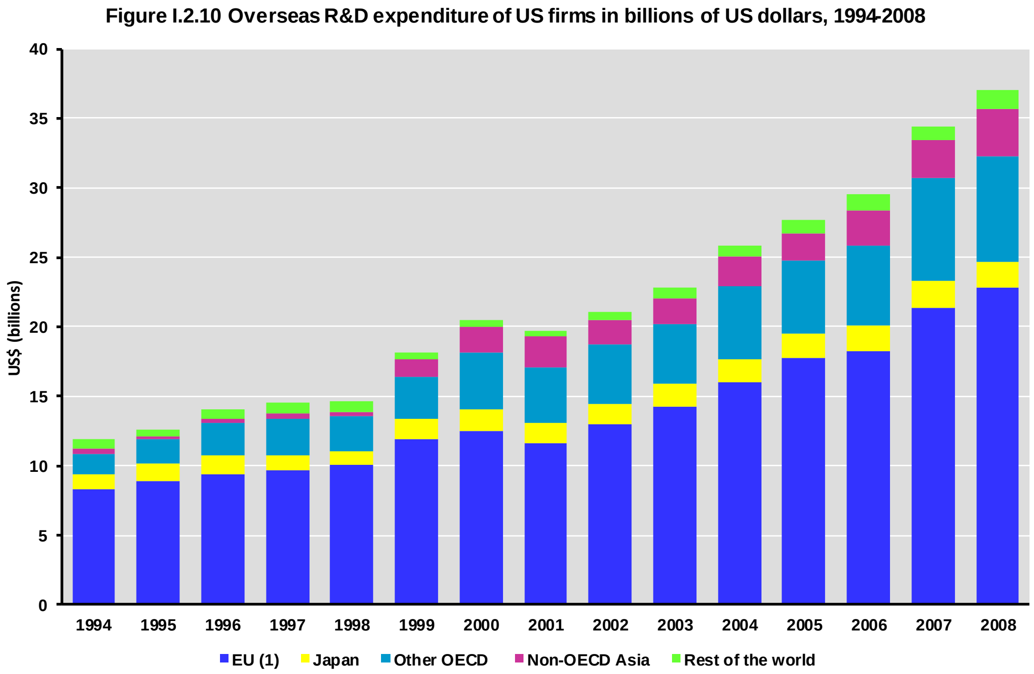
The EU remains an attractive R&D location for firms from outside the EU, but Asian economies are emerging as both host and home countries for international R&D investments

There is evidence that Asian countries, in particular China, India, Singapore, Taiwan and Malaysia, are emerging as new players in the internationalisation of R&D, both as host countries and as home countries for internationally active firms ([35]). Data availability and quality for these countries is however poor compared to the EU Member States.

The most reliable source to analyse the emergence of new players in R&D internationalisation is data on overseas R&D expenditure by US firms. These data also bring forth conclusions on the attractiveness of the EU vis-à-vis emerging economies as a location for R&D.

Figure I.3.8 displays R&D expenditure by US firms outside of the US in million USD between 1994 and 2008. The figure includes the EU, Japan, other OECD countries (including Australia, Canada, South Korea, Israel, Mexico and New Zealand), non-OECD Asia (including China, India, Taiwan, Singapore or Malaysia) and the rest of the world (including Africa and South America).

Figure I.3.8: Overseas R&D expenditure of US firms, 1994–2008, Mio USD



Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: 'Internationalisation of business investments in R&D' study (2012), based on data from Eurostat, OECD and national statistical offices.
Note : (1) EU does not include Croatia.

[35] This is confirmed by data on FDI flows, in particular for China over the 2007–2011 period.

The figure conveys two messages. In relative terms, the rise of Asian countries as R&D locations for US firms has led to a shift in the distribution of US overseas R&D expenditure. The share of US overseas R&D expenditure in the EU decreased from around 75 % in 1994 to around 60 % in 2008, with corresponding increases for Asian countries and non-European OECD member states. It is remarkable that most of this decrease occurred in the second half of the 1990s: the share of US overseas R&D expenditure within the EU has remained relatively stable since the early 2000s.

In absolute terms, however, R&D expenditure increased at each location, and overseas R&D expenditure by US firms in the EU more than doubled between 1994 and 2008. Developments in the years immediately preceding 2008 gave no indication that US firms planned to increase their R&D efforts in Asia at the expense of locations in the EU. The internationalisation of R&D is not a zero-sum game. The EU remains an attractive location for R&D investments by US firms. China and India are not only host countries for R&D activities of foreign-owned firms. A small number of Chinese and Indian firms have already set up R&D activities in Europe and the United States. Some of these activities are not yet fully reflected in the data available.

The EU's strengths as a location for R&D include developed markets with sophisticated demand ('lead markets'), the quality and quantity of its pool of skilled labour, a stable economic framework, and excellence in academic and business R&D. EU countries benefit from foreign-owned firms' R&D activities. Their R&D investment helps to push up overall R&D intensity, moving the EU closer to the goal of investing 3 % of GDP in R&D, as laid down in the Europe 2020 strategy. Moreover, R&D expenditure and labour productivity of foreign-owned affiliates has a positive impact on labour productivity within domestic firms, suggesting spillover and competition effects. Moreover, EU firms are also very active in R&D abroad, in particular in the United States, helping them to open up new markets and expand globally.

However, the trend is a more fungible nature of capital. Foreign investment dynamics and the increased trend of sourcing parts and components from dispersed global value chains (GVCs) indicate how the globalisation of technology and production is being driven by large multinational corporations. This evolution is important since it increases competition between knowledge centres, triggering specialisation profiles. It can also be the basis for complementarities and networked specialisation, based on related variety and overcoming sub-criticality ([36]). The globalisation of high value-added products and services can be measured by the composition and direction of overall FDI flows, as well as by international financial flows oriented predominantly towards R&D ([37]).

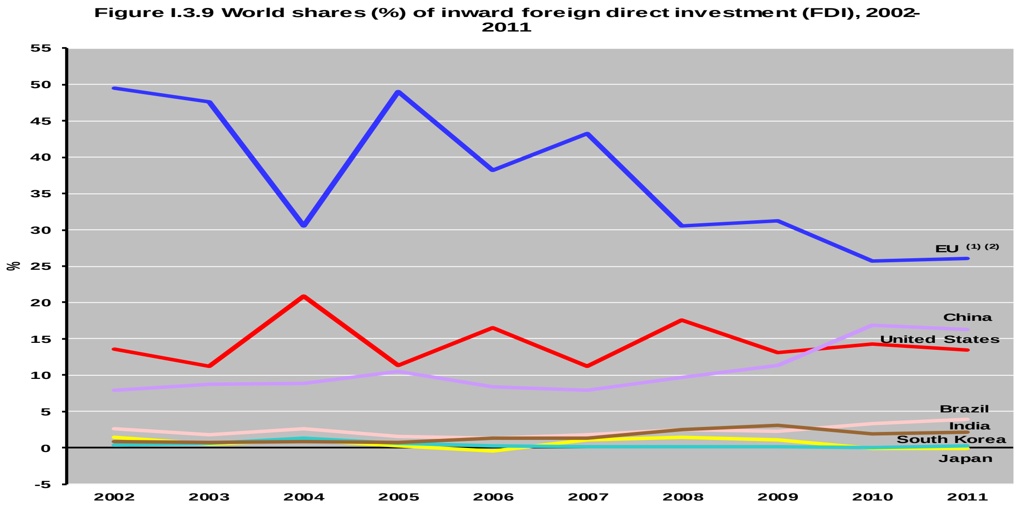
[36] Expert group to the European Commission, 2008.

[37] The globalisation of production can also be measured by input–output tables on trade, indicating income generated from the global value chains. The most recent data (2011) is consistent with the overall finding of FDI data, namely of the EU's slightly falling but persisting world lead. However, China is rapidly increasing its

The EU remains the most attractive market for FDI, although investments have fallen with the current economic downturn

For FDI, the EU is still the world's number one destination, representing over one quarter of FDI inflows, twice the level of the United States or China. However, the EU's share has been falling, in particular since 2007. This evolution is visible in most EU Member States, with the notable exception of Belgium. At the same time, emerging economies such as China and India have increased their share of total world FDI inflows.

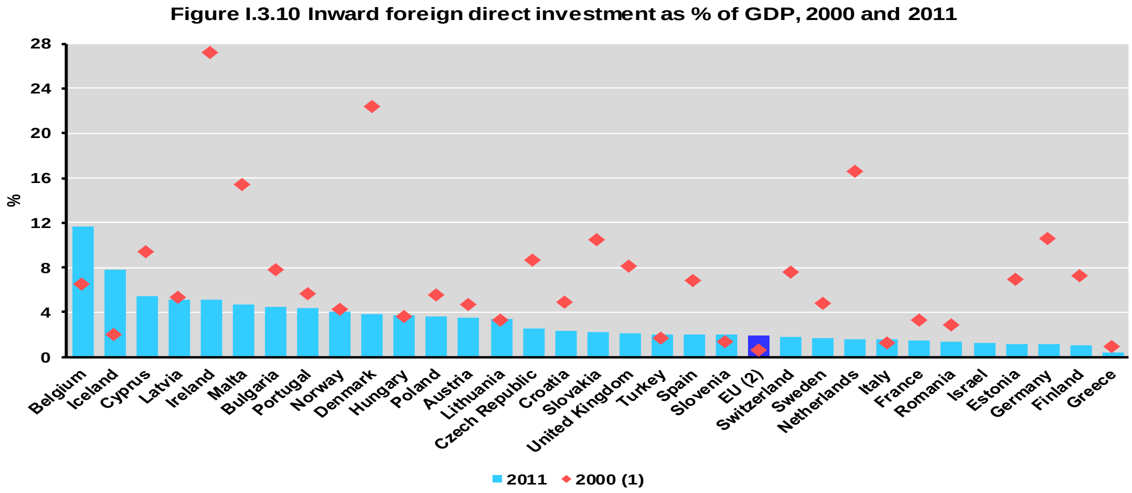
Figure I.3.9: World share of Foreign Direct Investment (FDI), 2004–2011



Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: OECD
Notes: (1) EU does not include BG, HR, CY, LV, LT, MT, RO for 2002-2003; EU does not include BG, HR, RO for 2004-2006; EU does not include HR for 2007-2011.
(2) EU does not include Special Purpose Entities (SPEs) for Luxembourg, Hungary, Netherlands and Austria.

global value chain income and is competitive at both the lower and the higher end of the value chains. See Chapter III.4.

Figure I.3.10: Inward foreign direct investment as % of GDP in European countries



Source: DG Research and Innovation
Data: Eurostat, OECD
Notes: (1) SI, SE,TR: 2001; BE: 2002; EU27: 2004.
(2) EU refers to extra-EU27.
(3) Luxembourg with a value of 510% for 2002 and a value of 645% for 2011 is not shown on the graph.

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EU firms expect to further expand their worldwide R&D investments, impacting mainly the most knowledge-intensive Member States

Overall, businesses in the EU increased their expenditure on R&D as a share of GDP from 2007 (1.18 %) to 2011 (1.26 %). This is in part due to sustained R&D investment by European firms, which expect their worldwide investments in R&D to continue growing, by an average of 4 % annually, over the period 2012–2014. Figure I.3.11 shows that this evolution affects mainly the knowledge-intensive Member States. The figure depicts investments by R&D-intensive firms in absolute numbers as a share of total domestic R&D investments financed by businesses in absolute numbers. The numerator is based on firm-level data by headquarter, and the denominator on national data (firms operating in the country independently of the location of their headquarters) ([38]). When a country has several large multinational corporations investing in R&D worldwide (at home and abroad), these investments can be larger than the sum of R&D investments financed by the businesses registered in the country (business enterprise research and development (BERD) data). The values for the country in Figure I.3.11 are in this case larger than 100. Given the methodological differences between the two data sets, these shares are only proxies of the extent to which a country is affected by the internationalisation of business R&D investments. The number of firms in each country is indicated in parentheses.

Figure I.3.11 shows that it is mainly knowledge-intensive countries that are most affected by the internationalisation of business R&D. Switzerland has the highest ratio, followed by the Netherlands, Ireland, the United Kingdom, Finland and Sweden. Germany and France are also

[38] For a more extensive methodological note, explaining the differences between BERD and Industrial scoreboard datasets, see Azagra-Caro, J. and Grablowitz, A., 2008.

affected, but in these countries business R&D investments seem to have grown more than French and German firms' worldwide R&D investments. The data for the United Kingdom are particularly interesting, since the overall R&D intensity in the country is much lower than in other EU Member States. The table in Figure I.3.11 seems to indicate that UK businesses do indeed invest considerably in R&D, but on a worldwide scale.

Figure I.3.11 R&D investment by the top 1000 EU companies as % of total business R&D financed by companies [(1)], 2005-2011

	2005		2006		2007		2008		2009		2010		2011	
	%	Total companies	%	Total companies	%	Total companies	%	Total companies	%	Total companies	%	Total companies	%	Total companies
Belgium	58,6	37	63,5	33	70,3	40	65,1	39	62,3	40	:	39	:	34
Bulgaria	:	:	:	:	:	:	-	-	9,8	1	15,6	1	-	-
Czech Republic	1,7	2	5,2	4	7,8	4	2,1	1	3,0	2	8,8	3	6,3	2
Denmark	72,0	37	:	38	82,8	42	84,5	47	85,9	46	93,3	45	73,8	35
Germany	108,1	167	107,6	167	105,6	189	106,8	209	105,6	206	110,2	206	116,2	233
Ireland	34,6	12	39,0	12	37,2	11	42,7	12	100,0	16	156,6	17	208,3	14
Greece	17,8	6	:	3	20,5	5	:	4	:	5	:	5	:	2
Spain	26,8	22	25,9	23	23,9	21	24,1	21	50,5	27	62,5	25	:	22
France	117,3	112	120,9	114	128,0	113	127,5	125	113,5	116	111,9	125	:	126
Italy	76,6	40	75,1	48	73,7	51	77,4	57	77,6	53	80,1	54	:	51
Latvia	-	-	6,7	1	-	-	-	-	-	-	-	-	-	-
Luxembourg	81,9	6	:	5	128,5	6	:	10	138,7	8	225,9	9	175,7	13
Hungary	27,7	3	28,2	3	29,9	3	23,6	2	29,1	2	29,3	2	24,5	2
Malta	-	-	-	-	-	-	57,7	1	355,4	2	62,9	1	69,5	1
Netherlands	207,6	44	:	50	199,0	49	:	53	242,3	52	:	54	:	52
Austria	:	28	18,3	31	18,6	30	:	32	22,5	31	:	29	:	27
Poland	5,1	2	7,4	2	12,1	4	:	6	12,7	5	18,1	7	1,7	2
Portugal	3,6	2	0,6	1	7,6	3	12,5	4	33,2	8	27,1	6	:	6
Slovenia	19,4	1	21,4	2	23,9	2	24,7	2	26,3	2	24,5	2	19,2	2
Slovakia	14,9	1	-	-	-	-	-	-	-	-	-	-	-	-
Finland	148,7	70	136,5	67	164,4	60	145,5	58	143,0	56	140,5	52	136,1	46
Sweden	103,2	81	:	75	107,6	78	:	70	107,7	76	:	74	121,4	84
United Kingdom	170,5	327	160,9	321	134,5	289	141,3	247	162,2	246	171,3	244	185,9	246
EU [(2)]	108,7	1000	107,1	1000	105,8	1000	104,6	1000	107,2	1000	111,0	1000	:	1000

Source: DG Research and Innovation - Economic Analysis Unit

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Data: EU Industrial R&D Investment Scoreboard, Eurostat

Notes: (1) Business R&D financed from abroad is not included.

(2) The EU average does not include: EE, HR, CY, LT and RO. These Member States are not shown on the Table.

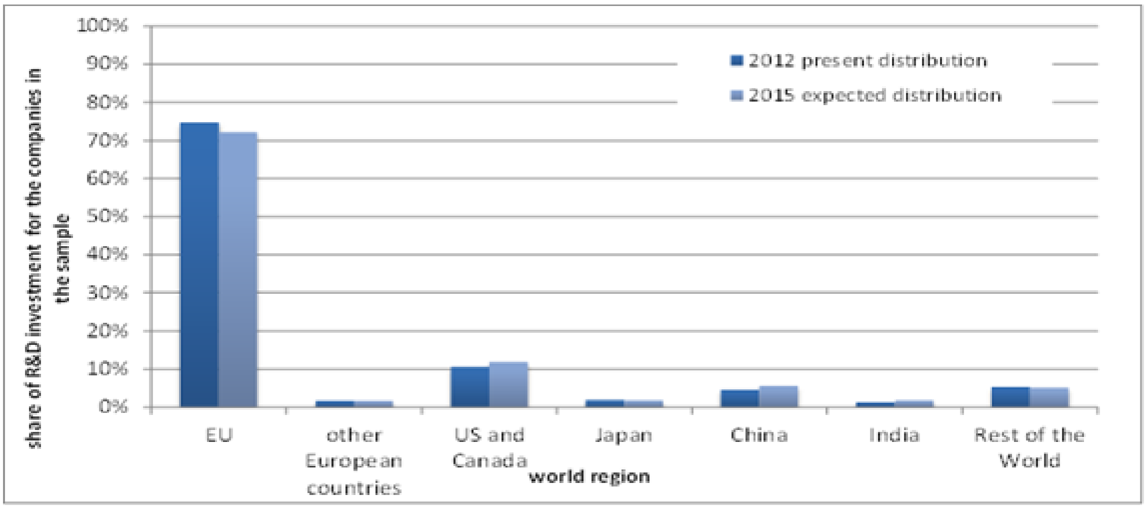
EU firms carry out three quarters of their R&D investments inside the EU. However, business R&D investment outside the EU is growing faster

Expectations of large EU firms for R&D investment for the next three years (2013-15) show continued participation of European companies in the global economy, in particular growth opportunities in emerging economies, while maintaining an R&D focus in the EU. A recent survey of 172 out of the 1000 EU-based companies in the EU R&D Investment Scoreboard[39]

[39] http://iri.jrc.ec.europa.eu/scoreboard12.html

shows that the EU-based companies in the sample carry out a quarter of their R&D outside the EU. The largest share of R&D investment outside the EU is in the United States and Canada (10 %), followed by rest of the world (5 %), China (4 %), Japan (2 %), other European countries (2 %), and India (1 %). Altogether, the shares of R&D investment carried out in China and India remain at a stable 5 %, which is relatively low in the light of globalisation. However, generally higher percentages of R&D investment growth outside the EU have been observed repeatedly over the previous surveys of EU Scoreboard companies and can be considered a trend. In these past surveys, the highest growth was repeatedly expected for China and India, followed by the United States and Canada, while the other areas remained at a more modest level. In case the above pattern of R&D investment expectations materialises, this would lead to a future reduction of R&D investment shares in the EU together with growing shares in the United States and Canada, China and India (Figure I.3.12).

Figure I.3.12: R&D investment shares in 2012 and expected in 2015, by world region



Source: European Commission JRC-IPTS (2013)

Note: The figure refers to 111 out of the 172 EU companies in the sample, weighted by R&D investment and after elimination of outliers. Other EU countries include Switzerland, Norway and others, while the rest of the world includes a heterogeneous set of countries such as South Korea, Taiwan, and Brazil.

The decreasing shares of R&D invested in the EU occur within an overall increase in R&D investment amounts in all world regions over the coming years. The expected nominal investment increases inside the EU are in a similar magnitude like those outside the EU (around € 1.2 billion over three years). In other words, the expected R&D investment growth is not distributed according to the existing R&D investment distribution in 2012, but around half in the EU and the other half outside. This has also been observed in our previous surveys and reflects the increasing participation of European companies in the global economy, and in particular emerging economies, while they retain their R&D focus in the EU. It also indicates that the gap between R&D invested by the surveyed companies in the EU and countries like China and India has not widened significantly.

4. Delivering skilled labour, researchers and entrepreneurs

There is a growing demand for highly skilled workers and researchers

The EU is facing an increasing demand for skilled labour and researchers. At the same time, current demographic developments imply that the number of young people entering the labour market will decrease, while the baby boomer generation is set to retire in the next decade. The EU's working age population peaked in 2011, with southern and eastern European countries more affected by the shrinking labour force than northern and western countries. This demographic change also affects the science and technology (S&T) labour force in the EU, with 37 % now over 45 years old. The expected increase in R&D expenditure, coupled with the retirement of one third of the researchers in the EU between now and 2020, means that a sharp increase in the recruitment of new researchers is required. Women still represent only 11 % of A-grade personnel and fewer than 20 % of researchers in business enterprises.

Growth in the supply of skilled labour has been achieved, but challenges remain

Responding to labour market needs, the EU has been able to grow its supply of skilled labour. Between 2009 and 2010, government spending on education as a percentage of GDP in the EU increased from 5.41 % to 5.44 % despite fiscal constraints. Public investment in education in Europe is at the same level as that in the United States and even higher than in developed Asian countries, but private investment in tertiary education remains much lower in Europe. As a result of continued public investment, and in response to the growing economic demand for highly skilled labour, education levels around the EU are increasing. However, there is a need to improve the quality of education, in particular for basic skills, like reading, science and mathematics. In 2011, the EU produced over 1 million S&E graduates at tertiary or doctorate level. This is more than double the corresponding number for the United States, but less than that of China. With regard to researchers, the EU experienced an average annual growth rate of 3 % in full-time equivalent (FTE) over the period 2005–2011. The number of researchers in the private sector has increased slightly in the EU, but the EU still faces the challenge of having only 46 % of its researchers working in the private sector, a share that is much lower than those of the United States, Japan and China.

Employment in science and technology is expanding and is resilient even in times of crisis

A number of Member States have stepped up efforts to augment numbers of science and engineering (S&E) graduates, in particular Germany, Cyprus, Croatia and the Czech Republic, but also Malta, Romania and Slovakia. Overall, the Member States with the highest R&D intensities are also those with the highest intensities of new doctorate graduates in S&E. Sweden, the United Kingdom and Ireland have the highest employment shares for scientists and engineers. In the EU, employment in S&T has grown faster than total employment, and has been more resilient in times of crisis.

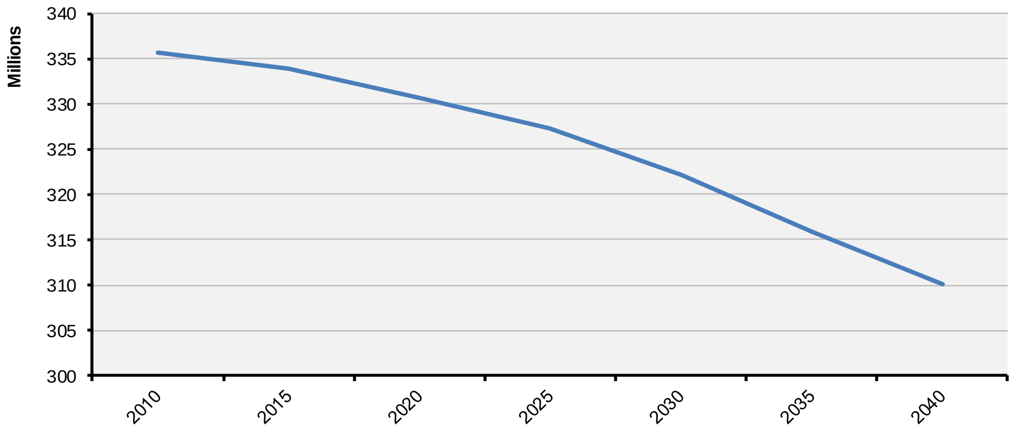
4.1. Are governments and firms investing in skilled labour, researchers and entrepreneurs?

The demographic ageing of the EU requires well targeted and effective investments in education, training and research

The shift in population demographics towards more elderly people and fewer young people require sufficient and effective investment in education and research. This will ensure Europe's competitiveness in an increasingly global and knowledge-based economy, plus the sustainability of its public finances and social model.

According to the Eurostat population projection Europop2010, the EU's working-age population peaked in 2011, and the size of the potential labour force has decreased since then ([40]). The EU working-age population (15–64 years) currently shrinks by about 250 000 people per year. This is expected to accelerate to more than 1 million each year after 2025 with the retirement of the baby boomer generation.

Figure I.4.1 EU [(1)] projected working age population (age 15 to 64 years)



Source: DG Research and Innovation - Economic Analysis unit
Data: Eurostat
Note: (1) EU does not include Croatia

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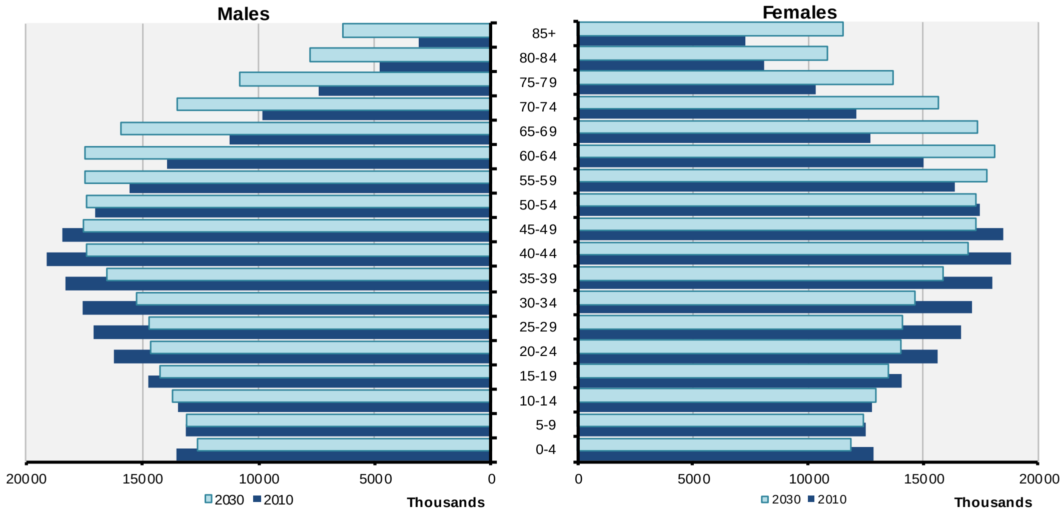
At the same time, an ongoing increase in life expectancy (in the past, by about two years each decade) will boost the number of elderly people among the population. The resulting challenges for the EU are twofold: a decreasing number of young Europeans will have to create the wealth needed to finance living standards for the growing number of elderly Europeans in an increasingly competitive world. Highly skilled human resources are a necessary pre-requisite if Europe is to face this growing challenge.

[40] See http://epp.eurostat.ec.europa.eu/portal/page/portal/population/data/database

Figure I.4.2 Projected EU [(1)] - population pyramid (by 5 year age groups), 2010 and 2030



Source: DG Research and Innovation - Economic Analysis unit
Data: Eurostat
Note: (1) EU does not include Croatia

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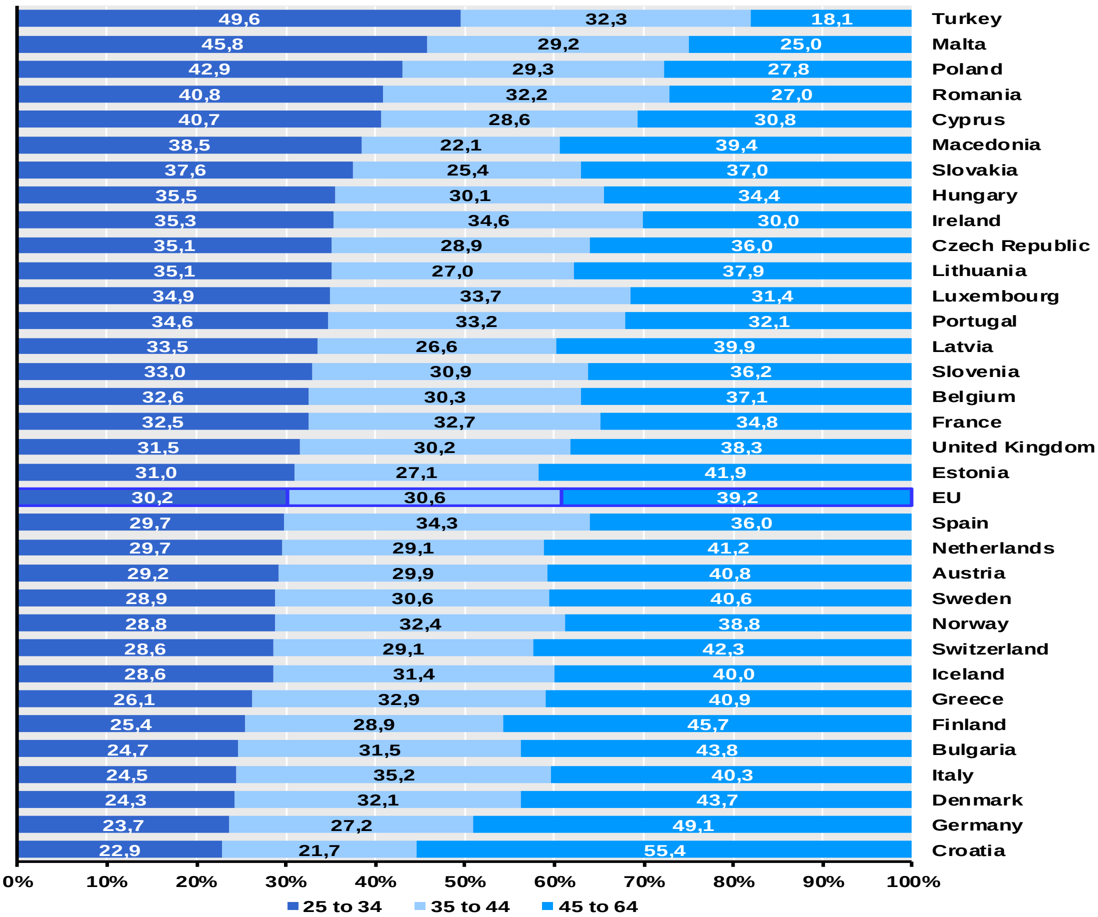
The ongoing demographic change affects EU Member States and regions in different ways, with southern and eastern countries more affected than northern and western countries. Combined with an apparent re-urbanisation in many countries, this leads to a shrinking population in many peripheral rural regions. Furthermore, Europe has to compete with emerging economies for highly skilled, internationally mobile labour. Demographic change could thus lead to a scarcity of qualified human resources in Europe in the long term. Governments and enterprises have to invest in mobilising all talents, women and men, disadvantaged groups, migrants and older workers. Working conditions and incentives for these groups will have to improve in order to attract them to or retain them in the labour market.

Demographic change also affects the S&T labour force. Overall, the core of S&T human resources (HRSTC) in Europe is already of a mature age. Of the HRSTC, 37% is older than 45 (see Figure I.4.3). Human resources in science and technology are on average younger in countries with medium and low R&D intensities, like Poland, Malta, Ireland and Portugal. However, in Member States with high or medium-high R&D intensities (Austria, Denmark, Germany, Finland and Sweden), the share of individuals younger than 35 is very low, implying that replacement needs will grow in the future. The economic future of these countries, with their above-EU–average levels of GDP per capita and their export-oriented economies, depends on the renewal of their human capital, especially within S&T.

Figure I.4.3 Human Resources in Science and Technology - Core (HRSTC)
% distribution by age group, 2012



Source: DG Research and Innovation - Economic Analysis Unit   Innovation Union Competitiveness report 2013
Data: Eurostat

On an aggregated level, available data suggest that the EU does not have a general skills gap for highly skilled labour. However, individual Member States and industries may experience a mismatch between supply and demand

The European economy faces an ongoing and long-term structural change towards more knowledge-intensive products and services. The demand for high-skilled labour is therefore on the increase. At the same time, as upper secondary and tertiary attainment rates for younger people entering the labour market are still increasing, there is no shortage of supply of skilled graduates. As regards the broad category 'high skilled', as measured by educational attainment, there will therefore be no skills gap until 2020 for the EU as a whole (see Cedefop demand and supply of skills forecast 2012, shown in Figure I.4.4). However, the picture changes in the longer term, as attainment levels reach saturation and as fewer young people enter the labour market. The global data also hide differences between countries and specific skills areas. The rising importance of information and communication technologies (ICT), the globalisation of the economy, the blurring of borders between traditional fields of study in the search for solutions to societal challenges, and the accelerating pace of structural reform imply, together, a greater need for training, including in increasingly important interdisciplinary skills and entrepreneurial skills.

Figure I.4.4: EU labour market forecast (demand and supply)

Figure I.4.4 Labour market skills forecast (by Cedefop) - demand and supply

	Demand - % change						Supply - % change					
	Highly-skilled		Medium-skilled		Low-skilled		Highly-skilled		Medium-skilled		Low-skilled	
	2000-2010	2010-2020	2000-2010	2010-2020	2000-2010	2010-2020	2000-2010	2010-2020	2000-2010	2010-2020	2000-2010	2010-2020
Belgium	29,1	15,9	21,4	13,9	-28,3	-18,7	31,3	18,1	25,0	9,9	-25,3	-32,3
Bulgaria	18,0	5,3	22,8	-1,9	-26,5	-27,9	17,9	7,3	3,1	-2,9	-32,3	-37,1
Czech Republic	36,9	30,6	2,7	-2,7	-36,5	-16,2	39,3	26,5	1,7	-0,7	-36,3	-34,4
Denmark	23,7	15,8	-22,8	-15,0	33,3	21,2	38,8	21,3	-18,7	-13,1	9,4	4,2
Germany	9,8	2,2	5,3	2,0	-14,8	-4,2	16,5	10,0	7,9	-1,5	-15,5	-17,3
Estonia	16,4	6,5	-11,8	7,5	-21,8	17,8	37,0	11,6	-0,7	-6,8	-31,3	-24,0
Ireland	66,0	16,9	4,9	11,4	-33,3	-31,8	85,9	14,0	20,2	5,0	-23,2	-34,2
Greece	45,6	9,5	17,6	6,9	-12,1	-29,9	51,2	22,4	13,1	8,8	-15,9	-28,5
Spain	52,5	23,2	51,0	27,1	-17,8	-34,4	66,7	24,0	69,3	31,1	-4,0	-39,1
France	32,4	29,5	4,9	1,3	-19,8	-18,5	45,5	27,1	10,1	1,1	-18,6	-23,2
Croatia	18,8	6,0	18,9	0,7	-19,8	-17,5	26,9	17,9	4,7	3,3	-26,2	-33,2
Italy	42,4	24,1	23,1	13,1	-16,0	-17,9	56,6	35,4	19,6	13,7	-18,4	-24,6
Cyprus	62,9	27,9	29,4	6,6	-12,0	-22,4	68,2	31,3	40,8	14,6	-7,2	-33,2
Latvia	29,7	22,6	-10,0	-11,1	-13,5	26,4	47,0	29,4	0,0	-11,5	-30,8	-28,0
Lithuania	-11,6	-8,8	15,5	17,8	-46,3	5,2	4,4	4,3	11,6	2,6	-62,1	-38,6
Luxembourg	91,1	34,3	36,2	21,6	0,6	-22,3	107,7	36,3	17,7	21,6	-22,2	-38,7
Hungary	36,3	27,3	-6,8	-5,4	-38,7	-20,5	42,5	23,2	1,0	-0,9	-24,4	-32,9
Malta	118,3	20,5	53,0	33,5	-16,4	-20,9	92,8	42,3	46,9	35,1	-12,9	-35,6
Netherlands	45,9	22,8	-1,6	-4,6	-12,5	-13,3	49,3	30,0	0,5	-5,9	-12,8	-25,9
Austria	46,1	32,0	5,1	-0,7	-7,3	-9,3	62,4	50,7	5,4	-7,2	-10,6	-23,7
Poland	56,8	27,0	9,9	-11,2	-12,0	-1,0	39,9	44,7	-5,4	-14,2	-18,9	-31,7
Portugal	50,0	17,2	34,6	39,3	-17,8	-16,1	71,5	24,5	49,5	29,2	-11,9	-18,5
Romania	12,4	23,1	-2,2	-1,8	-45,4	-11,5	18,6	30,7	-5,0	1,0	-42,8	-31,8
Slovenia	55,2	22,8	0,1	-6,6	-29,6	-17,9	66,2	27,4	2,8	-8,7	-23,7	-31,5
Slovakia	51,2	38,0	3,1	-4,5	-44,1	-12,6	66,7	39,7	0,5	-3,9	-36,7	-41,0
Finland	31,7	14,9	8,1	3,9	-32,9	-20,6	32,0	17,8	4,3	-0,1	-41,0	-33,1
Sweden	18,4	8,6	0,6	3,1	-4,1	3,4	35,5	22,6	6,5	-0,5	-0,1	-15,3
United Kingdom	29,2	20,6	16,3	17,8	-30,6	-42,9	40,0	20,3	19,6	14,1	-29,8	-42,4
EU	31,2	19,1	9,4	4,6	-20,8	-20,2	39,7	24,0	9,8	3,2	-19,1	-28,8

Source: DG Research and Innovation - Economic Analysis Unit
Data: Cedefop - Skills forecast 2012

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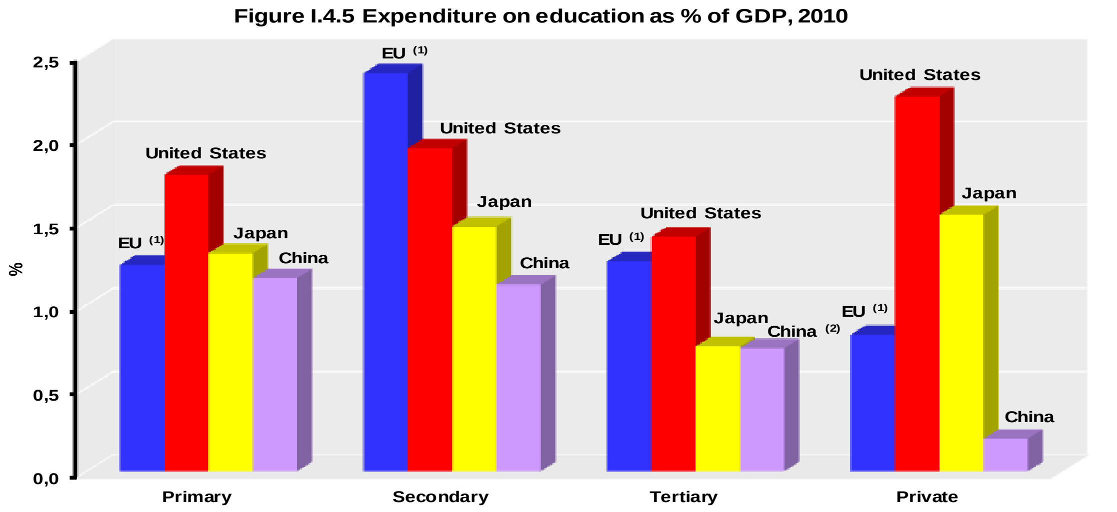
The current economic crisis has led to an increase in unemployment rates in most European countries. Currently (third quarter 2013), the EU unemployment rate is at around 12 %, or 26 million people. However, rates are much lower for those with tertiary education compared to those with lower levels of education (lower secondary or less). Despite the crisis, the employment of high-skilled people has increased in recent years in the EU as a whole.The on-going structural change towards a knowledge based -economy implies, that a further up-skilling of the labour force isnecessary. Furthermore, the business sector needs more entrepreneurs and entrepreneurial skills if it is to increase the creation rate of new, innovative, high-growth companies, which play a vital role in the creation of new jobs.

Education investments must be well targeted, addressing both the need to invest in early stages of learning and growing participation in non-compulsory education

Research shows that returns on investment are higher in the early stages of learning than later in life. But at the same time, compulsory education (primary education and lower secondary education in some countries, also parts of pre-primary education) is affected by a decline in cohort size. Meanwhile participation rates in non-compulsory education are rising as people stay in education longer. In many countries, this compensates for the demographic decline in the number of young people. Furthermore, with the population ageing and tending towards later retirement, lifelong learning is becoming more important. In this situation, it is a challenge for countries to find the right balance between investing early and adapting resource allocation to the increasing share of learners in later stages of education and training, for example in tertiary education. Technological progress, for example as regards ICT, furthermore enables new forms of learning in formal, non-formal and informal contexts, often linked to higher initial investment but potential savings over longer periods.

Figure I.4.5: Education spending as a % of GDP, 2010



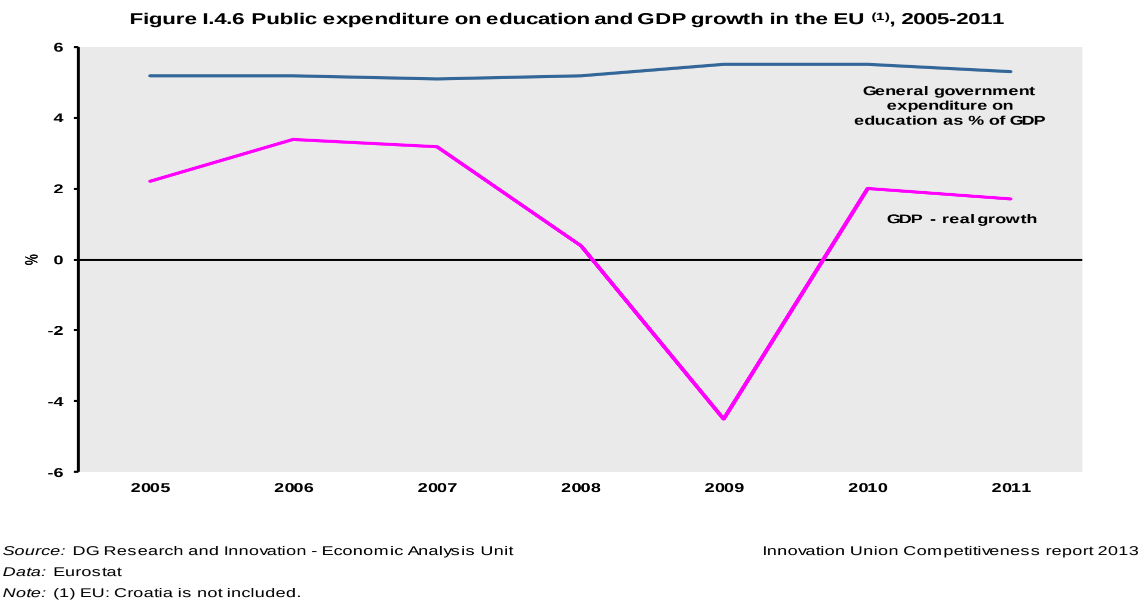
Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Eurostat, China Statistical Yearbook 2012
Notes: (1) EU: Croatia is not included.
(2) CN: Tertiary Education includes institutions of higher education for adults.

Public spending on education (percentage of GDP) in the EU as a whole is on a similar level as in the United States, but higher than in Japan. The focus in the EU is more on secondary education, including vocational education and training (VET), in which business investment plays a role in some countries. However, in overall terms, private spending, which especially contributes to tertiary education, is both higher in the United States and in Japan. The percentage of GDP spending on tertiary education in the United States is about twice the EU level (the largest part of private spending is on tertiary education). Per tertiary student, the United states invests more than twice the EU amount, or over EUR 11 000 per year more than the EU. The EU would have to spend over EUR 200 billion per year to close the higher education financing gap with the United States. In eight EU Member States, public expenditure on education (all levels) is below the OECD average of around 5 % of GDP, in particular in southern and eastern European countries (figure I.4.7). Worryingly, the low levels decreased further in some countries in recent years (including Bulgaria and Romania). In times of scarce public resources, it is hugely important to increase the efficiency and effectiveness of public spending on education. During the crisis year of 2009, many Member States applied the principle of smart fiscal consolidation, giving priority to spending on education and research with the goal of securing long-term economic growth ([41]). However, the number of countries where public education spending as a percentage of GDP increased declined, according to Eurostat data, from 24 in 2009 to only 6 in 2010 and 2011. On the other hand, the number of countries where public education spending as a percentage of GDP shrank increased from 3 in 2009 to 14 in 2010 and 20 in 2011.

The number of Member States which have protected or increased public investments in education despite fiscal constraints has been declining in recent years

In the 2008–2009 recession, general government spending in the EU on education as a percentage of GDP increased to 5.5 % (from 5.2 % in 2008), a result of a falling GDP and stable or increasing levels of spending on education. Spending remained at 5.5 % of GDP in 2010, only to decline to 5.3 % in 2011 in response to increasing budgetary pressures in many Member States.

Figure I.4.6: Public education spending and GDP growth 2005–2011, EU (1)



[41] See also Chapter I.2.

Figure I.4.7 Expenditure on education, 2010

	Expenditure on educational institutions from public and private sources as % of GDP					Expenditure on public and private educational institutions per pupil / student (FTE) (thousands of PPS€) 2010 (2)	
	Public expenditure for all levels of education combined		Public expenditure on tertiary education		Private expenditure for all levels of education combined	Total	Tertiary level
	2010 (1)	Average annual growth rate 2007-2010	2010 (1)	Average annual growth rate 2007-2010	2010 (1)		
Belgium	6,3	3,1	1,5	3,9	0,3	8,0	11,7
Bulgaria	3,4	0,3	0,6	-1,6	0,6	2,6	3,8
Czech Republic	4,1	1,7	1,0	-2,3	0,6	4,6	5,9
Denmark	7,5	4,7	2,4	1,9	0,4	9,6	14,6
Germany	4,5	4,1	1,4	6,6	0,7	7,7	12,4
Estonia	5,4	6,4	1,2	5,8	0,4	4,2	5,0
Ireland	5,9	10,2	1,4	7,8	0,5	6,0	8,9
Greece	4,1	:	1,5	:	0,3	4,5	5,0
Spain	4,8	4,3	1,2	5,4	0,8	6,9	10,3
France	5,6	1,4	1,3	2,6	0,6	7,3	11,6
Croatia	4,2	2,0	0,8	-0,8	0,3	3,8	5,2
Italy	4,2	1,3	0,8	3,8	0,5	6,1	7,4
Cyprus	6,7	4,0	2,1	9,4	1,6	9,1	9,9
Latvia	4,7	-0,6	0,8	-4,9	0,6	3,6	4,3
Lithuania	5,1	4,9	1,3	7,9	0,7	3,7	5,1
Luxembourg (3)	3,1	:	:	:	:	:	:
Hungary	4,6	-2,9	1,0	-2,0	0,5	4,0	5,0
Malta	5,7	-2,9	1,5	18,3	1,3	7,6	11,7
Netherlands	5,2	3,7	1,7	4,6	1,0	8,5	13,2
Austria	5,3	2,9	1,6	3,3	0,5	9,2	11,9
Poland	5,0	1,3	1,2	8,3	0,8	4,5	6,0
Portugal	5,3	2,8	1,1	-0,9	0,4	5,3	7,7
Romania	3,4	-6,5	1,0	-3,7	0,1	2,1	3,0
Slovenia	5,2	3,1	1,4	4,0	0,7	6,6	7,3
Slovakia	3,9	5,0	0,8	1,7	0,7	4,2	5,3
Finland	6,4	5,0	2,2	5,6	0,2	7,4	12,9
Sweden	6,2	1,7	2,0	4,3	0,2	8,3	15,1
United Kingdom	4,4	3,5	1,0	3,1	2,0	8,3	12,8
EU (4)	4,9	2,8	1,3	4,3	0,8	6,9	9,6
Iceland	7,0	0,1	1,6	5,5	0,8	7,2	6,7
Liechtenstein	2,5	11,6	0,2	:	:	:	:
Norway	5,8	2,7	2,0	-1,4	0,1	10,4	14,3
Switzerland	5,1	2,8	1,3	5,0	0,5	:	:
United States	5,1	0,4	1,4	3,8	2,3	11,5	21,1
Japan	3,6	3,2	0,8	6,0	1,5	7,8	11,8
China (5)	3,0	:	0,7	:	0,2	1,1	2,4

Source: DG Research and Innovation - Economic Analysis Unit   Innovation Union Competitiveness report 2013

Data: Eurostat, China Statistical Yearbook 2012

Notes: (1) EL: 2005; HU: 2006 (private expenditure); LI: 2006 (tertiary); LU: 2007.

(2) IE, EL: 2005; HU: 2006; PT: 2009 (total expenditure).

(3) LU: Public expenditure on tertiary education is not included.

(4) EU: Croatia is not included.

(5) CN: Tertiary Education does not include institutions of higher education for adults.

Further efforts are still needed to improve the quality of education at all levels and in particular for foundation skills, such as mathematics

Data on mathematics and science education in schools show strong differences between countries, and hence reveal a potential for further improving the quality of education offered in many Member States. According to the OECD PISA study (2009), the best performer in the EU is Finland, while within the OECD, Japan and South Korea are leading. Lower secondary school students in many Member States with a relatively low level of public investment in primary and secondary education (with some exceptions) perform relatively weakly. This is evident in the OECD's PISA study and in the Trends in International Mathematics and Science Study (TIMSS) study by the International Association for the Evaluation of Educational Achievement (IEA). Both raise concerns about the quality of the future labour force. Only seven EU countries (Finland, the Netherlands, Belgium, Germany, Estonia, Denmark and Slovenia) have a Programme for International Student Assessment (PISA) score in mathematics that is above OECD average, while the EU Member States Bulgaria and Romania score relatively low in international comparison. The situation is somewhat better in science, where 13 EU Member States score above the OECD average. The performance of secondary school pupils in mathematics and science has an impact on later learning, employability and the take-up of tertiary studies in these fields (and also on the performance of students therein) later in life.

Over one million additional researchers are needed, in particular in the private sector

Achieving the 3 % R&D intensity target will have broader implications for both the economy and the educational systems needed to provide the skills needed, including research-related skills. A growing number of researchers will have to be trained or attracted to research jobs if increases in private and public R&D budgets are to be absorbed efficiently. There is also a qualitative dimension that will need to be taken into account. Many of the new researchers will be employed in the private sector, where skills profiles tend to differ from the public sector. The needs of different scientific fields, combined with new interdisciplinary and trans-disciplinary competences for new areas of demand (like key enabling technologies) and a growing need for transversal skills will have to be taken into account.

The growth rate for the number of researchers in the EU tends to correspond to increases in R&D budgets in real terms. By 2020, an increase in R&D intensity combined with economic growth is expected to result in substantially higher R&D spending, requiring a significant increase in the number of researchers. Estimation based on the assumption of a growing economy and growth in R&D intensity from 2 % of GDP in 2010 to 3 % in 2020 will result in a need for about one million additional researchers by 2020. This estimation does not include the replacement of retiring researchers. Generally, about one third of research staff retires every decade. To replace those retiring between today and 2020 would require about half a million researchers. Increased researcher mobility and increasing competition for highly qualified human resources from non-European countries, including newly industrialised countries and emerging economies, should also be taken into account.

Another challenge for S&T is to reach a better gender balance. European research still suffers from not exploiting the full potential of highly skilled women. Despite the fact that nearly half of new PhD graduates are now women (46 % in 2010 ([42])) and that over the period 2002–2010 the number of female PhD graduates increased by 3.7 % per year compared to 1.6 % for men, women in research remain a minority, representing only 33 % of researchers and less than 20 % of researchers in the business sector. The under-representation of women is even stronger in the field of S&E. Here, the share of women amounts to 31 % of students at first level, 38 % of PhD students and 35 % of PhD graduates, but to only 32 % of academic grade C personnel, 23 % of grade B personnel and just 11 % of grade A personnel.

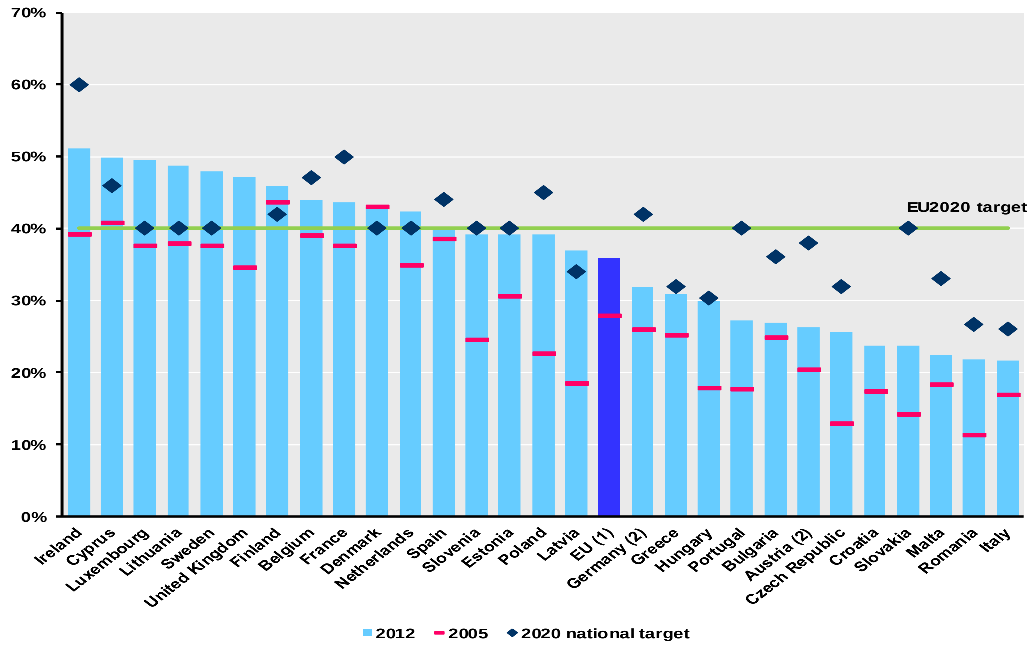
4.2. Tertiary education and training to respond to these challenges

Tertiary attainment is still increasing, but growth in the number of new tertiary graduates will slow down in the future

Educational attainment is increasing. Young people entering the labour market are bringing with them higher levels of formal qualification than those leaving for retirement. This is welcome not only because of the growing demand from the economy for high-skilled labour, but also to compensate for the shrinking cohort size.

[42] 'She Figures 2012'.

Figure I.4.8 The EU headline target on the tertiary attainment of 30-34 year olds



Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Eurostat
Notes: (1) EU: Croatia is not included.
(2) DE, AT: The 2020 national targets include ISCED4 attainment.

In its Europe 2020 Strategy, the EU has set the target of reaching a tertiary attainment rate among young adults (aged 30–34 years) of 40 % by 2020. The current figure (2012) is 35.8 %. Twelve EU Member States have already reached or surpassed the 40 % EU target, but there are strong differences in the level reached and in the rate of progress between Member States. Nordic and western European countries tend to have high rates of tertiary attainment. Southern, central and eastern European countries tend to show lower rates. But among the latter group, many are catching up. Ireland and Luxembourg have the highest rates of tertiary attainment, partly explained by the characteristics of their labour market, which have attracted high-skilled workers from other countries in the past. While catching up, Italy, Malta and Romania till show the lowest rates of tertiary attainment.. Since 2005, tertiary attainment in the EU has increased by about one percentage point per year, and it is thus likely that the 40 % target can be achieved by 2020.

However, the population’s tertiary education levels are only a very general indicator of the skill levels within the labour force. It is important to look also at the level and field of tertiary degrees. Based on the International Standard Classification of Education (ISCED 97 ([43])) terminology, the first stage of tertiary education (ISCED level 5) programmes include ISCED 5A programmes, which are 'largely theoretically based and are intended to provide sufficient qualifications for gaining entry into advanced research programmes and professions with high skills requirements', while ISCED 5B are programmes that are 'practical/

[43] An updated classification (ISCED 2011) was adopted in 2011, but still needs to be implemented in statistics.

technical/occupationally specific'. The ISCED 6 level, 'second stage of tertiary education leading to an advanced research qualification', is reserved for tertiary programmes that 'are devoted to advanced study and original research and are not based on coursework only'.

Today's students are the R&D human resources of tomorrow. This section presents a picture of the number of new tertiary degrees obtained in the EU in the period 2005–2011. The focus is on the analysis of tertiary degrees at the ISCED 5 level, and of doctoral degrees (ISCED 6), given that these graduates provide the main 'pool' of potential employees for scientists and researchers.

The EU has a similar number of graduates within the first stage of tertiary education per 1 000 inhabitants as the United States, but a higher share of graduates in S&E

Tertiary graduates provide the bulk of Human Resources in Science and Technology for industry, as well as a talent pool for doctoral (PhD) students (and future researchers). Figure I.4.9 provides a comparison between the EU, the United States and Japan on the number of tertiary degrees awarded and the share of S&E degrees. In 2011, 4.7 million tertiary degrees were awarded in the EU, or 72.8 per 1 000 inhabitants, compared to 3.1 million in the United States (71.2/1 000) and about 1 million in Japan (70.1/1 000). The world leader was, however, China, with 8.7 million new tertiary graduates. S&E graduates in 2011 represented 22 % of all tertiary graduates in the EU, 15 % in the United States and 20 % in Japan.

There has been a significant growth in the number of new tertiary S&E graduates in the EU in the last decades. However, growth rates vary between fields of study and tend to be overstated as a result of more people taking several degrees (Bologna effect)

The number of S&E degrees (ISCED 5) awarded in the EU increased from about 830 000 in 2005 to 1 030 000 in 2011, or 16.0 per 1 000 of the population aged 20–29 years. The EU shows greater production of S&E degrees compared to the US (474 000, 10.9/1 000) and Japan (191 000, 14.0/1 000), both in absolute figures and relative to the size of the population aged 20–29 years. Together with the 43 000 doctorate graduates (ISCED 6) in S&E, the EU produced over 1 million new S&E graduates in 2011.

There are strong differences in trends between fields, with computing growing strongly since 2000 but showing lower growth in recent years, and natural science rather stagnating. Trends are also very different between countries. A number of countries have strongly stepped up their efforts in the education of S&E graduates in the last decade, such as the Czech Republic, Croatia, Cyprus, Malta, Romania and Slovakia, partially from a low starting level. But strong innovation performers such as Austria and Germany have also been proactive. Growth in some of these countries is however overstated, because of the introduction of the Bologna degree structure and the growing number of students who take two degrees (bachelor and later master). They are therefore counted twice in statistics. In France, Ireland and the United

Kingdom, the Bologna effect did not play a role because a Bologna-type degree structure was already established. Furthermore, tertiary participation and the number of S&T graduates has traditionally been relatively high in these countries, leaving less potential for further growth, which partially explains low or negative growth rates. Nevertheless, in growth terms, the EU as a whole is outperforming the United States and Japan with the latter, in particular, experiencing a decrease in the number of S&E graduates, mainly as a result of a saturation in tertiary participation rates and a declining cohort size.

Emerging economies are progressing quickly and China now produces more new S&E graduates than the EU

While Europe is outperforming the US and Japan, growth in emerging economies is even stronger. According to national statistical sources, the number of tertiary S&T graduates in China nearly tripled to reach about 1.4 million in 2010. According to United Nations Educational, Scientific, and Cultural Organization (UNESCO) statistics, the number of engineering graduates in Brazil doubled between 2003 and 2010 (while the number of science graduates remained stable). According to an OECD projection, in 2020, 4 out of 10 tertiary graduates worldwide will be from India and China. The share of the two countries in S&T graduates will probably be similar or even higher.

Figure I.4.9 Graduates from tertiary education (ISCED 5), 2011

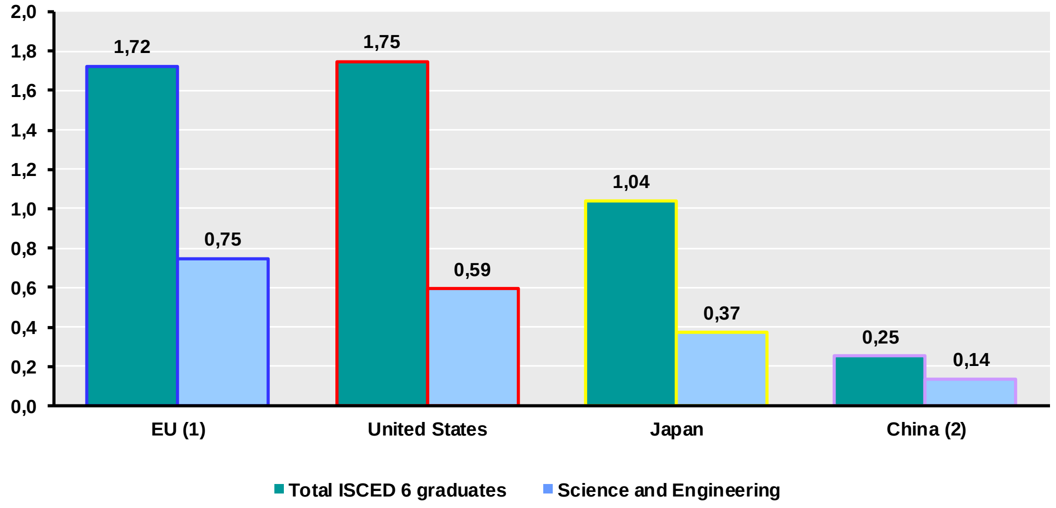
	Total ISCED 5			Of which: Science and Engineering		
	2011 (1) (thousands)	Average annual growth rate 2005-2011 (2)	per thousand population aged 20-29	2011 (1) (thousands)	Average annual growth rate 2005-2011 (2)	per thousand population aged 20-29
Belgium	103,1	4,8	74,5	16,4	3,5	11,8
Bulgaria	63,4	5,7	64,6	12,0	3,8	12,2
Czech Republic	104,7	12,0	74,5	22,2	10,5	15,8
Denmark	56,0	2,3	86,3	11,0	3,4	16,9
Germany	582,6	10,6	58,6	153,3	10,5	15,4
Estonia	11,6	-0,1	55,4	2,4	0,4	11,3
Ireland	57,8	-0,3	86,3	13,4	-3,3	20,0
Greece	63,6	1,4	47,1	17,5	2,0	12,9
Spain	373,2	4,8	64,9	92,3	3,3	16,1
France	616,1	-1,5	76,5	157,4	-2,4	19,5
Croatia	33,5	11,8	56,3	6,6	14,6	11,1
Italy	377,6	0,0	57,2	79,5	0,2	12,0
Cyprus	5,9	8,2	41,4	1,0	15,4	7,0
Latvia	24,6	-1,0	80,9	3,8	2,8	12,5
Lithuania	43,1	0,8	104,3	9,2	0,5	22,2
Luxembourg	1,4	:	20,9	0,2	:	2,7
Hungary	66,6	-1,4	50,2	10,9	6,1	8,2
Malta	3,4	3,7	56,9	0,4	10,3	6,2
Netherlands	135,1	4,5	66,3	17,7	1,9	8,7
Austria	61,4	12,2	56,8	16,4	10,1	15,1
Poland	645,0	4,5	105,4	107,1	7,6	17,5
Portugal	84,8	4,3	68,3	20,5	7,4	16,5
Romania	254,0	8,9	77,4	49,7	6,2	15,1
Slovenia	19,9	4,4	73,1	4,5	8,9	16,6
Slovakia	72,9	12,8	86,5	14,5	8,3	17,2
Finland	49,6	4,2	73,6	13,6	3,2	20,1
Sweden	66,0	3,1	54,3	17,3	3,4	14,2
United Kingdom	734,2	2,5	84,9	159,9	2,4	18,5
EU (3)	4705,5	3,8	72,8	1033,3	3,7	16,0
Iceland	4,1	7,0	86,4	0,6	7,6	13,1
Liechtenstein	0,2	11,5	55,4	0,1	-0,6	12,2
Norway	39,1	3,9	61,8	6,2	4,9	9,9
Switzerland	75,2	3,8	74,7	14,9	2,0	14,8
Macedonia (4)	11,1	12,1	34,0	2,4	11,1	7,3
Turkey	529,4	11,9	41,7	117,1	7,6	9,2
United States	3091,9	3,6	71,2	474,1	2,4	10,9
Japan	952,9	-1,5	70,1	190,8	-2,4	14,0

Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Eurostat, OECD
Notes: (1) FR: 2009; HR, IS: 2010.
(2) FR: 2005-2009; HR, IS: 2005-2010.
(3) EU: Croatia is not included.
(4) The Former Yugoslav Republic of Macedonia

The EU produces almost twice as many S&E doctoral degrees as the United States. But relative to the size of the population the number is similar and the growth dynamics is stronger in the US

Figure I.4.10 and the table in Figure I.4.11 provide a comparison between the EU, the United States and Japan for the number of doctoral degrees awarded in 2011 (tertiary graduates at level ISCED 6), as well as for the share of S&E doctoral degrees awarded. In 2011, around 117 000 doctoral degrees were awarded in the EU, compared with 73 000 in the US and 16 000 in Japan. Per 1 000 population aged 25–34 years, the EU had 1.7 new doctoral degrees and 0.6 new doctoral S&T degrees, compared to 1.7 new doctoral degrees and 0.6 new doctoral S&T degrees in the United States and only 1.0 new doctoral degrees and 0.4 new doctoral S&T degrees in Japan. Per 1 000 population, the EU hence performs at a similar level to the United States, but has had lower growth rates over the past six years. The EU outperforms Japan, which showed low growth rates in the past and for demographic reasons is expected to face a decline in the production of new doctoral degrees in the coming years.

Figure I.4.10 New doctoral graduates (ISCED 6) per thousand population aged 25-34



Source: DG Research and Innovation - Economic Analysis Unit — Innovation Union Competitiveness report 2013

Data: Eurostat, OECD

Notes: (1) EU: Croatia is not included.

(2) CN: Science and Engineering graduates per thousand population aged 25-34 was estimated from the number of ISCED6 graduates per thousand population aged 25-34.

Member States with a high R&D intensity are also those with the highest intensity of doctorate graduates in S&E

EU Member States with a high number of new doctorate-level graduates per 1 000 young people include Sweden, Germany, Finland, the United Kingdom, Austria and Denmark. With the exception of the United Kingdom, these are also the countries with the highest research intensity (R&D expenditure > 2.5 % of GDP) in the EU. The same pattern holds for doctorate graduates in S&E. Malta, Cyprus and Poland are countries with a relatively low number of ISCED 6 graduates per 1 000 people aged 25–34 years. On the other hand, the growth in the number of ISCED 6 graduates in the period 2005–2011 was the highest in Cyprus and Malta, countries with relatively new and small higher education systems. Science, engineering, technology and mathematics (STEM) graduates at ISCED 5 and 6 levels are in demand in many economic sectors. In some countries a considerable share of STEM graduates works outside STEM professions.

Figure I.4.11 Graduates from tertiary education (ISCED 6), 2011

	Total ISCED 6			Of which: Science and Engineering		
	2011 (1) (thousands)	Average annual growth rate 2005-2011 (2)	per thousand population aged 25-34	2011 (1) (thousands)	Average annual growth rate 2005-2011 (2)	per thousand population aged 25-34
Belgium	2,2	5,2	1,52	1,0	3,3	0,70
Bulgaria	0,6	3,2	0,62	0,2	5,4	0,23
Czech Republic	2,5	4,3	1,53	1,2	2,8	0,72
Denmark	1,5	7,9	2,30	0,6	7,7	0,97
Germany	27,4	0,9	2,79	10,8	3,0	1,10
Estonia	0,3	11,4	1,27	0,1	11,2	0,60
Ireland	1,4	10,2	1,91	0,7	7,6	0,94
Greece	1,7	5,1	1,05	0,7	-2,0	0,43
Spain	8,7	4,0	1,22	4,3	8,9	0,60
France	12,7	5,7	1,59	7,6	7,1	0,95
Croatia	0,8	16,8	1,35	0,3	14,1	0,52
Italy	11,3	2,7	1,50	4,8	1,4	0,63
Cyprus	0,0	43,1	0,31	0,0	29,3	0,20
Latvia	0,3	17,3	1,05	0,1	10,6	0,38
Lithuania	0,4	1,6	0,92	0,1	4,1	0,35
Luxembourg	0,1	:	0,79	0,0	:	0,30
Hungary	1,2	2,4	0,82	0,4	9,9	0,24
Malta	0,0	26,0	0,33	0,0	28,5	0,12
Netherlands	3,7	4,3	1,85	1,3	3,6	0,66
Austria	2,4	1,0	2,16	1,0	2,1	0,93
Poland	3,1	-9,9	0,49	1,7	-1,7	0,27
Portugal	2,3	-9,3	1,61	0,9	-5,8	0,66
Romania	5,6	6,4	1,66	2,7	30,6	0,80
Slovenia	0,5	6,0	1,72	0,2	3,0	0,70
Slovakia	1,7	8,6	1,86	0,6	7,1	0,70
Finland	1,9	-0,9	2,71	0,7	-1,5	1,05
Sweden	3,4	3,2	2,88	1,6	5,2	1,41
United Kingdom	20,1	4,1	2,44	8,7	3,0	1,05
EU (3)	116,7	2,4	1,72	50,5	3,6	0,75
Iceland	0,0	20,8	0,77	0,0	65,7	0,54
Liechtenstein	0,0	20,1	2,63	0,0	:	0,00
Norway	1,3	7,6	2,05	0,6	7,1	0,88
Switzerland	3,7	2,0	3,51	1,5	2,4	1,44
Macedonia (4)	0,2	13,5	0,61	0,0	4,4	0,10
Turkey	4,7	8,6	0,37	1,8	12,7	0,14
United States	73,0	5,6	1,75	24,8	4,7	0,59
Japan	15,9	0,7	1,04	5,7	-0,2	0,37
China (5)	50,3	:	0,25	27,6	:	0,14

Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Eurostat, OECD, China Statistical Yearbook 2012
Notes: (1) PL: 2009; FR, HR, IS: 2010.
(2) PL: 2005-2009; FR, HR, IS: 2005-2010; MT: 2006-2011.
(3) EU: Croatia is not included.
(4) The Former Yugoslav Republic of Macedonia.
(5) CN: Science and Engineering graduates per thousand population aged 25-34 was estimated from the number of ISCED6 graduates per thousand population aged 25-34.

The EU has invested in tools for the recognition and the transparency of skills and qualifications, which is an important pre-condition for an optimal allocation of resources within the internal market.[44] However, recent evaluations reveal that these tools fall short of setting up a genuine European area in which people with various skills and qualifications can move readily. Member States are slow in implementing these tools (9 Member States have not yet linked their national qualifications systems to the European Qualifications Framework), but sometimes the tools are not fit to address new developments. Moreover, obstacles to the recognition of qualifications still exist even within countries and sectors. In order to exploit the full potential of the internal market, these remaining obstacles need to be addressed.

Over half of the EU's workforce is employed in science and technology sectors. These jobs have grown faster than total employment and have been more resilient in times of crisis

The following section will look in more detail at the current stock of human resources in Europe. The table in Figure I.4.12 gives a general picture of the human resources in S&T in the EU (HRST). It provides data on HRST and its sub-groups, Scientists and Engineers and Researchers.

The EU's active population for 2011 (referring to the total labour force, which includes both employed and unemployed persons) was about 240 million, of which 218 million were employed and 22 million unemployed. HRST accounted for 112.4 million or 51.5 % of total employment. Those who have successfully completed tertiary-level education (HRSTE) accounted for 38.7 % of total employment, with Ireland, Cyprus and Luxembourg showing the highest shares, while those who have both completed a tertiary-level education and are currently employed in an S&T occupation (HRSTC) accounted for 20.4 % of total employment. This implies that about half of tertiary education graduates are employed in S&T occupations.

In the EU, the total R&D personnel amounted in 2011 to 3.7 million, or 1.7 % of total employment (2.6 million or 1.2 % in full time equivalents, FTE). Researchers were estimated to represent more than 2.2 million or 1.1 % of total employment in headcounts, while researchers in FTEs accounted for 1.6 million or 0.7 % of total employment.

[44] The tools include the European Qualifications Framework, the Europass, the Youthpass and several credit systems.

Figure I.4.12 EU - Human Resources in Science and Technology, R&D personnel and researchers, 2011

	Total (thousands) 2011 (1)	as % of total employment	Total growth (%) 2005-2011 (2)
Total employment	218477	100	3,0
HRST - Human Resources in Science and Technology	112395	51,4	8,8
HRSTE - Human Resources in Science and Technology - Education	84592	38,7	11,9
HRSTO - Human Resources in Science and Technology - Occupation	72384	33,1	8,6
HRSTC - Human Resources in Science and Technology - Core	44582	20,4	14,5
SE - Scientists and Engineers	15514	7,1	34,0
Total R&D personnel (Head Count)	3662	1,7	14,5
Total R&D personnel (FTE)	2588	1,2	17,5
Researchers (Head Count)	2333	1,1	15,4
Researchers (FTE)	1615	0,7	17,5

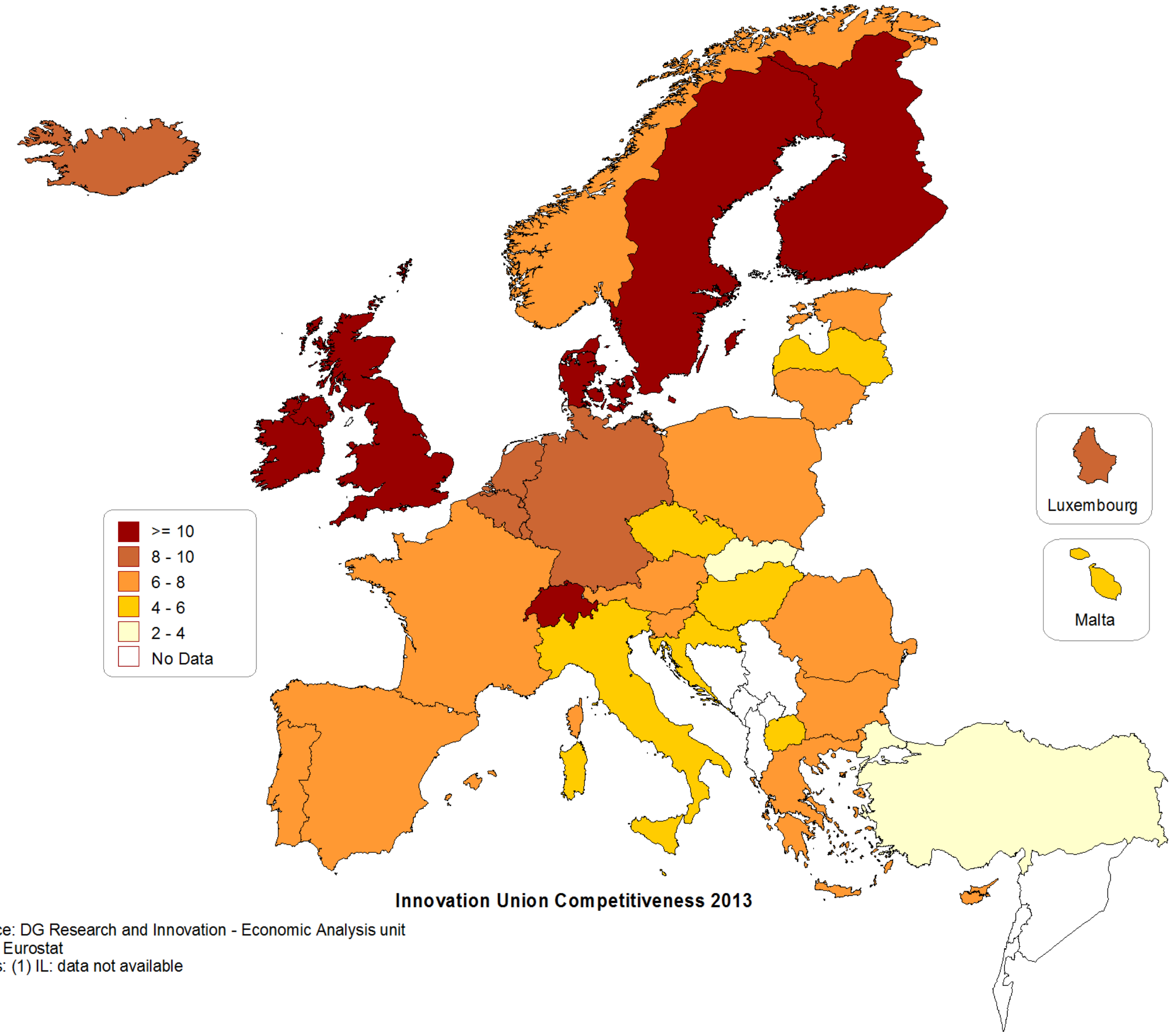
Source: DG Research and Innovation - Economic Analysis Unit   Innovation Union Competitiveness report 2013
Data: Eurostat
Notes: (1) Total R&D personnel (Head Count) and Researchers (Head Count) refer to 2009.
(2) HRST, HRSTE, HRSTO, HRSTC, SE: 2008-2011; Total R&D personnel (Head Count), Researchers (Head Count): 2005-2009.

Human resources in Science and Technology have grown faster than total employment in the past, and employment in this area has been more resilient in times of crisis. Whilst total employment decreased by 1.9 % between 2008 and 2011, HRST increased by 8.7 %, or 9 million, research personnel by 6.1 % and the number of researchers by 7.5 %. This reflects the rising educational attainment level among the labour force, as well as the shift to skilled staff and a knowledge-intensive economy.

Denmark, Finland, Sweden, the United Kingdom and Ireland are the EU Member States with the largest employment shares for scientists and engineers

In the EU, scientists and engineers accounted for 4.8 % of the active population and 5.2 % of total employment in 2012. Figure I.4.13 presents the share of scientists and engineers as a percentage of the active population in 2012. Sweden, Denmark, Finland, the United Kingdom and Ireland have the highest rates of scientists and engineers. Outside the EU, Switzerland and Iceland have high rates. These are all countries with knowledge-intensive economies (see Part III) and with a high R&D intensity, with the exception of the United Kingdom. Among the Candidate Countries, Turkey has the lowest share.

Figure I.4.13 Scientists and engineers (age group 25-64) as % of total employment, 2012



Source: DG Research and Innovation - Economic Analysis unit
Data: Eurostat
Notes: (1) IL: data not available

The number of researchers in the EU increased between 2005 and 2011 at an average annual growth rate of 2.4, or by more than 15 % in total. This falls roughly in line with the growth of R&D spending in absolute terms. In 2011, researchers (FTEs) represented 0.7 % of total employment in the EU, versus 0.65 % in 2005. The number of researchers in FTEs in the EU increased from 1.37 million in 2005 to 1.62 million in 2011. For the United States, data is only available for the period 2005–2007, showing an annual growth of 1.3 % to reach 1.41 million in 2007. In Japan, the number of researchers in FTEs stagnated at about 0.7 million (latest data for 2009), while in South Korea the number of researchers increased in the period 2005–2010 by 47 %. China has also experienced a rapid increase in the number of researchers in FTEs, from 1.1 million in 2005 to almost 1.6 million in 2008 ([45]). Growth in the EU was not homogeneous across sectors. The average annual growth rate for researchers in the period 2005–2011 in all sectors amounted to 2.7 %, in higher education it amounted to 3.3 %, in the private sector to 2.5 % and in government to just 1.7 %.

Figure I.4.14 EU - Researchers (FTE) by sector

Sector	Thousands			Sectoral shares (%) 2011	Average annual growth 2005-2011
	2005	2010	2011		
Business enterprise sector	626	714	727	45	2,5
Government sector	182	200	201	12,5	1,7
Higher education sector	552	665	668	41,4	3,3
Private non-profit	16	18	19	1,2	3,4
All sectors	1375	1597	1615	100	2,7

Source: DG Research and Innovation - Economic Analysis Unit
Data: Eurostat

Innovation Union Competitiveness report 2013

The share of researchers in the private sector in the EU has declined slightly, and today lags behind levels reached in the United States, Japan and China. Positive trends are, however, visible in several catching-up countries

The share of researchers employed in the private sector differs significantly within the EU and between the EU and other major economies. EU countries with a high share of business researchers (over 60 %) include Denmark, Malta, Austria and Sweden, while the share is very low (below 20 %) in Bulgaria, Croatia, Latvia, Lithuania, Poland and Slovakia. In the EU, less than half of researchers (45 %) are employed in the private sector. This share is significantly higher in the United States (79 %, data for 2007), South Korea (77 %, 2010), Japan (68 %, 2009) and China (61 %, 2009).

In terms of growth, the number of researchers employed in the business enterprise sector increased on average by 2.5 % per year between 2005 and 2011 in the EU, against 1.5 % in the United States (2005–2007), 0.5 % (2005–2009) in Japan and over 16 % in China. In the period 2005–2011, EU countries showed strong differences with respect to the growth of researchers in the business enterprise sector, with Estonia, Croatia, Hungary, Lithuania, Malta, Portugal and Slovenia showing more than 50 % total growth, although mostly from a low level. Luxembourg, Romania, Sweden and the United Kingdom show a worrying decline in the number of business enterprise researchers (Romania from an already low level).

[45] For graphs benchmarking the EU with other major research-intensive countries in the world, see also the first section of the report 'Overall picture', and Chapter I.3 for the corresponding trends in business R&D investments.

Figure I.4.15 Researchers (FTE) - Total and business enterprise, 2011

	Total reserchers (FTE)			Business enterprise researchers (FTE)			
	2011 (1) (thousands)	Average annual growth rate 2005-2011 (2)	as % of total employment (3)	2011 (1) (thousands)	Average annual growth rate 2005-2011 (4)	as % of total employment (3)	as % of total researchers (FTE)
Belgium	40,5	3,4	0,9	18,6	1,8	0,4	46,0
Bulgaria	11,9	2,9	0,4	1,5	5,0	0,1	13,0
Czech Republic	30,7	4,1	0,6	14,0	5,5	0,3	45,5
Denmark	37,5	5,6	1,4	23,1	4,8	0,9	61,6
Germany	338,3	3,7	0,9	191,0	2,3	0,5	56,5
Estonia	4,4	4,9	0,7	1,4	8,4	0,2	32,2
Ireland	15,5	4,9	0,8	8,9	4,8	0,5	57,9
Greece	21,0	3,6	0,5	6,3	2,1	0,1	29,9
Spain	130,2	2,9	0,7	44,9	4,2	0,3	34,5
France	239,6	3,7	0,9	139,9	5,4	0,5	58,4
Croatia	6,8	3,0	0,5	1,2	9,7	0,1	18,0
Italy	106,8	4,4	0,5	41,3	6,7	0,2	38,6
Cyprus	0,9	4,8	0,2	0,2	6,1	0,1	20,4
Latvia	3,9	3,1	0,5	0,6	2,8	0,1	14,0
Lithuania	8,4	1,6	0,7	1,4	11,4	0,1	16,3
Luxembourg	2,6	2,8	1,2	1,5	-2,5	0,7	55,4
Hungary	23,0	6,4	0,6	11,8	15,3	0,3	51,1
Malta	0,8	7,9	0,5	0,5	13,0	0,3	65,2
Netherlands	53,6	2,3	0,6	26,1	3,0	0,3	48,7
Austria	37,1	4,5	0,9	23,1	4,1	0,6	62,3
Poland	64,1	0,5	0,4	10,6	1,9	0,1	16,5
Portugal	47,3	5,4	1,0	10,6	17,5	0,2	22,4
Romania	16,1	-5,8	0,2	3,5	-10,7	0,0	21,9
Slovenia	8,8	4,7	0,9	4,5	5,3	0,5	51,4
Slovakia	15,3	5,8	0,7	2,1	0,9	0,1	13,4
Finland	40,0	0,9	1,6	22,9	0,7	0,9	57,4
Sweden	49,1	2,6	1,1	29,6	0,7	0,6	60,4
United Kingdom	262,3	0,9	0,9	85,9	-1,4	0,3	32,8
EU	1615,4	2,7	0,7	726,9	2,5	0,3	45,0
Iceland	2,9	7,3	1,7	1,1	2,7	0,7	39,4
Norway	27,2	4,2	1,1	12,9	3,9	0,5	47,2
Switzerland	25,1	-0,3	0,6	10,3	-4,9	0,2	41,1
Macedonia (5)	0,9	-5,3	0,1	0,1	-4,5	0,0	9,0
Turkey	72,1	10,7	0,3	30,4	21,5	0,1	42,2
United States	1412,6	1,3	1,0	1130,5	1,5	0,8	80,0
Japan	656,7	0,0	1,0	490,9	0,3	0,8	74,8
China	1318,1	7,0	0,2	818,8	7,6	0,1	62,1

Source: DG Research and Innovation - Economic Analysis Unit   Innovation Union Competitiveness report 2013

Data: Eurostat, OECD

Notes: (1) EL, US: 2007; CH: 2008; IS, MK: 2009; FR: 2010.

(2) CH: 2004-2008; EL, US: 2005-2007; FR, IS, MK: 2005-2009; FI, NL: 2005-2010; SE: 2007-2010; DK: 2007-2011; SI: 2008-2010; PT, JP: 2008-2011; CN: 2009-2011.

(3) EL, US, CN: 2007; CH: 2008; IS, MK, JP: 2009; FR: 2010.

(4) CH: 2004-2008; EL, US: 2005-2007; IS, MK: 2005-2009; NL, RO: 2005-2010; FR: 2006-2010; DK, SE: 2007-2011; SI: 2008-2010; CN: 2009-2011.

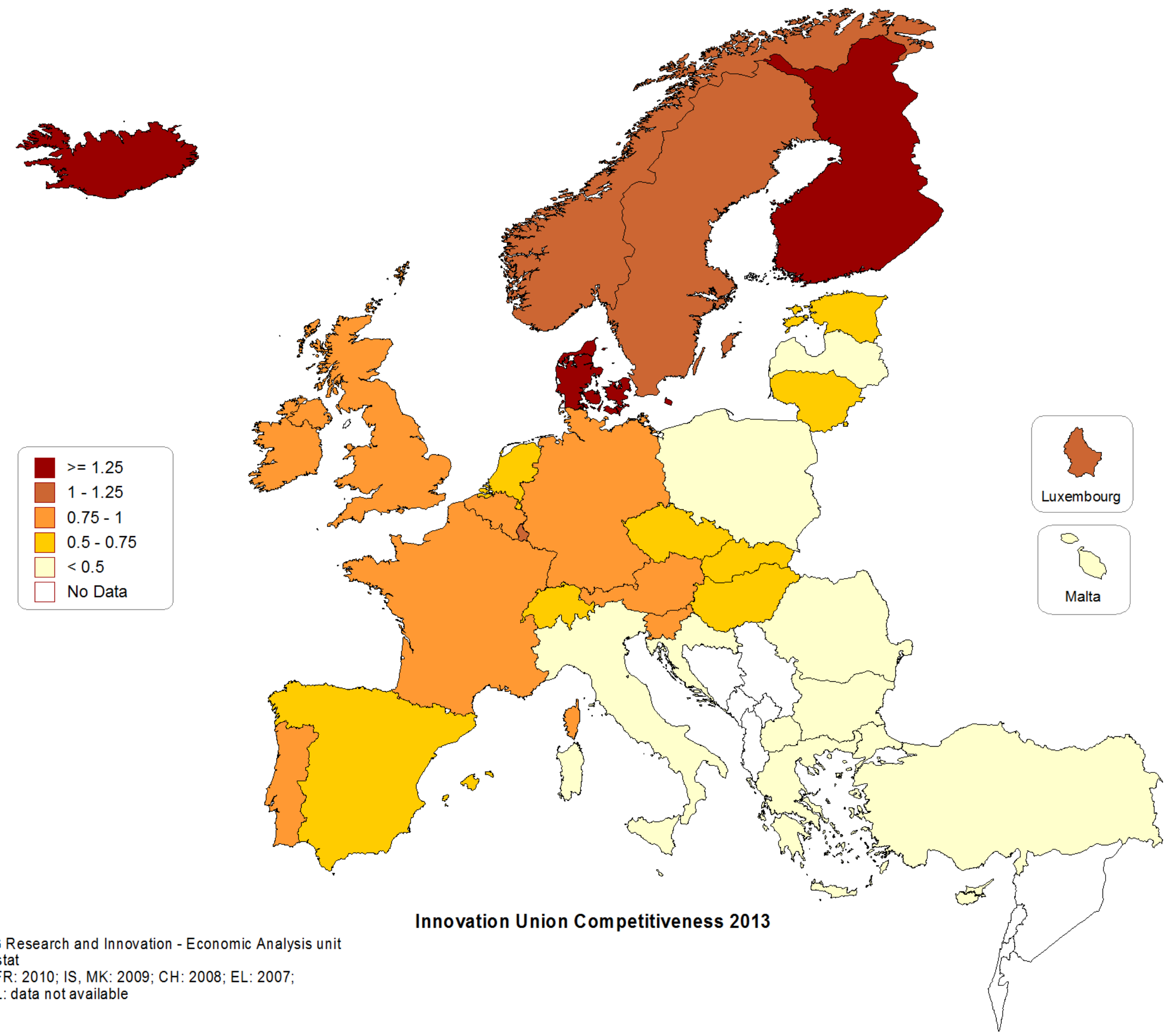
(5) The Former Yugoslav Republic of Macedonia.

The share of researchers in the labour force in 2011, among EU countries, was highest in Finland and Denmark, and lowest in Cyprus and Romania

Figure I.4.16 illustrates researchers as a percentage of total employment. In the EU, Finland has the highest penetration of researchers in the labour force (1.6 % being researchers). Other Nordic countries (Iceland, Denmark, Norway and Sweden) also count over 1 % of employees as researchers, together with Luxembourg. In contrast, Romania and Cyprus have the lowest shares, with only 0.2 % of employees being researchers. The EU average amounts to 0.7%, below the levels of the United States (1.0), Japan (1.0) and South Korea (1.1), but clearly above the Chinese level (0.2).

When it comes to business enterprise researchers, Finland and Denmark show the highest penetration, followed by Luxembourg. Romania has the lowest level.

Figure I.4.16 Researchers (FTE) as % of total employment, 2011



Source: DG Research and Innovation - Economic Analysis unit
Data: Eurostat
Notes: (1) FR: 2010; IS, MK: 2009; CH: 2008; EL: 2007;
IL: data not available

5. Matching education profiles and skills to the knowledge economy's demands

Highlights

The knowledge economy requires new skills and training profiles

A persistent challenge for education and training systems is to keep up with the economy's accelerating structural change and to match education outputs with rapidly evolving labour market needs. The economy is becoming more knowledge intensive, digital, international, service oriented and greener. These medium-term trends call for education and training systems that provide everybody with good basic skills, key transversal skills and lifelong learning capabilities that also create extensive expertise.

The skills profiles in demand include, in addition to a good level of key foundation skills like literacy and numeracy, entrepreneurial skills, digital skills, language skills and problem-solving skills. At the same time, solid domain-specific expertise is considered an important condition for innovation, especially if combined with inter- and trans-disciplinary capabilities. In light of high youth unemployment rates, efforts are being made to increase the employability of graduates. Reforms are being carried out in many Member States to increase the labour market orientation of education and training, e.g. by enhanced university–business collaboration and stronger involvement of enterprises in VET systems.

Demand for science, technology, engineering and mathematics skills is still increasing. The European economy may face a skills gap of STEM graduates

The demand for science, technology, engineering and mathematics (STEM) professionals is forecast to grow significantly until 2020 (+ 14 %), but demand for associate STEM professionals will also grow robustly. Within STEM-related sectors, demand for labour in the fields of professional services, computing and mechanical engineering will grow most quickly.

The increasing demand caused by structural changes to a knowledge-based economy, combined with demographic development, with fewer people entering the labour market, a saturation in tertiary participation rates and more people retiring (baby boomer generation), implies that a gap in the supply of graduates with knowledge in STEM is likely in the medium term.

Lifelong learning and mobility are important factors to balance supply and demand

Lifelong learning and mobility across Europe are important for upgrading and enhancing skills, and for balancing supply and demand for skilled labour, given the on-going structural changes to the economy and the fact that some Member States and regions are experiencing a shortage in human resources for science and technology, while others have a surplus.

Introduction

As shown in Chapter I.4, Europe has made progress in the last decade in improving educational attainment rates, in particular as regards tertiary education, and skills levels among the population in terms of formal educational attainment. While there was progress on an aggregated level of skills supply, the question however remains whether concrete education and skills profiles match the demand of the knowledge economy in more specific terms, notably in the field of higher education and for certain fields of study. Despite the progress achieved, challenges and inherent problems remain in matching supply and demand, and in addressing the risk of skills depreciation, caused by, amongst other factors, high youth unemployment rates.

One challenge is rapid scientific progress and technological change, which are often accompanied by a change in economic structures and job profiles. Even if education and training systems react swiftly to new needs, the decline in the half-life of knowledge, together with the time it takes for a learner to pass through the educational system, could mean that parts of prior learning are already obsolete by the time someone graduates. This implies that lifelong learning and good foundation skills, like reading and mathematics, which are important for later learning and indeed learning to learn, are growing in importance.

The constant change in labour market needs, inherent time lags between the formal education process and the labour market availability of graduates only reinforces the need to anticipate skills needs. As the average number of years spent in schooling increases, along with time spent in the labour market, time lags are getting wider, making anticipation even more urgent. Since it takes decades to replace an entire labour force, it is particularly important that new graduates satisfy new labour market needs. They should at the same time be equipped with broader foundation skills critical to lifelong learning, labour market mobility and employability over time. However, the anticipation of new skills will only having a real impact if education and training systems adapt and provide the skills needed, and if learners receive information and guidance so that they can make informed decisions on education pathways and fields of study ([46]).

5.1. Dynamics enhancing a better match between supply and demand

Today's economy and labour market are characterised by an overlay of ongoing medium- to long-term trends and short-term developments. Medium- to long-term trends include:

- *growing knowledge intensity within economic activities;*
- *growing importance of Information and Communication Technologies;*
- *servitisation/tertiarisation of the economy (relative growth of the service sector);*

[46] It should be noted that frequent changes in curricula and in the labelling of programmes may negatively impact on transparency in education supply for both students and employers. A good balance between a core curriculum and new elements is necessary.

- *internationalisation of the economy;*
- *internationalisation of labour markets and growth of labour mobility;*
- *greening of the economy.*

Short-term developments include a growing policy focus on the manufacturing sector as a source of employment and solid economic growth. There are also new developments as regards key enabling technologies and new manufacturing processes, such as 3D printing, with potential huge long-term impact. While it is a challenge for education and training systems to address short-term needs, the provision of skills should at least match the economy's medium- and long-term needs. Against the background outlined above, a number of key factors contribute to a better match between skills supply and labour market needs.

- ***Persistence of general skills premium implies need to further up-skill people***

The knowledge intensity involved in economic output is rising. Within the EU, there are today 75 million jobs in knowledge-intensive activities (KIAs) (about one third of all employment), and this is also where employment growth takes place. Data still show a skills premium in terms of higher wages and high returns to additional education when it comes tothe labour market: in 2012, while the overall unemployment rate in the EU amounted to 10.6 % according to Eurostat data, the unemployment rate for people with low levels of education (lower secondary and less) was higher, at 18.6 %. This was three times the unemployment rate for people with a tertiary degree (university or equivalent) and hence a high level of education (6.2 %) and skills. And as regards this aspect the returns to education are even increasing: while in 2007 the unemployment rate for people with high levels of education was 7 percentage points lower than for those with low levels of education, by 2012 it was already more than 12 percentage points lower.

- ***Stronger links between labour market and education curricula***

Action is needed to address the inherent time lag between education and training content, and labour market needs. This could be achieved through closer links between the labour market, notably the business economy, and the world of education, perhaps via traineeships, cooperation in curricula development and the exchange of teachers and trainers. This could help make education and training more labour market-relevant and increase the employability of graduates. Labour market-oriented Vocational education and training (VET) systems, like the dual systems in Germany and Austria, lead to good labour market absorption of graduates, as evidenced by low youth unemployment rates in these countries. While the economy increasingly needs people with tertiary attainment, it is also important to have the right balance between VET and general education, both at a secondary and on a tertiary education level, to ensure the uptake and diffusion of technologies through value chains.

- A premium for labour market experience

There is a premium for graduate labour market experience, and the earlier this experience is acquired, the better. Traineeships during education and training would not only give learners labour market experience and opportunities to acquire the soft skills increasingly in demand; they would also bring graduates into contact with potential future employers. Such contacts can help reduce the transition time from education to work.

- Demand for key skills for a knowledge-based economy

- *Continuing importance of good levels of basic skills*
  A good level in foundation skills such as reading and writing is important for all professions and, during the later stages of a career, for lifelong learning. Good maths and science skills are of key importance for employability and later learning, and also have an important impact on the uptake of STEM studies. International student achievement tests like the OECD PISA study or the IEA TIMSS and PIRLS ([47]) studies reveal strong differences between countries and thus considerable potential for further improvement in countries performing below average. The results of the PIAAC study[48] furthermore show considerable differences between countries in skills levels of the adult population.

- *Growing importance of digital skills*
  As ICT is increasingly in everything and everywhere, digital skills are of growing importance in the labour market. While everybody needs to be equipped with basic ICT skills, the demand for workers with advanced information technology (IT) skills continues to grow.

  Technological developments in the field of ICT have furthermore prepared the ground for a paradigm shift in learning: people are able to learn anywhere, anytime, through any device, at their personal speed. Such new opportunities offer significant potential for improving educational outcomes at lower costs. However, education and training systems in Europe are slow to respond and often fail to provide the necessary digital skills to young people: 20% of secondary students have never used a computer in school, and 60% of nine-year old pupils are not digitally equipped. A lack of action as regards tackling this digital challenge adds to Europe's unmet investment needs and increases the risk of a digital divide.

[47] PISA, the Programme for International Student Assessment, is a three-yearly study administrated by the OECD assessing 15-year–olds' competencies in reading, mathematics and science. TIMSS, Trends in International Mathematics and Science Study, is conducted by the IEA every four years and looks at mathematics and science achievements of pupils in grades 4 and 8. PIRLS, the Progress in International Reading Literacy Study, is conducted by the IEA every five years and looks at student achievements in reading after four years of schooling.

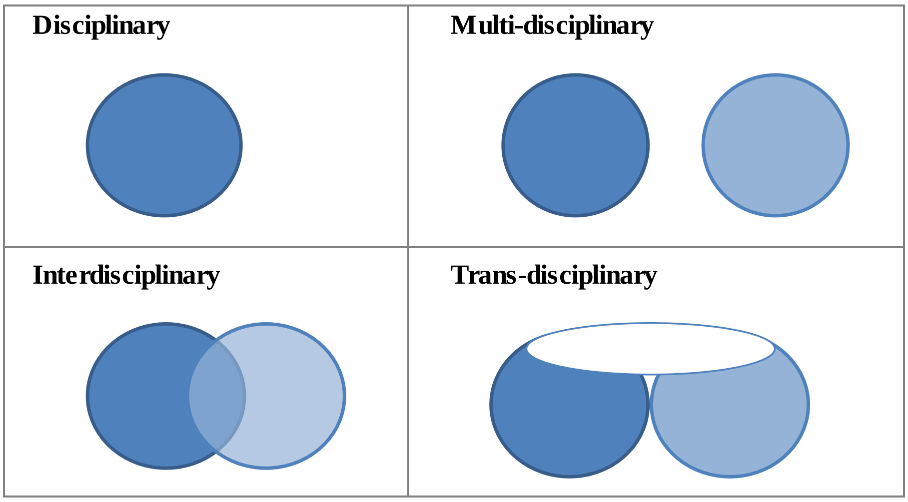
[48] Programme for International Assessment of Adult Competences, first results were released in October 2013.

- *Entrepreneurship skills*
  Entrepreneurship education may have a positive impact on motivation for business start-up, on developing competences conducive to innovation, and on employability — aspects that are important in times of economic uncertainty and high unemployment.
- *Language skills*
  In an increasingly international society and global economy the importance of language skills is increasing. Mastering English is almost considered a basic skill today, while additional languages are an important asset within the labour market ([49]).
- *Importance of learning to learn and lifelong learning*
  Given a rapidly changing labour market and a decreasing half-life of knowledge, it is of growing importance to constantly update what has been learned. Learning to learn skills, in addition to a good level of foundation skills, is vital.

-Transform trans-disciplinarity into an emerging asset

The skills requirements for tertiary graduates in S&T are currently changing beyond deep disciplinary skills and specific key competences. Increasingly, the workforce will be expected to work in environments requiring collaboration across multiple fields and disciplines, and to interact and work with people outside academia to identify innovation opportunities and bring opportunities to the market more quickly and more efficiently. Professionals who can correlate material from diverse knowledge bases and extract tangible results — whether for new business initiatives or global issues such as resource scarcity or health — are seen as future-critical R&D and innovation resources.

Figure I.5.1: Graphic comparison of different approaches



[49] According to the Eurostat Adult Education Survey 2011, 66 % of the population aged 25–64 years state they know at least one foreign language, ranging from 99 % in Luxembourg to 37 % in Hungary.

Trans-disciplinarity refers to knowledge and skills that transcend and unify different disciplines. It is driven by the views that complex, ill-defined real-world challenges call for multiple perspectives to generate new knowledge that can lead to innovations in the way particular challenges are dealt with. Another defining characteristic of trans-disciplinarity is the inclusion of stakeholders in defining research objectives and strategies in order to better incorporate the diffusion of innovation as an outcome of research. Trans-disciplinarity therefore requires an integration of problem framing, problem solving, communication and collaboration that cuts across discipline and organisation boundaries.

However, these skills are not easily acquired in traditional modes of instruction or classical lab work. These emerging skills requirements question the value and continued relevance of traditional higher education systems, and how teaching and learning processes are organised — particularly as opportunities to acquire knowledge and skills in self-paced instruction-based modes, free of charge, are soaring through a growing number of MOOCs ([50]).

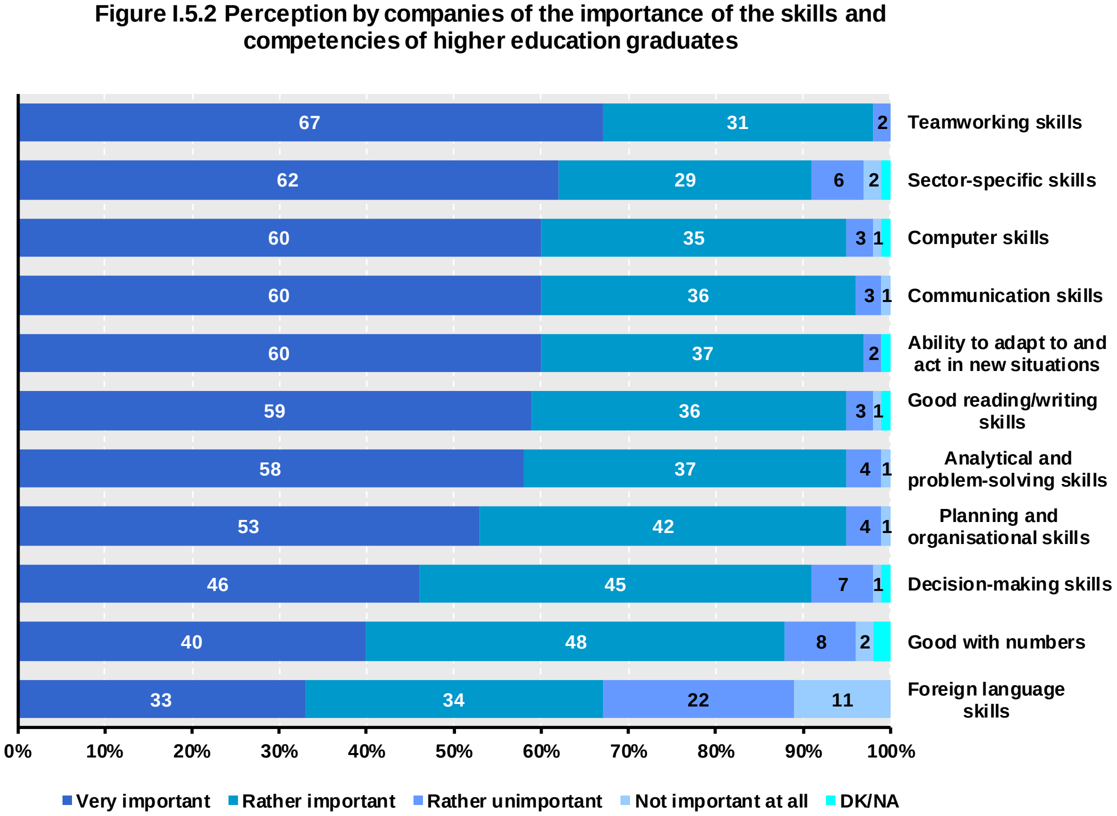
5.2. Findings from recent studies on labour market demand for skills

Employers stress the need for skills in team working, problem solving, reading and writing, and computer literacy

The European Commission Flash Eurobarometer survey 304 from 2010 (EC, 2010) 'Employers' perceptions of graduate employability' gives some indication of employers' and recruiters' views of changing work practices and the implications of these changes on skills demands. The survey data show that each of the 11 skills areas listed were considered by more than two thirds of recruiters as being very important or rather important. Respondents in particular highlighted 'team working' as very important when recruiting new graduates (67 %). Other competences, skills and abilities rated as ‘very important’ by a majority of respondents — around 60 % — were: problem solving, first class ability in reading and writing, computer literacy, communication, and being able to adapt to and act in new situations.

[50] Massive open on-line courses.

Figure I.5.2: Perception of importance of skills and competences of higher education graduates- (Result of the Flash Eurobarometer Survey 304)



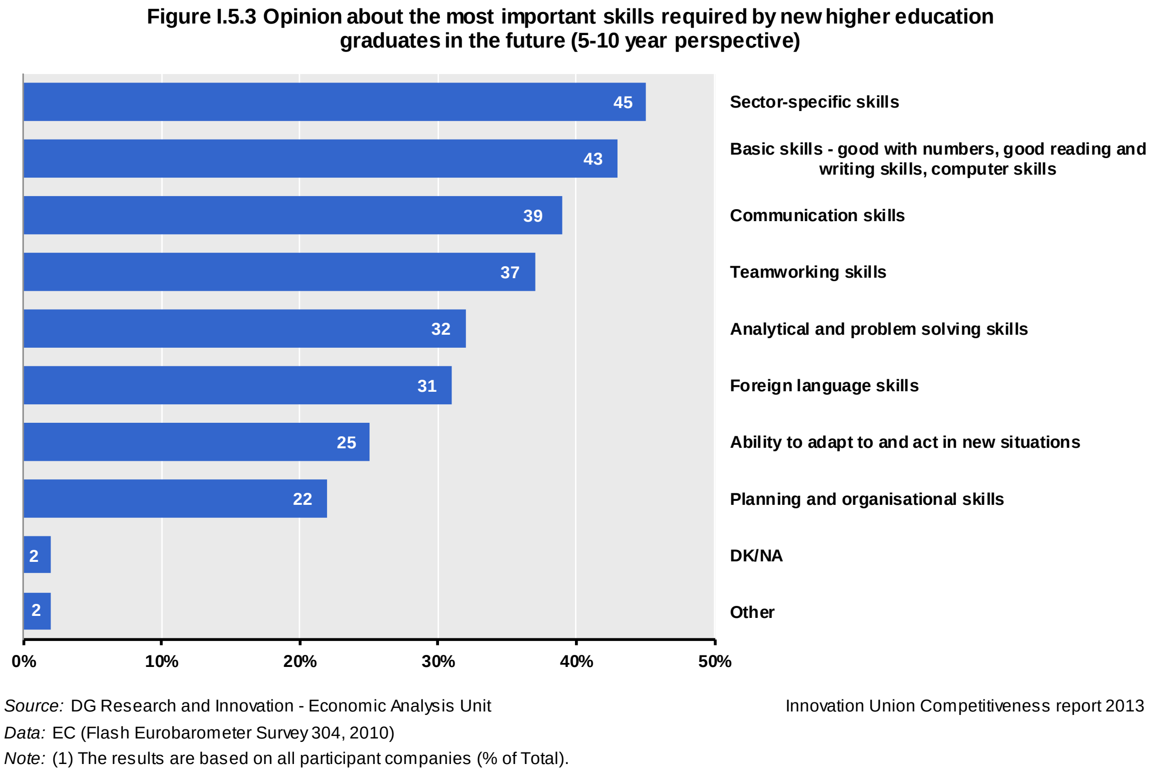
Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: EC (Flash Eurobarometer Survey 304, 2010)
Note: (1) The results are based on all participant companies (% of Total).

Language skills are rated even more important for the coming years (in a 5 to 10-year perspective). The importance of language skills is also rated rather high in small, internationally oriented countries like Luxembourg and Cyprus, but considered of lower importance in English-speaking countries ([51]).

In view of the upcoming 5 to 10-years, teamworking skills are rated somewhat less important in comparison to current recruitments, while sector-specific skills, analytical and problem-solving skills rise in importance.

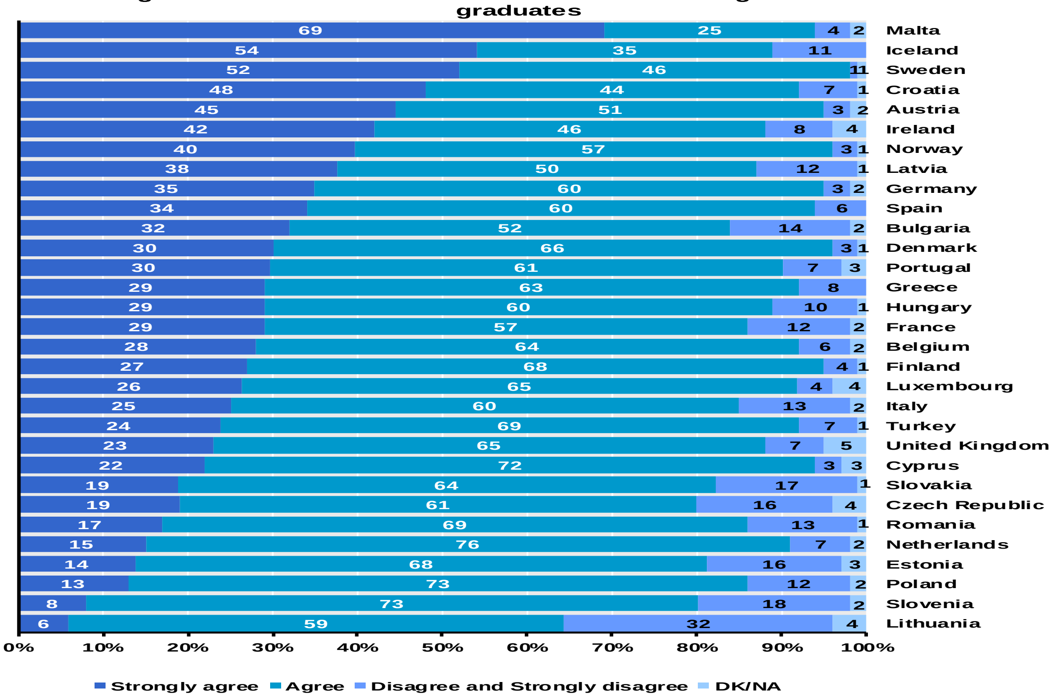
[51] The Eurostat Adult Education Survey is a source for data on adult language skills. According to this survey, the share of population stating they know at least one foreign language was highest (over 90 %) in Luxembourg, Lithuania, Latvia, Slovenia and Sweden, while it was lowest (below 40 %) in Bulgaria and Hungary. No data were available for the United Kingdom or Ireland.

Figure I.5.3: Opinion about the skills higher education graduates should have in the future-(5-10 year perspective) (Source: Flash Eurobarometer Survey 304)



Respondents to the Flash Eurobarometer survey 304 were also asked about their overall satisfaction with graduates recruited in the past three to five years. The responses indicate a relatively high level of satisfaction, which could be seen as surprising given the urgency in the debate about higher education systems not delivering candidates with the right profiles. The figures should be read with caution, though, as the survey did not address the surveyed firms' skills demands within the wider context of competitiveness strategies and the relative importance of highly specialised human capital. It is known from other studies that all these factors impact the strategic importance of a firm's advanced skills base and how employees are recruited, organised and developed.

Figure I.5.4 Satisfaction with the overall skills of higher education graduates

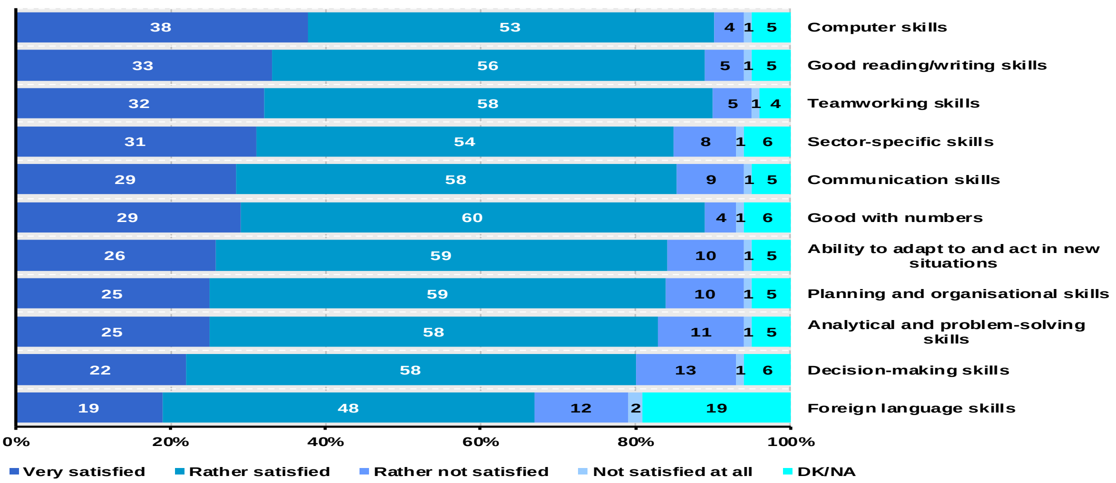


Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: EC (Flash Eurobarometer Survey 304, 2010)
Note: (1) The results are based only on companies that have recruited higher education graduates (% by country).

Recruiters were relatively satisfied with computer skills, reading/writing skills and teamworking skills, but relatively less (although in the majority still satisifed) as regards decision-making skills and foreign language skills.

Figure I.5.5: Satisfaction with higher education graduates' specific skills
(Source: Flash Eurobarometer Survey 304)

Figure I.5.5 Satisfaction with the specific skills of higher education graduates



Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: EC (Flash Eurobarometer Survey 304, 2010)
Note: (1) The results are based only on companies that have recruited higher education graduates (% of Total).

The supply of employees with STEM skills is projected to be insufficient

According to the European Skills Panorama, STEM (Science, Technology, Engineering, Mathematics) professionals and associate professionals accounted each for 3.7 % (together 7.4 %) of employment across the EU in 2010. In the medium term, the supply of STEM () skills has been projected as insufficient in the EU due to:

- declining numbers of graduates in the future;
- continuing insufficient achievement in science in schools across the EU;
- ageing of STEM professionals and the HRST workforce.

Furthermore only a few EU countries are among the top destinations in global mobility patterns of STEM professionals, while the ongoing economic crisis in many Member States might imply a risk of increasing outwards migration of STEM professionals.

The demand for STEM professionals and STEM associate professionals is projected to grow by 14 % and 7 %, respectively between 2010 and 2020, whereas the demand for other professions is expected to grow by only 3 % in the EU. Even the structural shift to a service economy will not reduce the need for STEM-skilled professionals. Data from the United Kingdom show that one of the challenges to meeting future demands for STEM skills is that graduates and PhDs with advanced STEM skills are also attractive employees in a broad range of industries — particularly due to their problem-solving, hypothesis testing, data analysis and advanced numerical skills ([52]). Previously, the financial services have been an important career option for graduates with a STEM qualification. The financial crisis may well have changed these patterns, at least for a while.

Figure I.5.6 Projected demand in the EU (1) for STEM (2) skills, 2020

	Total		% change 2010-2020	Expansion demand 2020	Replacement demand 2020	Total requirement 2020
	2010 (thousands)	2020 (thousands)				
STEM (2) professionals	8290	9472	14,3	1183	2364	3546
STEM (2) associate professionals	8333	8877	6,5	543	2253	2797
All occupations	223219	230847	3,4	7627	4617	12244

Source: DG Research and Innovation - Economic Analysis Unit   Innovation Union Competitiveness report 2013
Data: Cedefop, EU Skills Panorama
Note: (1) EU: Croatia is not included.
(2) For the purposes of Figure I.5.6 STEM refers to physical, mathematical and engineering science professuionals.

[52] UKCES, 2011.

Demand for STEM graduates is expected to be highest in computing and professional services

The penetration of ICT and advanced automation and robotics across a range of industries depends upon STEM skills to fully exploit the innovation potential of these technologies. The developments and opportunities stemming from 'big data', also in sectors such as education, health and care services, as well as retail business, also depend upon STEM skills — as can be seen in the growth of job openings for STEM skills graduates in the field of data analysis. There is a need for VET systems to more systemically embed STEM skills in VET programmes as a feature of VET excellence. This will avoid the risk of unmet demand at the technician level, as well as structural skills mismatches. As Figure I.5.7 shows, the largest anticipated growth in the demand for STEM skills within the EU is in computing (ICT) and professional services.

Figure I.5.7 Anticipated future employment demand in key STEM-related sectors in the EU [(1)], 2020

	2010 (thousands)	2020 (thousands)	% change 2010-2020
Pharmaceuticals	494	493	0,0
Chemicals not specified elsewhere	1168	1169	0,1
Non-metallic mineral products	1618	1549	-4,3
Mechanical Engineering	3453	3644	5,5
Electronics	967	980	1,3
Electrical Engineering and Instruments	2750	2780	1,1
Motor Vehicles	2208	2164	-2,0
Manufacturing not specified elsewhere	2204	2206	0,1
Communications	3011	3156	4,8
Professional services	7530	8578	13,9
Computing	3040	3270	7,6
All industries	223219	230847	3,4

Innovation Union Competitiveness report 2013

Source: DG Research and Innovation - Economic Analysis Unit

Data: Cedefop, EU Skills Panorama

Note: (1) EU: Croatia is not included.

Cedefop's June 2013 forecaset for future skills demands extends the horizon to 2025 ([53]). Its baseline scenario forecasts employment in the EU-27 plus Switzerland and Norway reaching 243 million, an increase of almost 10 million from 2012. Technicians, associate professionals and professionals will experience the highest employment growth in absolute terms, while there will be a decrease in employment for clerks, skilled agricultural and fishery workers, craft and related trades workers, and plant and machine operators and assemblers.

The employment shares of highly skilled workers will increase from 40.5 % to 44.1 %. The share of highly skilled people in the labour force will grow even faster, from 31 % in 2012 to 39 % in 2025. Interestingly, the employment share of those with only elementary skills will

[53] See http://www.cedefop.europa.eu/EN/Files/9081_en.pdf.

also increase, while the share of low-skilled labour forces will strongly decrease. Job opportunities for low-skilled people might hence improve.

Figure I.5.8 Anticipated future distribution of skills and qualifications in EU+ (1), 2025

	2010 / 2012 (2) %	2025 %
Distribution of employment by skill level		
Elementary	10,2	11,2
Skilled manual	24,8	22,1
Skilled non-manual	24,5	22,6
Highly skilled	40,5	44,1
Total	100	100
Distribution of labour force by level of qualification (3)		
Low (ISCED <3)	22,0	14,0
Medium (ISCED 3-4)	47,0	47,0
High (ISCED 5-6)	31,0	39,0
Total	100	100

Innovation Union Competitiveness report 2013

Source: DG Research and Innovation - Economic Analysis Unit

Data: Cedefop

Notes: (1) EU+ includes Norway and Switzerland and does not include Croatia.
(2) Employment refers to 2010; Labour Force refers to 2012.
(3) By highest level of attainment.

Highly skilled employees are of great importance for high-growth innovative enterprises

A study on high-growth innovative enterprises (HGIEs) ([54]), carried out for the European Commission by Empirica, showed the importance of highly skilled employees for enterprise growth. Of the HGIEs interviewed, 77 % stated that company growth was partly explained by the presence of particular, high-skilled employees, while 9 % of HGIEs stated that difficulties in finding skilled employees was a barrier to their growth.

The growth in the supply of graduates is highest in health, business administration and science and engineering

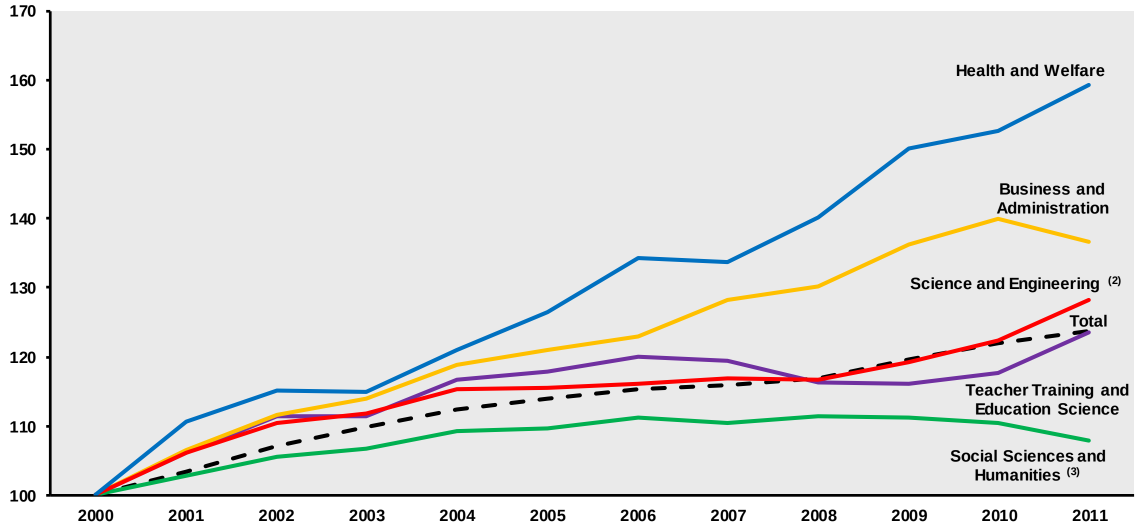
Eurostat data show that the number of tertiary science and engineering (S&E) students is progressing broadly at the same rate as the total number of students. Tertiary student population growth started to decelerate after 2005 as a result of demographic development (smaller cohorts) and because participation rates were approaching saturation levels in some Member States. But growth has picked up again since the start of the economic crisis. The growth in the S&E student population has also accelerated since 2008. The fastest growing field is, however, health and welfare. The field with the slowest growth in the same period was social sciences and humanities (without business and administration). Business and administration showed strong growth until 2010, but decline in 2011.

[54] This study is presented in section III, Chapter 1. High-growth innovative enterprises were particularly found in the business sectors 620 Computer programming; 702 Management consulting, and 711 Architectural and engineering activities.

Countries with strong growth in the number of tertiary S&E students include Germany, Estonia, Cyprus, Malta, Hungary, Austria and Romania. Poland only showed high growth in science. After high growth until about 2006, growth rates slowed down in many eastern European countries, including Romania and Poland, for demographic reasons.

The Nordic countries, which have the highest research intensity in Europe, have only increased their S&E student population slightly in the last decade. However, they still have relatively high numbers of S&E students per million inhabitants.

Figure I.5.9 Tertiary students (ISCED 5 and 6) in the EU (1) by field of education - index 2000 = 100, 2000-2011



Source: DG Research and Innovation - Economic Analysis Unit   Innovation Union Competitiveness report 2013

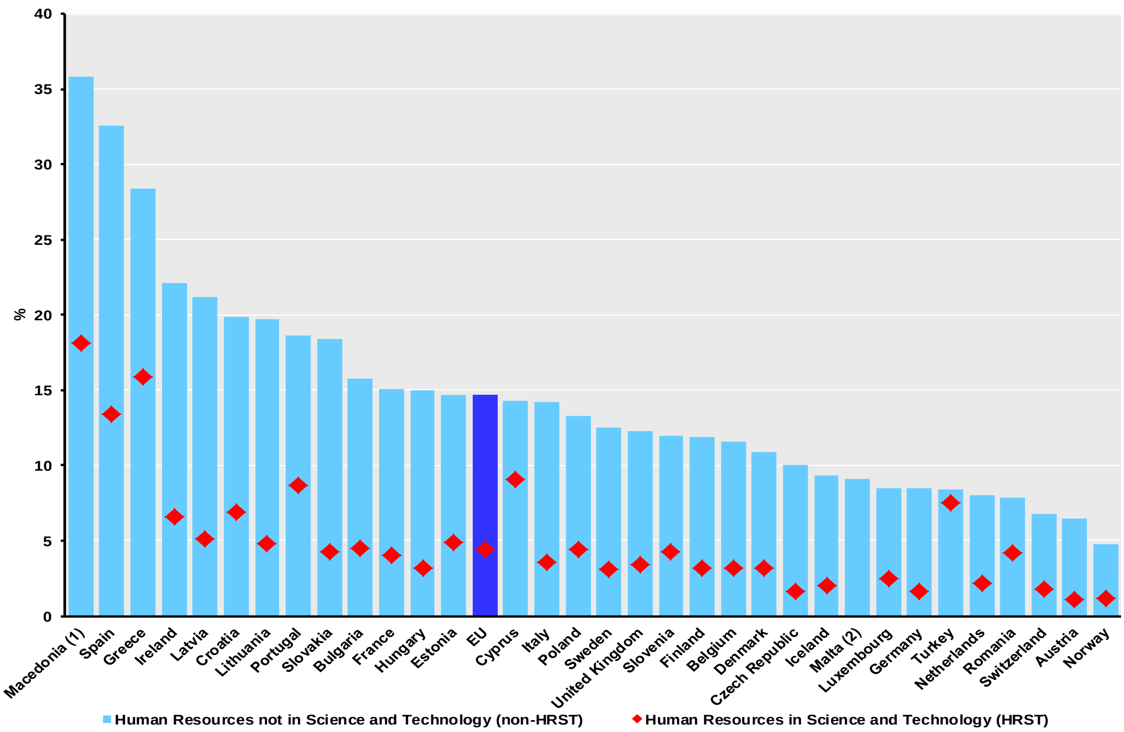
Data: Eurostat

Note: (1) Based on the available data and including estimated values for some Member States.

While some Member States experience a shortage of human resources for S&T, other countries have a surplus

A shortage of Human Resources for Science and Technology (HRST) is sometimes considered a sign of an innovative, fast-growing economy. Since there is always frictional unemployment linked to enterprises being closed or people changing jobs, unemployment rates of below 5 % can be considered a sign of full employment and of a shortage of human resources. Eurostat Labour Force Survey (LFS) data show that the unemployment rate of HRST is much lower (EU: 4.0 % in 2011) than that of the rest of the labour force (13.4 %). In 20 EU countries the unemployment rate for HRST is below 5 %. EU countries with particularly low HRST unemployment rates, and hence a shortage of HRST, include the Czech Republic, Germany, the Netherlands and Austria. EU countries with high HRST unemployment rates and hence no apparent shortage of HRST include Greece and Spain.

Figure I.5.10 Unemployment rates for Human Resources in Science and Technology (HRST) and for Human Resources not in Science and Technology (non-HRST), 2012



Source: DG Research and Innovation - Economic Analysis Unit — Innovation Union Competitiveness report 2013
Data: Eurostat
Notes: (1) The Former Yugoslav Republic of Macedonia.
(2) MT: Umemployment rate for Human Resources in Science and Technology is not available..

5.3. Addressing skills gaps through adult lifelong learning and mobility

The speed of change in different labour market segments makes it difficult to assess whether higher education systems provide the right skills for future labour markets. Skills gaps and skills mismatches can even be a sign of a dynamic, fast-changing knowledge economy. Successful innovation often creates a demand for new skills sets, which may be very specific in nature and which education systems can only meet gradually because of the normal time lag between when a bundle of new skills needs is identified and a cohort of graduates equipped with the new skills enters the labour market.

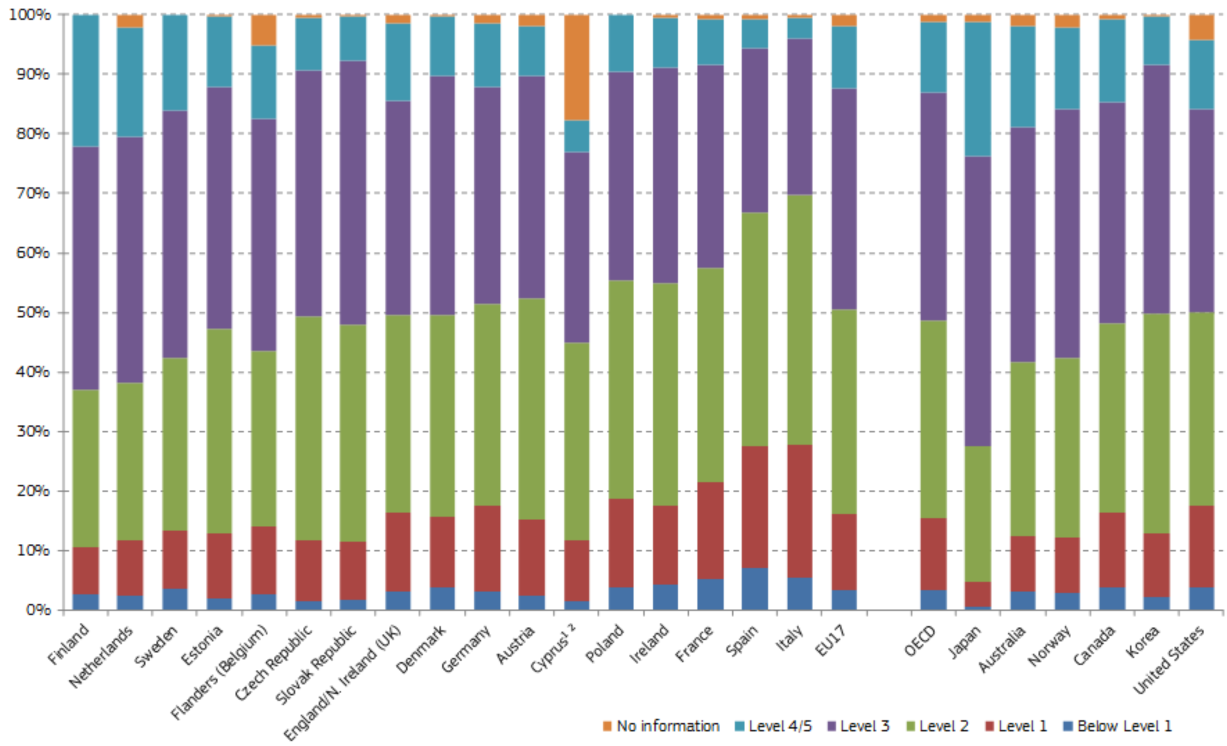
Advanced economies characterised by rapid change can therefore expect to experience skills mismatches and to some extent skills shortages. Part of the answer to a better match between demand and supply of high-level skills therefore rests, apart from on a flexible workforce willing to learn and adapt, on the further development of transparent and flexible lifelong learning systems that offer pathways between vocational and non-vocational continuing education and training at all levels. In economic sectors of high priority to Europe as a whole, benefits of scale could be obtained through European collaboration on curricula to avoid duplication of efforts and to achieve benefits of increased mobility.

The current level of adult skills- results from the OECD PIAAC study

Data on formal educational qualifications (educational attainment) are often used as a proxy for skills. However, the results of the OECD PIAAC[55] study on adult skills published in October 2013 show strong differences between countries in average skills levels for people with the same level of educational attainment.

As regards overall performance (age group 16-65 years), roughly three groups of EU countries can be identified: countries with high shares of top performing adults and low shares of low performers, like Finland the Netherlands and Sweden; countries with varying patterns but whose results are not significantly different; and, finally, countries with few top performers and high shares of low performers such as Spain and Italy. Of the countries participating in the study Japan shows the highest share of top performing adults and the lowest share of low performers. Finland comes close to the performance level of Japan. The EU as a whole (results for 17 Member States) performs on a similar level as the US. However, the EU has also the lowest performing countries in the study.

Figure I.5.11: Share of the population (16-65 old) at each literacy skills level



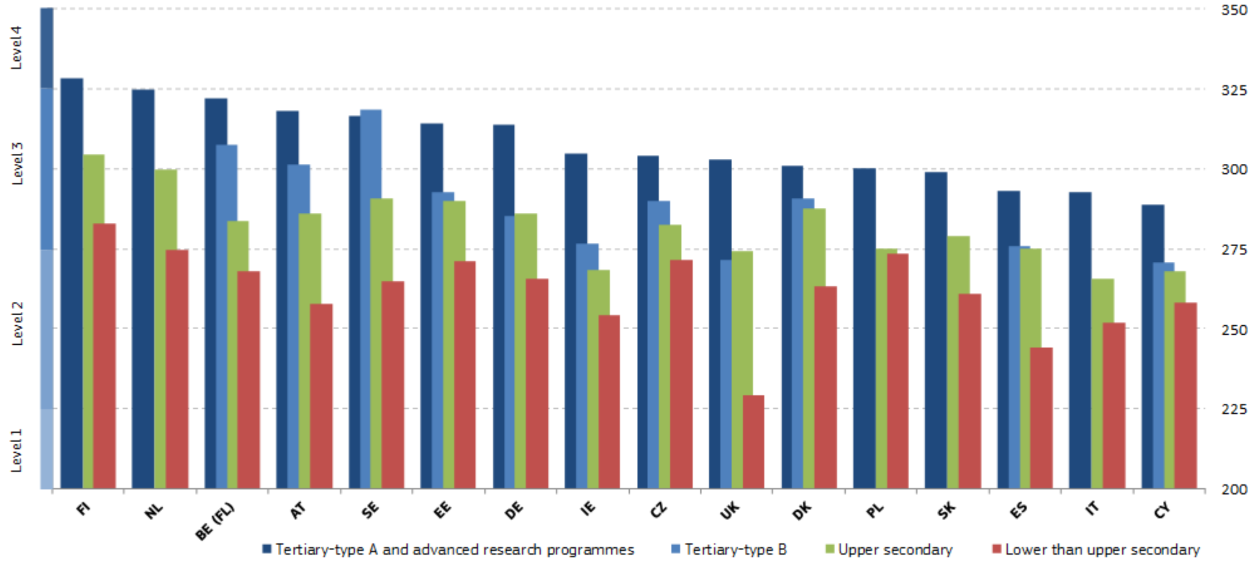
Source: DG Research and Innovation - Economic Analysis unit
Data: OECD - Survey of Adult Skills (PIAAC) (2012)
Notes: Adults in the missing category were not able to provide enough background information to impute proficiency scores because of language difficulties, or learning or mental disabilities (referred to as literacy-related non-response).

[55] Programme for International Assessment of Adult Competencies. The results of the first PIAAC study, which covers 17 EU countries, were published on 8 October 2013.

When comparing performance across countries, for example as regards literacy, young tertiary graduates in Finland, the Netherlands, Sweden, Belgium (Flanders), Austria, Estonia and Germany score among the highest of any participants in the survey, with tertiary degree holders in Finland reaching the lower end of level 4. Upper secondary graduates on average perform at the lower end of level 3, scoring 20 points lower (equalling roughly three years of education) than tertiary graduates. It is interesting to note that upper secondary graduates in Finland and the Netherlands score on average higher than tertiary graduates in countries such as Italy, Spain, the UK and Cyprus. This implies that there is still substantial room for improving the level of skills acquired in tertiary education in many member states and that there are good practices to learn from within the EU. Nevertheless results should be analysed with care, since skills levels of young adults might also be influenced by factors outside education, such as work experience, long unemployment spells or non-formal learning and the skills level acquired at tertiary level is also dependent on the kills acquired at earlier stages of education.

As educational attainment rates in upper secondary and tertiary education reach saturation in many member states, attention must shift to the quality of education and the acquisition of skills, especially labour-market relevant skills. The demographic dividend, the declining cohort size in many countries, helps to provide the resources for that.

Figure I.5.12: Mean literacy proficiency scores of 16-29 years olds by highest educational attainment



Source: DG Research and Innovation - Economic Analysis unit
Data: OECD - Survey of Adult Skills (PIAAC) (2012)
Notes: Lower than upper secondary corresponds to the International Standard Classification of Education (ISCED) categories 1, 2 and 3C short. Upper secondary education includes ISCED 3A, 3B, 3C long and 4. Tertiary type B corresponds to ISCED 5B. Tertiary type A corresponds to ISCED 5A and advanced research programmes correspond to ISCED 6.
Where possible, foreign qualifications are included as per their closest correspondance to the respective national education systems.

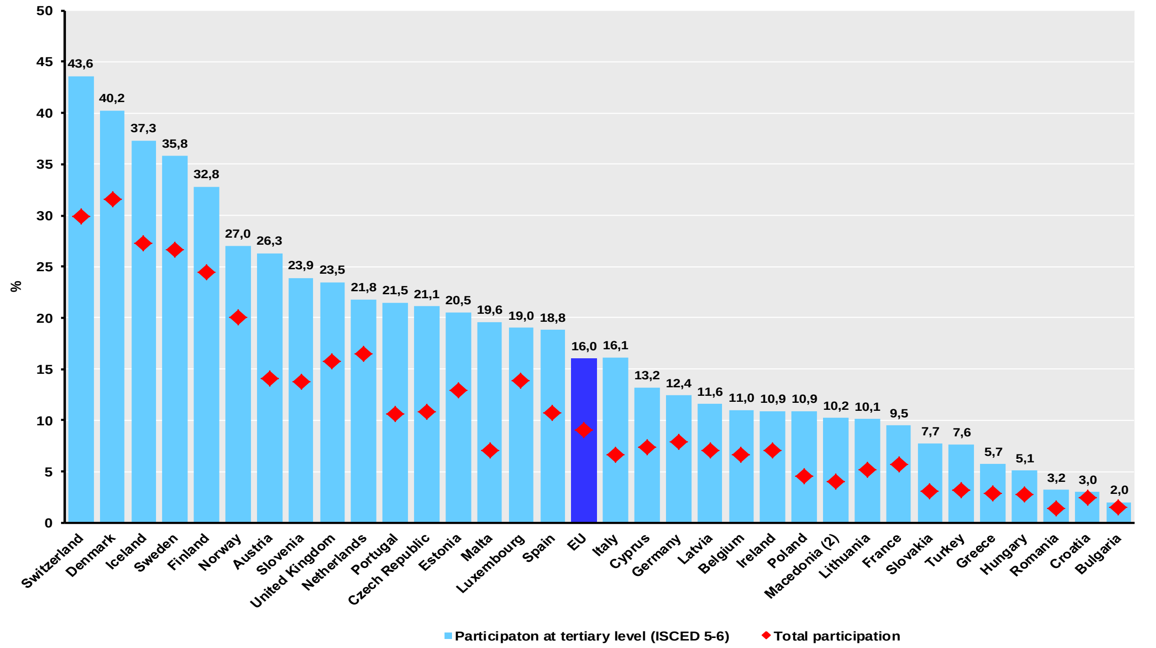
Lifelong learning is associated with innovation and productivity

Eurostat data on adult lifelong learning participation ([56]) show that countries with a high participation rate tend to be the same countries that score well on innovation and on productivity (the direction of the causality is, however, still debated). The EU Member States with high adult lifelong learning participation rates include Denmark, Sweden and Finland. The EU countries with the lowest participation rates are Bulgaria, Croatia and Romania. In all countries, lifelong learning participation increases with educational attainment. People with a tertiary level of education show the highest participation rates, and younger age groups participate more than older people.

In adult lifelong learning, non-formal and informal learning plays an important role. The Eurostat Continuing Vocational Training Survey (CVTS) shows large differences between Member States in the percentage of enterprises offering training (providing non-formal learning). Austria, Sweden and the United Kingdom show rates of 80 % and above, while in Bulgaria, Poland and Romania less than one third of enterprises offer training. The recognition of prior learning is important in making good use of private investment in non-formal and informal education and training. Though recognition of prior learning is promoted both by the EU and in the policy frameworks of Member States, the actual uptake is moderate. The supply via open education resources and platforms increases opportunities to participate in online learning. This includes educational resources offered by the best universities in the world (via MOOCs).

[56] The data is from the Eurostat Labour Force Survey and refers to participation in the four weeks prior to the survey.

Figure I.5.13 Participation in adult lifelong learning (%) (1), 2012



Source: DG Research and Innovation - Economic Analysis Unit — Innovation Union Competitiveness report 2013
Data: Eurostat
Notes: (1) The data refer to age-group 25-64.
(2) The Former Yugoslav Republic of Macedonia.

Mobility of students helps develop skills that also spur future mobility of S&T professionals

As national economies become more interconnected and participation in tertiary education expands, international student mobility plays a critical role in developing students' key competences — in particular languages and intercultural competences, but also entrepreneurship. However, mobility is a useful learning experience at all stages of learning, including adult lifelong learning. It also has a positive impact on helping educational institutions connect internationally, and on enhancing the quality of study programmes. Mobility of skilled staff, furthermore, helps to ensure a better match between supply and demand for skilled labour. Even in the current economic situation there are regions and countries in Europe with an unfulfilled demand for skilled labour. Once the economic situation improves, people engaged in mobility may return home, bringing back higher skills and experience levels that will have a positive impact on the national and local economy ([57]). Studies show that graduates are more willing and likely to participate in international mobility if they have had mobility experiences as a student.

The OECD publication Education at a Glance 2013 ([58]) shows that in 2011 about 4.3 million tertiary students were enrolled outside their country of citizenship. In absolute terms, the

[57] An analysis of mobility from the perspective of knowledge circulation in the economy is presented in Chapter II.4.
[58] See http://www.oecd.org/edu/eag2013%20(eng)--FINAL%2020%20June%202013.pdf.

largest numbers of foreign students ([59]) are from China, India and South Korea. Asian students represent 52 % of foreign students enrolled worldwide. The US (16.5 %), the United Kingdom (13.0 %), Germany (6.3 %), France (6.2 %) and Australia (6.1 %) are the most popular host countries for foreign students. Europe is the preferred destination for students studying outside their country, with 40 % of all international students studying in the 21 EU countries that are members of the OECD (representing 98 % of student mobility to the EU). North America hosts 21 % of all international students. Nevertheless, the fastest growing regions with respect to destination are Latin America and the Caribbean, Oceania and Asia, mirroring the internationalisation of higher education in an increasing set of countries.

Figure I.5.14 Student mobility at tertiary level, 2011

	Students (ISCED 5-6) studying in another EU, EEA or Candidate country as % of all students		Foreign students as % of the student population in the host country 2011		% share of ERASMUS mobility students (outgoing) in total ISCED 5A students		% share of ERASMUS mobility students (incoming) in total ISCED 5A students	
	2011	Annual average growth rate 2005-2011 (1)	All foreign students	Students from the EU	2011	Annual average growth rate 2005-2011 (2)	2011	Annual average growth rate 2005-2011
Belgium	2,9	1,8	11,9	7,8	3,1	5,6	3,5	8,9
Bulgaria	8,6	-0,2	3,7	0,6	0,7	13,2	0,3	26,1
Czech Republic (4)	2,9	8,3	8,5	6,2	1,7	7,7	1,3	17,0
Denmark	2,6	2,1	11,5	5,9	1,3	9,2	3,1	7,7
Germany	3,9	10,0	10,2	2,8	1,5	5,8	1,2	7,1
Estonia	6,0	8,9	3,9	1,3	2,3	13,7	1,9	21,6
Ireland	12,8	5,5	11,9	4,9	1,7	8,3	3,7	6,7
Greece (4)	5,5	-1,4	5,1	2,4	0,8	5,4	0,7	7,6
Spain	1,4	4,1	5,5	1,6	2,3	9,6	2,4	6,4
France (4)	2,6	3,6	11,9	2,0	2,0	6,4	1,7	5,0
Croatia	6,0	-0,8	0,9	0,1	0,5	93,7	:	:
Italy (4)	2,6	9,6	3,7	0,9	1,1	5,2	1,0	6,1
Cyprus	53,8	-0,8	31,2	7,7	1,2	15,6	2,9	32,8
Latvia (4)	5,9	23,0	1,9	0,8	2,3	20,1	0,8	29,0
Lithuania	6,4	16,2	1,7	0,1	2,6	13,4	1,2	25,3
Luxembourg	71,8	-2,3	51,5	41,4	10,2	21,4	9,4	63,4
Hungary	2,5	8,9	4,9	2,6	1,2	9,5	1,0	16,4
Malta (4)	11,2	6,2	4,1	1,8	0,0	2,0	9,7	21,4
Netherlands	2,7	7,0	20,6	5,1	1,1	10,1	1,2	5,4
Austria	4,5	0,4	19,5	13,4	1,8	5,6	1,8	7,2
Poland	2,0	7,4	1,1	0,3	0,7	9,0	0,4	21,2
Portugal	4,9	9,1	5,5	1,2	1,6	7,8	2,3	12,0
Romania	3,7	8,2	2,2	0,5	0,5	6,4	0,2	16,3
Slovenia	2,5	3,8	2,1	0,3	1,8	12,9	1,8	23,9
Slovakia	13,8	8,2	4,0	3,3	1,2	15,5	0,6	25,0
Finland	2,9	1,2	5,1	1,3	1,8	4,3	2,4	3,7
Sweden	3,4	6,7	10,8	2,3	0,8	4,1	2,4	6,6
United Kingdom	0,8	8,1	22,5	7,5	0,7	9,6	1,3	6,8
EU (3)	3,3	6,2	9,4	3,0	1,3	7,6	1,3	7,7
Iceland	17,0	0,0	6,6	4,5	1,5	4,0	3,0	12,3
Liechtenstein (4)	66,6	-2,4	88,4	58,2	4,2	5,6	6,2	20,0
Norway	5,8	3,2	7,2	2,6	0,7	4,1	1,9	13,1
Switzerland	:	:	22,9	14,6	0,0	:	0,0	:
Macedonia (5)	6,5	-9,6	2,6	0,1	:	:	:	:
Turkey (4)	1,4	-2,2	0,8	0,1	0,4	39,6	0,2	50,7
United States	:	:	:	:	-	-	-	-
Japan	:	:	3,9	0,1	-	-	-	-

Source: DG Research and Innovation - Economic Analysis Unit   Innovation Union Competitiveness report 2013
Data: Eurostat, DG Education and Culture (Education and Training, ERASMUS statistics)
Notes: (1) LU: 2006-2011.
(2) MT: 2005-2010; HR: 2010-2011.
(3) EU: Croatia is not included.
(4) Based on the citizenship of students.
(5) The Former Yugoslav Republic of Macedonia.

[59] OECD definition: Students are classified as 'international' if they have left their country of origin and moved to another country to study. Students are classified as 'foreign' if they are not citizens of the country in which they are studying. This latter category includes some students who are permanent residents, albeit not citizens, of the countries in which they are studying (for example, young people from immigrant families).

The EU has set itself the objective of increasing the percentageof higher education graduates spending a period of higher education-related study or training (including work placements) abroad to 20 % by 2020([60]). There are no precise data yet on tertiary mobility levels as defined by the benchmark. Currently, 1.3 % of EU students are on credit mobility in any given year. Over a five-year period (as the average duration of a tertiary study), 6–7 % of students are likely to have participated in credit (and hence short-term) mobility (EU *Erasmus* programme). In addition, between 2 % and 3 % of EU students participate in long-term/degree mobility in another EU Member State or Associated country in a given year. There are, in addition, students who acquire mobility experience outside of Europe. In total, slightly more than 10 % of new EU tertiary graduates probably have a higher education-related learning mobility experience.

As regards long-term (degree) mobility, the highest levels are found in smaller Member States, such as Luxembourg and Cyprus, followed by Ireland, Malta and Slovakia. Luxembourg and Cyprus are also among the countries that are particularly successful in attracting foreign students, along with Austria, the Netherlands and the United Kingdom.

As shown by the figures above, EU programmes like *Erasmus* have played an important role in boosting student mobility in higher education in Europe. Since its launch in 1987, 3 million students have participated in Erasmus-supported mobility. Currently, more than 200 000 students participate per year. In the period 2014–2020 the new programme *Erasmus+* will integrate the current programmes for higher education, VET, schools and adult education— *Erasmus*, *Leonardo da Vinci*, *Comenius* and *Grundtvig* — into a single programme. Financial resources are expected to grow by 40 % to reach the level of 1 out of 4 people with a EU programme-supported mobility experience by 2020.

As developments in the United States in particular have shown, digital technologies available through massive open online courses (MOOCs) will likely transform the traditional concept of international mobility. They areproviding students and adults who want to participate in continuing education with a much wider choice by putting together a course programme fitting their interests and enabling them to learn from acknowledged professors in a particular field. Much will depend upon how the whole field of credits and recognition evolves in the coming years.

[60] SEC (2011) 1063 final. The mobility threshold applied in this benchmark is a minimum of 15 European Credit Transfer System (ECTS) credits or lasting a minimum of 3 months. In addition, there is a 6 % mobility target for initial vocational education and training.

5.4. The importance of partnerships with business

Case studies and reviews on collaboration between higher education institutions and businesses, including its impact on matching skills demand in dynamic ways, provide a number of findings that can be transferred and replicated in other contexts. Common good practice characteristics are:

- Multidimensionality of academia: While universities are an integral part of the skills and innovation supply chain to business, this supply chain is not a simple linear supplier–purchaser transaction but a multidimensional one to ensure quality, strength and resilience.
- Cooperation fit: The type and method of cooperation needs to fit the regional context to maximise impact.
- Multiple actors or ecosystems of partnerships: This is often needed to deliver truly new and sustainable value to a region, also impacting entrepreneurial opportunities for graduates.
- Longer term commitment to university–industry collaboration from both sides.
- Mutual trust to reinforce different areas of collaboration, often spanning the knowledge triangle.
- High level of institutional autonomy favouring such a dynamic, in combination with appropriate accountability mechanisms.

(Science Marketing, 2009; Wilson, 2012; OECD, 2011a; Shapiro, 2011, Shapiro 2012)

University–business collaboration is being expanded to improve the labour market relevance of curricula and skills, and to enhance the employability of graduates and the impact of higher education institutions on the regional economy

Structural changes in recent years have had major implications on skills demands in Europe. In countries with well-developed vocational education systems, where collaboration with industry is a systemic feature, youth unemployment levels tend to be relatively low.

Examples of university–business collaboration training environments

The National Research Councils in the United Kingdom have implemented innovative initiatives that seek both to establish knowledge flows between academia and industry and to enhance high-skilled collaboration in innovative growth areas where the United Kingdom has a strong competitive position, for example in biotech. In Denmark, a successful industrial PhD programme was established as a research training programme with an industrial focus, managed jointly by a private company and a university, financed by the Danish Council for Technology and Innovation, and administered by the Danish Agency for Science, Technology and Innovation (DASTI). In France, the CIFRE programme ([61]) seeks not only to give companies access to cutting-edge public research, but also to help students gain a foothold in the company to improve their future job prospects (see Kitagawa, 2011).

Public sector partnerships can also give students valuable experiences that support the development of a broader set of skills and competences. Though many universities have expanded their collaboration with the business sector in the production of graduates, including at a PhD level, this is still not a systemic feature to the extent found in VET systems with a work-based learning component. Some VET systems offer programmes at different qualification levels. New models are emerging, including vocational education at a tertiary level. University–industry partnerships do not automatically lead to changes in the learning environment, since traditional teaching approaches are not well suited to support the development of the type of skills in demand in innovative firms. Whereas entrepreneurship has traditionally been a feature in business studies, the innovative or enterprising university aims to foster an environment where students have rich opportunities to learn from working on authentic challenges, which will often be interdisciplinary or trans-disciplinary in nature.

The European Institute of Innovation and Technology (EIT)

The European Institute of Innovation and Technology (EIT) is a body of the European Union based in Budapest, Hungary. It was established by Regulation (EC) No 294/2008 of the European Parliament and of the Council of 11 March 2008, and became operational in 2010. The EIT currently employs approximately 50 members of staff and is the EU's flagship education institute. Its aim is to enhance Europe's ability to innovate and generate economic growth. Despite an excellent research base, dynamic companies and creative talent, good ideas are too rarely turned into new products or services. The promotion of a more innovative and entrepreneurial culture is hence important.

Three Knowledge and Innovation Communities (KICs) have been created to integrate education, research and innovation, which constitute the so-called knowledge triangle, within one organisation: on climate (ClimateKIC), on sustainable energy (KIC InnoEnergy) and on Information Technology (ICT Labs).

[61] See http://www.france.fr/en/studying/following-training/long-training-courses/cifre-incentive-scheme-industrial-agreement-training-through-research.

At a doctorate level there are indications that targeted partnerships provide outcomes that increase the labour market value of PhD qualifications and contribute to the wider goal of adapting and delivering the right mix of skills for fast-changing labour market needs.

The European Industrial Doctorate as part of the Marie Curie Actions Programme
The European Industrial Doctorate (EID) was launched as a pilot project in 2012 as part of the Marie Curie Actions of the FP7 PEOPLE Specific Programme. The aim of the EID scheme is to provide PhD candidates with professional experience in excellent research projects, as well as to attract more young people into scientific careers. The participants from research enterprises, in collaboration with a university) structure a doctoral programme that brings the researchers to the non-academic sector for at least 50% of the duration of their PhD. The training incorporates non-scientific skills such as entrepreneurship, communication and intellectual property management in the curriculum. EID grants will be available under the renamed Marie Skłodowska-Curie Actions (MSCA) as part of Horizon 2020[62].

The European DOC–EU study (Borrell Damian, 2009) confirms a generally held view that doctoral candidates, in addition to their core research skills, need to develop transferable or integrative skills since the business economy values PhD holders with strong communication, negotiation and management skills in addition to deep domain knowledge and a capacity for complex problem solving.

Partnerships with business are also very important because knowledge-sharing, human resources, proximity to other company sites and market demand make countries attractive for R&D activities. According to a recent survey of 172 out of the 1000 EU-based companies in the EU R&D Investment Scoreboard shows that, for the countries where the companies have the biggest volume of R&D activities, the respondents state that knowledge-sharing and collaboration opportunities with universities and public research organisations, quality and quantity of R&D personnel in the labour market, proximity to other company sites, and innovation demand in terms of market size make these countries attractive. Labour costs of R&D personnel, innovation demand via product market regulation or public procurement were not so relevant for R&D attractiveness. Knowledge-sharing and collaboration opportunities are an important factor of country attractiveness not only for companies. They are widely recognised as a priority issue in many Member States and for completing the European Research Area (ERA). However, a recent report on the ERA progress shows that public research organisations and Universities still tend to put more emphasis on developing capacities and skills than the corresponding knowledge transfer strategies.

[62] The 50th EID to be selected was the subject of a Commission press release in August 2013.(http://europa.eu/rapid/press-release_IP-13-784_en.htm). The so-called VAMPIRE project ('Vascular Antibody-Mediated Pharmaceutically Induced tumour Resection') is led by the University of Birmingham in the UK and SomantiX, a Dutch biotech company based in Utrecht.

5.5. The importance of entrepreneurial skills

Entrepreneurial skills are increasingly promoted in Europe.[63] However, at the higher education level Europe still lags behind the US in entrepreneurship training

A report published by the European Commission in 2012 on the impact and effectiveness of entrepreneurship education concludes that entrepreneurship in higher education has a positive, measurable impact on motivation for business start-up, on developing competences, knowledge and skills conducive to innovation, and on employability ([64]). The report recommends that entrepreneurship be integrated in all higher education programmes, and that students acquire entrepreneurial competences through learning-by-doing (Gibcus, 2012).

There are several examples of how European higher education institutions are beginning to promote entrepreneurial competences across programmes, although it is by far less a systemic feature of higher education in Europe than in the United States. Moreover, despite growing recognition of the importance of entrepreneurship as a key competence, this still needs to be translated into changing teaching and learning practices in the higher education sector.

According to a literature review undertaken by NESTA, most research concludes that immersion in domain-specific knowledge is an essential prerequisite for entrepreneurship and innovation, as one must have an accurate grasp of a domain in order to contribute to innovation. Innovation is based on the ability to combine previous disparate elements in novel ways, which suggests a balance between breadth and depth of knowledge. Other competences seen as crucial are the ability to thrive on ambiguity, including an intrinsic motivation to deal with problems that are fuzzy in nature, the ability to cope with and handle disagreements, and the ability to collaborate and communicate across disciplines. Five areas of entrepreneurial competence are frequently described in studies on this topic. These areas could be seen as the backbone of entrepreneurial competence:

Entrepreneurial competences
1. **Opportunity competence.** Entrepreneurship in its essence relates to the identification of opportunities. Opportunity competence is more than just opportunity recognition; it focuses on the systematic development of adequate solutions to complex problems, thus emphasising the ability to view a problem from a different perspective. 2. **Social competence.** This refers to interactions with others. Networks play an essential role in the entrepreneurial process, fostering the collaborative generation and development of new ideas. This requires the ability to communicate across professional boundaries.

[63] See the Commission's Entrepreneurship 2020 Action Plan (COM(2012) 795) http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2012:0795:FIN:EN:PDF. A short summary of this plan can be found at http://ec.europa.eu/enterprise/policies/sme/entrepreneurship-2020/index_en.htm.

[64] This section draws primarily on a background report prepared by H. Shapiro for the Danish Ministry of Science, Research and Innovation as a contribution to the strategy for Innovation in Higher Education. However, one should note that overall the evidence is mixed, as shown for example by Oosterbeek, H. van Praag, M, Ijssselstein, A (2010) 'The impact of entrepreneurship education on entrepreneurship skills and motivation', *European Economic Review*, 54 (3) : pp. 442-454.

3. **Strategic business competence.** This competence involves the organisation of different internal, external, human, physical, financial and technological resources as well as setting, evaluating and implementing the strategies of the enterprise. These competences are critical to driving employment growth in a start-up.
4. **Industry-specific competence.** This involves domain-specific competence (know-how) and knows-what. To be able to identify and exploit opportunities, entrepreneurs need knowledge of the market, of clients' needs, of resources and of competitors. Market knowledge is constructed by participating in the market and in networks.
5. **Entrepreneurial self-efficacy.** This is a broad domain of competences, which influence other competences positively. This area comprises those constructs that have close conceptual links with more classical entrepreneurial psychological constructs.

In addition social entrepreneurship needs to be supported and an enabling framework for social innovators should be promoted.

5**.6. The importance of ICT skills**

While everybody needs to be equipped with basic ICT skills, the demand for workers with advanced IT skills continues to grow

Data from the Eurostat ICT household survey show that levels of e-skills among the EU population are improving. In 2012, 26 % of the EU population had carried out 5–6 of 6 selected computer-related activities[65] (an indicator of a good level of basic computer skills), compared to 21 % in 2006, and 40 % in the age group 16–24 years. There is thus also a generational effect. Each cohort of young people ('digital natives') is bringing a higher level of IT skills with them and replacing older workers with lower levels of e-skills. While the population's ICT skills are improving, there is still a growing need for IT professionals. After the boom of the so-called New Economy around the year 2000, the number of computing graduates in the EU increased with a time lag until about 2005. In the years after 2005 the number declined, reflecting — again with a time lag — the crisis of around 2001, to increase again since 2009. These developments are reflected in the fact that the number of computing graduates in the EU increased in the period 2005–2011 on average by only 0.1 % per year. In many Member States, however, it declined. As a result, there are not enough graduates to fill the vacancies available in this sector. According to an estimate from 2012, there will be up to 900 000 unfilled ICT practitioner vacancies in the EU by the year 2015.

In 2012, 2.7 million people or about 1.3 % of the EU workforce worked in the ICT services sector (computer programming, consultancy and related activities, NACE J62)[66]. Employment growth in the sector from 2000 to 2010 reached 29 %, a much faster rate than for the economy

[65] The following activities were selected in 2006 and 2012 for defining computer skills: copy or move a file or folder; use copy and paste tools to duplicate or move information within a document; use basis arithmetic formula (add, subtract, multiply, divide) in a spread sheet; compress files; connect and install new devices, e.g. a printer or a modem; write a computer program using a specialised programming language.

[66] Including the ICT specialists in other sectors the total share of ICT workers in the workforce stands at 3.1% (http://ec.europa.eu/enterprise/sectors/ict/files/eskills/vision_final_report_en.pdf).

as a whole (7 %). Even since the onset of the crisis, employment in IT services in the EU increased by 3 % from 2008 to 2010 and by over 10 % from 2010 to 2012. The IT services sector is expected to continue expanding faster than the rest of the economy. Employment growth of 7.6 % is forecast for the EU in the period 2010–2020, compared with the average of 3.4 % employment growth forecast across all sectors.([67]) And this forecast might even be overly pessimistic, given the strong growth of IT services employment since 2010.

Figure I.5.15 Tertiary education graduates in Computing, 2011

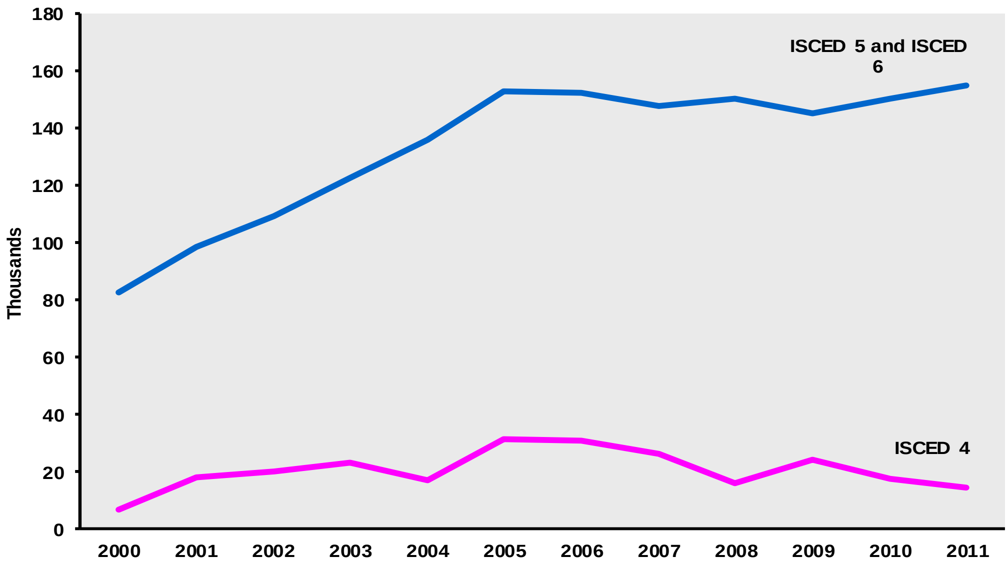
	Total ISCED 5			Total ISCED 6		
	2011 (1)	Average growth rate 2005-2011 (2)	per 1000 population aged 20-29	2011 (1)	Average growth rate 2005-2011 (3)	per 10000 population aged 20-29
Belgium	1935	-6,7	1,4	58	-1,9	0,4
Bulgaria	1528	7,5	1,6	15	31,6	0,2
Czech Republic	4102	13,6	2,9	81	5,4	0,6
Denmark	2379	4,0	3,7	:	:	:
Germany	19569	6,2	2,0	906	9,7	0,9
Estonia	557	-1,2	2,7	17	22,6	0,8
Ireland	1764	0,6	2,6	83	7,8	1,2
Greece	3053	-0,2	2,3	85	21,1	0,6
Spain	15952	-2,5	2,8	507	20,3	0,9
France	24382	-3,5	3,0	642	9,4	0,8
Croatia	752	10,1	1,3	19	18,9	0,3
Italy	4151	0,3	0,6	140	4,9	0,2
Cyprus	324	6,1	2,3	8	41,4	0,6
Latvia	828	0,7	2,7	10	46,8	0,3
Lithuania	1032	-1,2	2,5	11	3,4	0,3
Luxembourg	42	16,7	0,6	12	33,3	1,8
Hungary	2116	6,0	1,6	31	25,3	0,2
Malta	198	24,6	3,3	1	:	0,2
Netherlands	4512	1,5	2,2	:	:	:
Austria	2492	8,7	2,3	96	4,4	0,9
Poland	18960	-0,2	3,1	:	:	:
Portugal	1171	-0,5	0,9	34	-16,6	0,3
Romania	2001	-24,0	0,6	:	:	:
Slovenia	567	17,9	2,1	23	4,2	0,8
Slovakia	2264	10,2	2,7	45	21,5	0,5
Finland	1594	-2,1	2,4	67	4,3	1,0
Sweden	2098	-0,6	1,7	139	14,7	1,1
United Kingdom	30042	-3,9	3,5	871	8,1	1,0
EU (3)	151286	0,1	2,3	3899	8,9	0,6
Iceland	76	-6,8	1,6	2	:	0,4
Liechtenstein	17	:	3,8	:	:	:
Norway	1169	-5,2	1,8	432	11,8	6,8
Switzerland	1678	-8,8	1,7	96	2,7	1,0
Macedonia (4)	880	53,2	2,7	7	38,3	0,2
Turkey	17593	12,5	1,4	74	35,4	0,1
United States	99969	-1,4	2,3	1588	6,0	0,4

Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Eurostat, OECD
Notes: (1) FR:2009; HR, IS, NO (ISCED 6 only): 2010.
(2) FR: 2005-2009; HR, IS: 2005-2010; RO: 2008-2011; LU: 2010-2011.
(3) FR: 2005-2009; HR, IS, NO: 2005-2010; BG: 2007-2011; LU: 2010-2011.
(4) Former Yugoslav Republic of Macedonia.

[67] See http://euskillspanorama.ec.europa.eu/docs/AnalyticalHighlights/ICT_Sector_en.pdf.

However, as shown in Figure I.5.16, the number of IT graduates has stagnated on an EU level in the recent past. The ICT sector and ICT-intensive industries rely on a mix of hard technical skills and soft skills to carry out ICT functions, and there is a trend towards general up-skilling across the different categories of ICT occupations with lower-level jobs being either automated or outsourced. The demand for low-end developers and support staff is hence expected to decline, while demand for business analysts, security specialists and high-end developers will increase. In the United Kingdom, the share of highest qualified ICT employment is expected to increase from 55 % in 2010 to 60 % in 2020 (European Skills Panorama). A study conducted by the Danish Technological Institute with Fraunhofer in 2011 points in particular to two broad skills areas. One relates to ICT security, since increasing inter-firm connection and cloud applications are major drivers of demand for more advanced skills as ICT becomes the backbone of business and business service solutions. The other is business-related ICT skills, on the assumption that ICT can deliver improved company agility and business transformation, in particular via e-business services that may involve co-design with end users depending upon markets and industries. It is important to note that access to advanced e-skills is also increasingly critical to knowledge-intensive entrepreneurs, for example when it comes to the use of cloud platforms and e-business models (Laugesen, 2012).

Figure I.5.16 EU (1) graduates in Computing (thousands), 2000-2011



Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Eurostat
Note: (1) EU: Croatia is not included.

Rapid changes in the ICT technology base and the type of tasks that can be managed through ICT will probably continue to maintain an on-going skills mismatch regardless of the overall economic climate, not only in the ICT sector but also in a range of ICT-intensive industries. Part of the answer to the future e-skills demands is to further develop continuing education and training systems in the Member States. Currently, some 9 % of EU enterprises provide their ICT specialists with training to upgrade their ICT skills, while 17 % provided training for other staff to develop their ICT skills.[68] Some countries furthermore have increased the supply of work permits for IT experts from outside the EU. Whereas there seems to be sufficient supply of both vendor-specific and non-vendor-specific technical courses, gaps persist regarding business exploitation of ICT for innovation purposes (Laugesen, 2012). Opportunities to integrate advanced e-skills modules in different tertiary qualifications can also be a way to alleviate e-skills gaps and to stimulate the ICT-enabled innovation in Europe in a more flexible manner. The projected demand for advanced ICT skills, combined with an emerging skills supply gap caused by stagnation in the number of new IT graduates could in the future constitute a barrier to innovation in businesses. This could be exacerbated by the fact that businesses across industries are becoming more ICT-intensive, and that the ICT industry (like other knowledge-intensive industries) depends upon advanced STEM skills.

[68] 'Eurostat ICT Enterprise survey', 2012.

II. REFORM:

Research excellence and Knowledge circulation

1. Excellence in science and technology

Highlights

Research excellence is concentrated in a handful of countries

Science and technology follow two parallel tracks. On the one hand, an increasing number of countries are active in world science and technology production. On the other hand, excellence is concentrated in a handful of countries, which vary depending on the research field. Switzerland, the Netherlands, Denmark, Sweden and Israel score highest on the composite indicator of research excellence. Further analysis presents a mixed picture for Europe. While the United States outperforms the European Union as a whole, about one third of European countries have achieved higher scientific and technological research excellence than the United States. And many other European countries are catching up.

Only a few Member States are well positioned in* science and technology *for new growth markets; the United States excels in health, and Asia is driving change in energy and the environment.

In several strategic and growing science and technology fields, addressing societal challenges or key enabling technologies, the United States holds very strong positions, together with several Asian countries, in particular Japan and South Korea, and to a lesser extent China (the latter mostly in terms of absolute numbers of scientific publications). The United States is a world leader in science and technology for health. In Europe, the highest scientific impact is found in Iceland, Switzerland and the Netherlands, while the most dynamic technological development is in Sweden and Denmark. China produces the most scientific publications in the world in the field of energy, but with lower impact than other countries. Japan has the highest rate of technology development in energy. It is also strong in environmental technologies. But Germany, the Netherlands, Sweden and Finland combine high scientific impact with intensive technology development in these fields.

Key enabling technologies are driven by the United States, Japan, Germany, the Netherlands, Israel, South Korea and Austria

Although China produces the highest number of scientific publications in information and communication technologies (ICT) in the world, the ICT scientific publications produced by Switzerland, Israel and the United States have the highest scientific impact. Technology development in ICT is most intense in Japan, Israel and South Korea. With regard to nanoscience and nanotechnologies, the scientific publications produced by Israel, the Netherlands, the United States, Germany, Austria and Switzerland have the highest scientific impact, while technology development in this sector is more intensive outside Europe, in particular in Japan, the United States and South Korea.

Introduction

This chapter looks into the performance of national research systems in terms of scientific and technological research excellence ([69]). Striving for research excellence is not only the aim of research itself, it is also closely linked to the policy goal of increasing the accountability and competitiveness of publicly funded research actors. A country's competitiveness can either be measured *vis-à-vis* that of other countries (Thurow, 1992) or by the conditions and amenities available within that country that contribute to raising living standards (Boschma, 2004; Kitson et al., 2004). Notwithstanding differences in interpretation, most accounts of competitiveness attribute an important role to research. However, policymakers are not interested in just any research, but in excellent research in particular. So the focus on creating competitive economies automatically translates into a focus on establishing excellence in research (Power and Malmberg, 2008).

1. Measuring overall research excellence

Excellence in research is about top-end quality outcomes from creative work performed systematically, which increase stocks of knowledge and use it to devise new applications.

There are many challenges in monitoring research excellence, from defining the concept itself to rendering it analytically tractable (Tijssen, 2003). The added value of a well-constructed composite indicator lies in its ability to summarise different aspects of research excellence in a more efficient and parsimonious manner (OECD/JRC, 2008). This chapter defines excellence in scientific and technological research as the top-end quality outcome of creative work undertaken systematically to increase the stock of knowledge and new applications. Having evaluated the quality profile of a large set of potential variables, the focus is on four that measure output quality at the national level:

1) A field-normalised number of highly cited publications – from an individual country – as measured by the top 10 % most cited publications per total publications; as a share of all publications with a national author. A citation window includes the year of publication plus the three subsequent years (i.e. 2003 scores cover the period of 2003-2006). However, 2007 scores refer only to a window of 2007-2009 due to data limitations.
2) The number of high quality patents (those filed under the Patent Cooperation Treaty (PCT)[70]) that a country has per million population;

[69] The results reported are based on Hardeman, S., Van Roy, V., Vertesy, D., and Saisana M, 'An analysis of national research systems: A composite indicator for scientific and technological research excellence', 2013, a JRC report conducted on behalf of the Directorate-General for Research and Innovation (DG RTD) within the framework of the research project 'Indicators 4_IU'.

[70] Patent application data can be used to measure the capacity of research to produce technologies and science relevant for technology development. However, patents are also central to the innovation process, in particular

3) The number of world-class universities and public research institutes as measured by the GERD-normalised excellence scores of the top 250 universities (Leiden Rankings) and top 50 public research institutes (Scimago Institute excellence rankings);
4) The number of high prestige research grants received by a country, as measured by the total value of European Research Council (ERC) grants received in comparison to public R&D spending (HERD+GOVERD).

Field-normalised numbers of highly cited publications and high quality patents within a country reflect its new knowledge (in terms of texts and artefacts). But figures on the number of world-class universities, public research and institutes that it hosts, together with the high prestige research grants it receives, make it possible to monitor new knowledge attributed to a nation's people or groups of people. The research excellence composite index was calculated by geometric aggregation of the indicators, each one normalised by Min-Max 10-100. Multivariate analysis confirms that the indicators express a single latent phenomenon and contribute in a largely similar way to the composite scores. To facilitate comparison of European countries, all four variables are included in the composite for 2005 and 2010. For a global comparison, as shown in this report, the composite indicator was computed by taking the average of the first three indicators (excluding ERC grants, which are not meaningful for non-European countries) ([71]).

No country performs best on all dimensions of research excellence; there is space for improvement in all European countries

The ratio of highly cited publications per total publications is highest in Switzerland, Denmark, the Netherlands, Iceland, Belgium, the United States, Sweden, and the United Kingdom (between 18 and 14, see Figure II.1.1). On the other end of the scale, in Russia, Latvia , Croatia, Poland, Bulgaria, Brazil, Romania and Slovakia, the ratio is less than 7. The ratio of the number of world-class universities and public research institutes to public R&D spending is high in Switzerland, the Netherlands, Denmark, Israel, Sweden, Belgium, Germany and the United Kingdom, while there are 13 countries (among which 11 are EU Member States) that do not have a single university or institution in the top 250. The high number of zero values for this variable suggests that no distinction could be made between those 13 countries in 2010. Future data will show whether these countries have improved (see Aghion et al., 2008). Furthermore, the 'world-class universities and public research institutes' variable adds valuable information to the overall scores for Denmark, the Netherlands and the United Kingdom. The ratio of PCT patents per million population is very high in Sweden, Switzerland, Finland and Israel, while relatively low in India, Romania, Brazil, Cyprus, Bulgaria, China, Turkey, Lithuania and Russia. Finally, the ratio of high prestige research grants in comparison with public R&D spending (HERD+GOVERD) is higher in Switzerland,

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for knowledge-based innovation. Therefore, PCT patent applications are also included as one of the four pillars in the innovation output indicators, presented in part III, chapter 1.

[71] The 40 countries are 33 European countries (the EU-28 plus Turkey, Switzerland, Iceland, Norway and Israel) and 7 benchmark countries (Brazil, Russia, India, China, Korea, Japan and the US).

Israel, Cyprus, the Netherlands, the United Kingdom, Sweden, Belgium and Finland, while 6 of the 33 European countries studied — Lithuania, Luxembourg, Latvia, Malta, Slovakia and Croatia — did not receive ERC grants in 2008. All in all, there is space for improvement in all countries analysed, as no country scores highly for all four variables selected to capture research excellence.

Figure II.1.1 : Indicators of Research Excellence (non-normalised values), 2010

		2007 Highly Cited Publications per Total Publications	2010 Top universities & research inst's to GERD	2008 PCT applications per million population	2010 ERC grants per (HERD+GOVERD)
Austria	AT	14,1	119,5	157,7	3,7
Belgium	BE	15,9	370,5	108,7	5,8
Bulgaria	BG	5,8	131,8	4,3	1,5
Cyprus	CY	11,5	-	4,1	9,3
Czech Republic	CZ	7,1	190,7	20,6	1,1
Germany	DE	13,2	354,1	230,4	2,4
Denmark	DK	17,7	543,2	244,4	4,3
Estonia	EE	11,0	-	23,9	0,5
Greece	GR	11,3	177,3	11,0	3,5
Spain	ES	11,4	130,7	32,9	2,7
Finland	FI	13,8	187,3	310,2	5,2
France	FR	12,2	201,5	107,1	3,3
Hungary	HU	8,4	99,8	26,2	4,2
Ireland	IE	13,5	-	100,6	4,6
Italy	IT	12,1	199,4	56,1	3,4
Lithuania	LT	7,5	-	5,5	-
Luxembourg	LU	10,7	-	74,7	-
Latvia	LV	4,4	-	10,0	-
Malta	MT	12,4	-	18,9	-
Netherlands	NL	17,1	604,9	217,9	8,1
Poland	PL	5,6	26,2	4,5	1,0
Portugal	PT	11,7	-	10,9	1,5
Romania	RO	6,3	-	1,7	0,2
Sweden	SE	14,7	430,2	348,9	6,4
Slovenia	SI	9,8	-	58,4	0,5
Slovakia	SK	6,9	184,5	8,7	-
United Kingdom	UK	14,7	291,2	103,8	7,6
EU-27	EU27	11,5	217,8	102,2	3,8
Croatia	HR	4,9	-	12,4	-
Turkey	TR	7,3	-	5,3	0,0
Switzerland	CH	18,2	903,9	320,9	14,3
Iceland	IS	16,2	-	89,9	3,3
Norway	NO	13,8	207,1	140,6	2,1
Israel	IL	13,3	534,4	283,3	13,4
Brazil	BR	6,3	15,7	2,8	n/a
Russia	RU	4,3	14,1	5,9	n/a
India	IN	7,0	2,5	1,2	n/a
China	CN	7,2	9,7	4,9	n/a
Rep. of Korea	KR	9,0	122,0	151,2	n/a
Japan	JP	8,2	133,3	209,2	n/a
United States	US	14,8	352,1	164,3	n/a

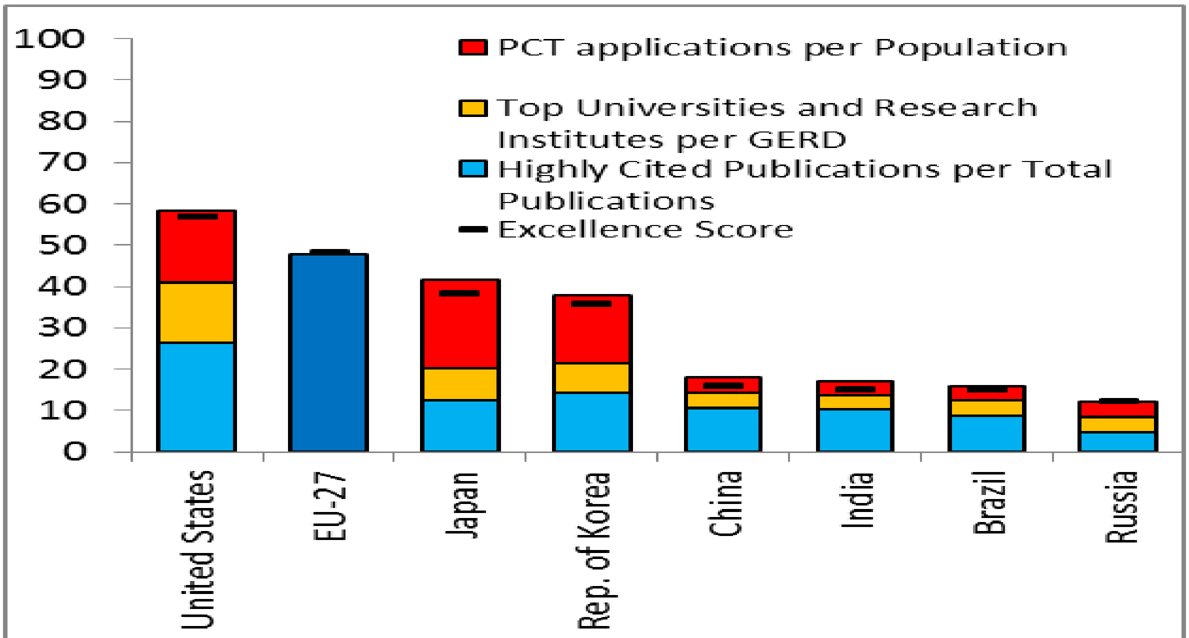
Source: JRC calculations using data from Science Metrix (highly cited publications), OECD (PCT patent applications), CWTS Leiden Ranking (world class universities) and Scimago (research institutes) and ERC/DG RTD CORDIS (ERC grants data). Population and R&D data are from Eurostat and OECD, GDP data from World Bank World Development Indicators.

Notes: Highly cited publications in relation to total publications measures the number of publications produced within a country that are among the global top 10% most cited publications (field-normalised count), measured during a three-year citation window, divided by total number of publications, Science Metrix calculations (Scopus data); top universities and research institutes indicator is an index based on the mean field normalised citation scores for all universities in country within global top 250 (CWTS Leiden Ranking) and Excellence scores of public research institutes in global top 50 from the 2012 Scimago Institute Ranking, divided by GERD, billion USD PPP at 2005 prices; PCT applications per million population is defined by the number of patent applications under the patent cooperation treaty by country of inventor and priority year, with a three-year moving average applied to compensate annual fluctuations (OECD data), divided by million population; and ERC grants to public R&D is calculated by spreading the total funding over the years of ERC funded projects, attributed to the country of the host organisation, dividing by GOVERD+HERD, million USD PPP at 2005 prices (GDP data source for all indicators: World Bank World Development Indicators). "n/a" denotes not applicable, "-" denotes a 0 value.

Research excellence is high in the European Union, although it is clearly outperformed by the United States

A comparison of the EU with the United States and other research leaders in the world can only take into consideration three of the four variables, since the number of ERC grants is only comparable for countries inside the European Research Area. Research excellence scores considering these three dimensions illustrate the strong position of the United States in terms of research quality, followed by the European Union. Japan and South Korea have their main strengths in technology development, while the opposite is true for the BRIC countries. Figure II.1.2 also illustrates that the catching up that the BRIC countries have done is still mainly visible in terms of quantity and not yet fully realised in terms of research quality.

Figure II.1.2 : Research excellence composite and indicator scores for the global comparison, 2008



Note: Excellence scores (black marker) are a geometric average of the 3 components; individual component scores were re-normalized between 0 and 33.3 for illustration purposes to allow direct comparison across countries.

Source: JRC calculations using data from Science Metrix (highly cited publications), OECD (PCT patent applications), CWTS Leiden Ranking (world class universities) and Scimago (research institutes), and ERC/DG RTD CORDIS (ERC grants data). Population and R&D data are from Eurostat and OECD, GDP data from World Bank World Development Indicators.

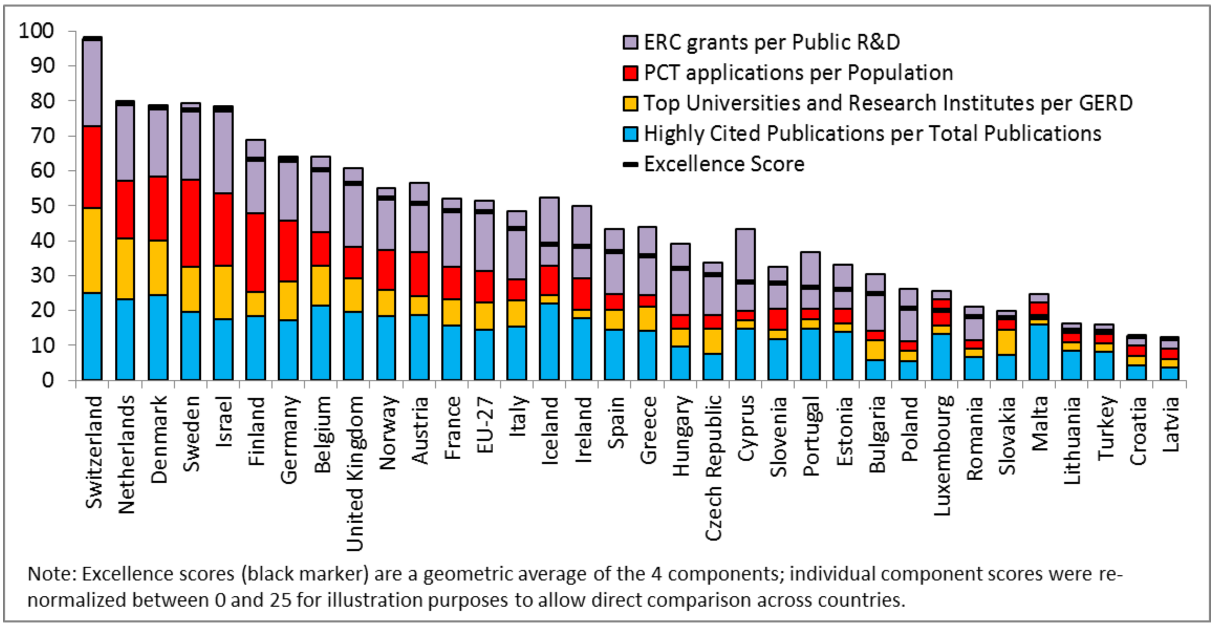
Switzerland, the Netherlands, Denmark, Sweden and Israel score highest on the composite indicator of research excellence

Figure II.1.3 focuses exclusively on countries in the European Research Area, for which the awarding of ERC grants is also relevant and comparable. When data on ERC grants are included, the composite scores for European countries remain similar to the scores obtained using just three indicators for global comparison. Switzerland, the Netherlands, Denmark, Sweden and Israel occupy the top positions, followed by a mix of larger and Mediterranean countries. Central and eastern European countries are ranked at the bottom (such as Latvia, Croatia, Turkey and Lithuania). In order to better understand the sources of excellence, Figure II.1.3. shows the overall excellence scores of European countries broken down into the four individual variables. Clearly, some countries (most notably Iceland, Cyprus, Finland and Hungary) score relatively highly on ERC grants, compared with, in particular, their scores for publication and patenting excellence ([72]). At the other end of the scale, a number of countries score relatively poorly for ERC grants in comparison with other variables, in particular Germany, Slovenia, Estonia and Luxembourg. It is interesting to note that most of the countries that score lower than the EU average have their relative strength in the 'highly cited publications' variable. They are however held back overall by a lack of universities or public research institutes within the global top 250. For the Member States that joined the EU after 2005 in particular, improving the quality of universities and research institutes is a relevant objective *en route* to improving excellence scores ([73]).

Figure II.1.3: Composite scores and individual indicator scores for European countries (2008)

[72] Not surprisingly, these countries also showed volatile scores in a sensitivity analysis.

[73] There would be hope for future improvement within the newer Member States if the excellence threshold for universities and public research institutes rose from 250 to 500. The Czech Republic, Hungary, Poland and Slovenia would then achieve non-zero (although still very low) scores for their numbers of world-class universities and public research. The same trend is observed when the scores from the Leiden Rankings (research excellence) are considered.



Source: JRC calculations using data from Science Metrix (highly cited publications), OECD (PCT patent applications), CWTS Leiden Ranking (world class universities) and Scimago (research institutes), and ERC/DG RTD CORDIS (ERC grants data). Population and R&D data are from Eurostat and OECD, GDP data from World Bank World Development Indicators.

Countries with a high level of research excellence are reinforcing their strengths. A catching-up process is taking place in most European countries, in particular in Norway, Estonia, Iceland and Austria

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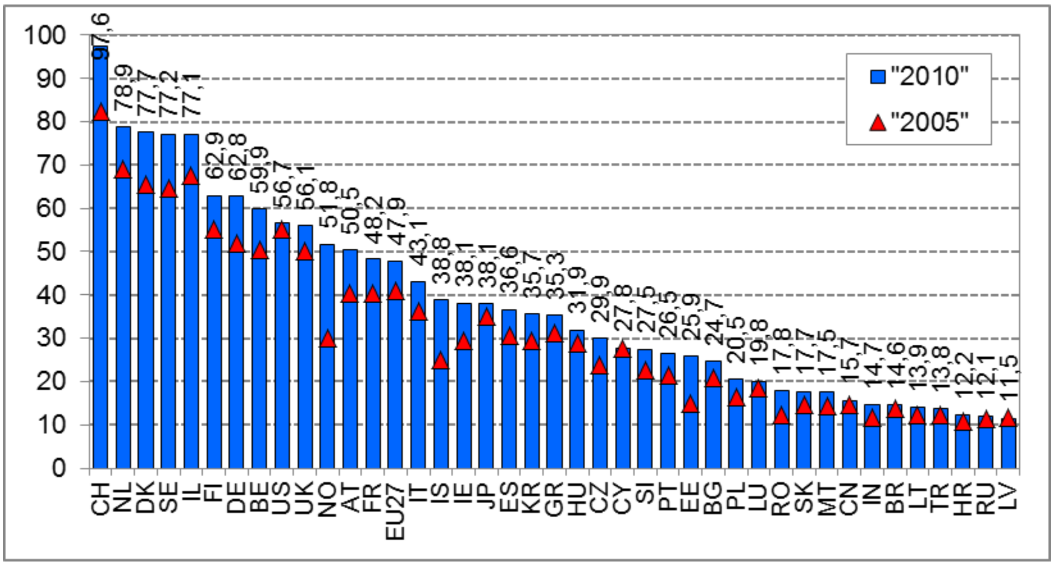
Figure II.1.4 depicts the change in research excellence between 2005 and 2010. The graph illustrates three key trends: reinforced research quality among the leading countries, catching up in most EU Member States, and stagnation of research excellence in the lower performing countries, including non-European countries such as China, India, Brazil and Russia. The United States also shows a very modest improvement in its research excellence over the five-year period in question.

The eight top performers in research excellence have all clearly improved their research quality over the five-year period. This is a positive sign that there is no stagnation effect in terms of research excellence. Another important finding is the improvement in research excellence taking place in most EU Member States. This improvement was greater than that of the leading countries in Norway, Estonia and Iceland, and on a similar level to that of the leading countries in Austria, Ireland, France and Romania. The worrying trend is the lower performing Member States, i.e. Latvia, Hungary, Turkey and Lithuania, where research excellence did not increase over the 2005-2010 period.

Figure II.1.4: Evolution of research excellence and clusters, 2005-08, global comparison



Source: JRC calculations using data from Science Metrix (highly cited publications), OECD (PCT patent applications), CWTS Leiden Ranking (world class universities) and Scimago (research institutes), and ERC/DG RTD CORDIS (ERC grants data). Population and R&D data are from Eurostat and OECD, GDP data from World Bank World Development indicators

High performance in research excellence is not automatically associated with attracting contractual business research

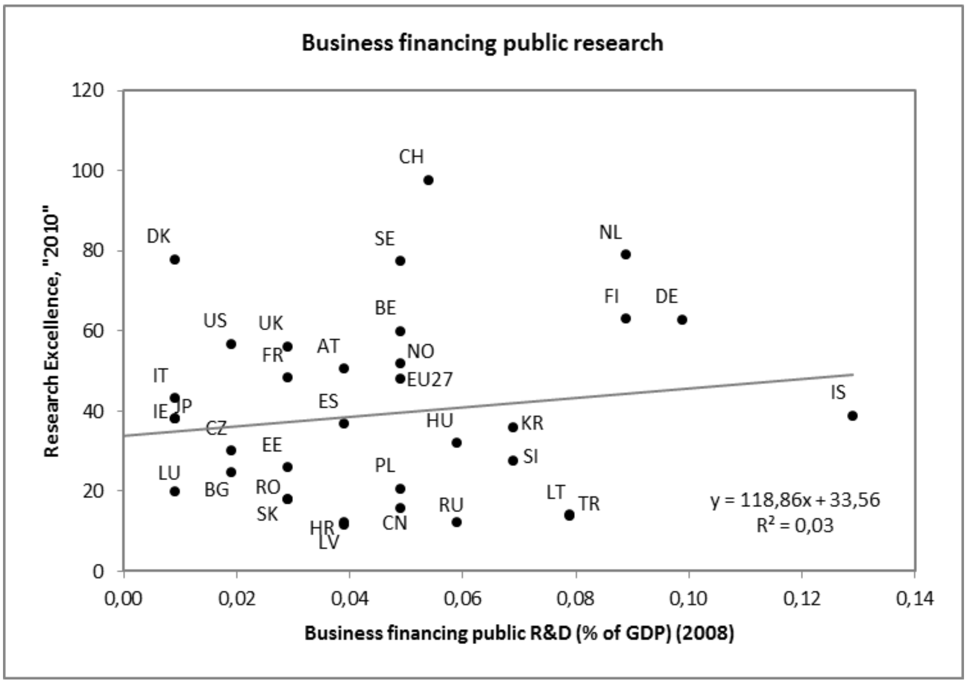
The variables used to measure research excellence did not cover any excellent outputs of scientific and technological research activity that were not published or patented, such as research carried out on a contractual basis for business enterprises.

A first hypothesis is that excellent research will attract more private funding. A second hypothesis is based on the argument that contractual research with a high private value (i.e. reflected by large amounts of funding paid by a private commissioner of research) may be considered excellent in the same way that private value qualifies PCT patents. However, unlike patents, there is a lack of systematic peer review or broad quality control of contractual research deliverables. Second, and similarly to the considerations for ERC grants, the ability of a research system to attract private funding contributes to sustaining excellence and in this way measures not only past results but future outcomes. However, while ERC grants (or other high-profile research international grants) have an explicit aim to produce results that can be published and used by a broad set of research actors, the results of contractual research may only reach a narrow audience. Contractual research outcomes can indirectly lead to peer-reviewed research outcomes, if researchers subsequently make the effort, but that requires additional time and a contract that allows this.

From a measurement point of view, it is very difficult to identify high-quality outcomes of contractual research. High quality could be inferred by high private value measured against the level of project funding. If excellent outcomes of contractual research are reflected in highly cited public–private co-publications, then such publications are counted twice, as the indicator measuring the number of world-class universities and public research institutes in a country is already included.

Figure II.1.5 shows low correlation between the research excellence composite indicator and the indicator measuring 'business financing publicly performed R&D' as a share of GDP. The overall conclusion is that public-private research collaboration requires specific efforts and framework conditions in addition to excellent research performance.

Figure II.1.5: Research Excellence vs. Business financing public research, 2008



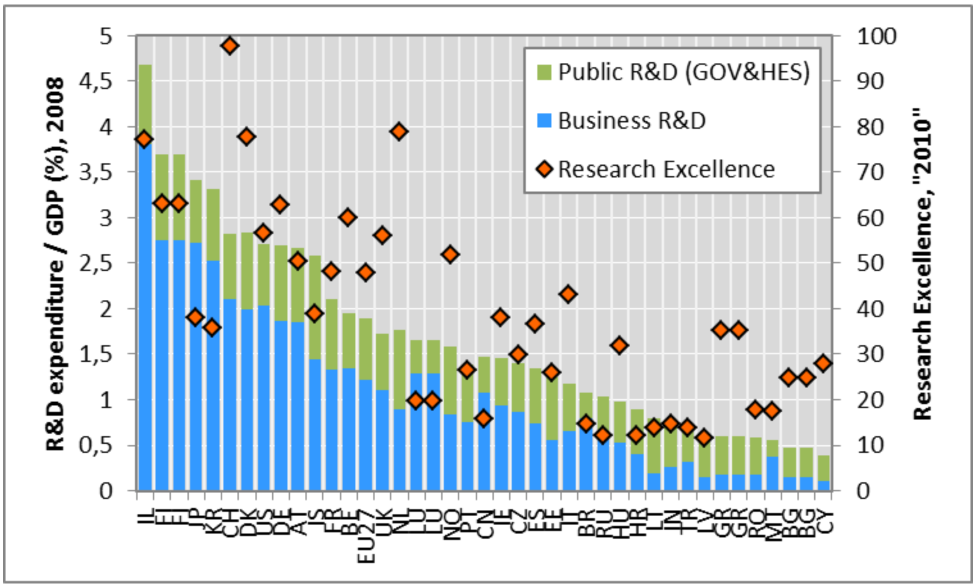
Source: Eurostat and OECD; JRC calculations Innovation Union Competitiveness report 2013

However, countries with medium to high performance in research excellence also have high private R&D expenditure

For most of the countries that perform relatively poorly in terms of research excellence, the lion's share of R&D spending is invested by public institutions (notable exceptions are Luxembourg, China and the Czech Republic) (see Figure II.1.6). This may suggest that these countries have difficulties in attracting large R&D spending multinationals, perhaps due to low levels of research excellence. On the contrary, in countries where the share of R&D expenditure in comparison to GDP shifts from public to private, research excellence rates medium to high. Nevertheless, many leaders in research excellence are also leaders in public R&D spending as a share of GDP (i.e. Sweden, Finland, Israel and the Netherlands). Figure II.1.6 also shows that even if some countries report high R&D investments (both public and private), they do not succeed in transforming them into excellent research outcomes (e.g. Japan and South Korea). It is also interesting to compare the European Union with the United

States. The public R&D spending of the United States is at similar levels with respect to the size of their economy in 2008 (around 0.68 % of GDP). This score correlates with higher business R&D expenditure, although not in proportional terms.

Figure II.1.6: Research excellence scores contrasted with public and business R&D intensity, 2008



Source: Eurostat and OECD; JRC calculations Innovation Union Competitiveness report 2013

2. Science and technology performance at sector level[74]

This chapter presents the research performance of 42 countries, focussing on the European countries in the European Research Area (ERA), but also including data on scientific publications and technological patents in China, India, Japan, South Korea, Brazil, Russia and the United States. This chapter focuses on the research production profiles of these countries in terms of scientific publications and patents in a limited number of sectors. The sectors presented in the chapter cover key fields relevant for the upcoming Horizon 2020, but they also present different types of dynamics in terms of science and technology strengths and change. A full set of data with all sectors can be found in the Statistical annex on the Europa page for the Innovation Union Competitiveness (IUC) report 2013.

The tables in this chapter present a large array of indicators ([75]) for both scientific and technological innovation performance, but the text analysis will focus on the PCT patents and

[74] The analysed sectors are those defined within FP7 as thematic priorities. For this purpose, the scientific papers indexed in Scopus have been classified using the 17 FP7 thematic priorities. More detailed information can be found in the Methodological Annex.
[75] Number of publications: publications are counted based on both full (FULL) and fractional counting (FRAC). Growth index (GI): measures the percentage increase in publications between two periods. In order to obtain a more accurate indicator, we used the last eight years of the actual study period for the calculation of the GI; as older data in Scopus may be incomplete, the GI is calculated comparing the output of the 2008–2011 period to

the 10 % cited publications to ensure consistency with the indicators in the composite indicator above on science and technology excellence. However, it is also very relevant to note the total numbers in absolute values, in publications as well as in patents in the European Patent Office (EPO) and United States Patent and Trademark Office (USPTO).

The largest number of scientific publications is produced in Europe

Over the period 2000–2010, the world produced about 10.9 million publications under the Seventh Framework Programme (FP7) thematic priorities. The European Research Area countries as a whole produced the highest number of scientific publications in these areas, although the United States is the single country with the greatest output. The second country in terms of scientific publications is now China, while the United Kingdom, Japan and Germany stay at a comparable but lower level in terms of their scientific output in these research areas.

Quite a few countries published fewer than 10 000 publications in these research areas. Not surprisingly, many countries achieved large increases in their scientific output over this period in most sectors. Smaller countries may present higher growth given their lower overall numbers. This is the case for countries such as Luxembourg, Lithuania, Latvia, Malta, Cyprus, the former Yugoslav Republic of Macedonia (FYROM) and Liechtenstein, which display large growth indices but have fewer than 10 000 publications. The increase in scientific output of China, Brazil, South Korea, India and Turkey in most of the FP7 thematic areas is in this sense quite remarkable as they all have a very large number of scientific publications (over 160 000 each).

However, the scientific impact of European countries is only slightly higher than the world average in most of these thematic areas

The Unites States clearly stands out, with a scientific impact noticeably above the world level in most of the thematic areas. In comparison, the scientific impact of the ERA countries is only slightly higher than the world level, while Japan and China display an impact below the

that of the 2004–2007 period. Specialisation index (SI): an indicator of research intensity in a given research area. Average of Relative Citations (ARC): a field-normalised measure of observed scientific impact (also takes account of the publication year and document type of scientific contributions in the normalisation process). In this report, the ARC is based on data from the 2000–2008 period, due to incomplete citation windows for documents published later. Average of Relative Impact Factors (ARIF): a field-normalised measure of the expected scientific impact of publications produced by a given entity (e.g. the world, a country, a NUTS2 region, an institution) based on the impact factors of the journals in which they were published. As such, the ARIF is an indirect impact indicator reflecting the scientific 'quality' measured by the average citation rate of the journal instead of the actual publications (also takes the publication year of scientific contributions into account in the normalisation process). Highly cited publications: the percentage of papers in the 10 % most cited papers in the reference database (makes use of the normalised citation score of individual publications). Collaboration index (CI): a scale-adjusted metric of scientific collaboration comparing the observed number of co-publications of an entity (e.g. a country or NUTS2 region) to that expected given the size of the scientific production of the given entity.

average observed at world level. However, European countries and the Unites States each have their respective strengths and weaknesses. Overall, the performance of European countries in most of the sectors suffers from lower scientific impact, whereas that of the United States is hampered by the relatively smaller size of its production and lower growth level. At country level, several European countries have comparable or higher scientific quality than the Unites states. This is the case for Iceland, Switzerland, Denmark, the Netherlands, Sweden, Belgium, Finland, Germany and the United Kingdom in most sectors.

Europe holds a strong position in quality science relevant to societal challenges in energy, transport and the environment

As pointed out previously in this report (see the introductory chapter on Europe's competitive position in research and innovation), ERA countries as a whole lead in several scientific fields related to societal challenges. Both in energy and in environment, European countries have a scientific impact above the world average. In the field of health research, the scientific impact of Europe clearly lags behind the United States, but it is still slightly above the world average. In the field of energy, Israel, Switzerland, Cyprus, Denmark, Germany, Portugal and Spain have the highest scientific impact. On the other hand, Malta, Switzerland, Belgium, Denmark, Sweden and the United Kingdom have the best performance in terms of scientific impact related to environment.

In terms of science for key enabling technologies, ERA countries as a whole, as well as the EU Member States, perform above the world average in terms of scientific impact in ICT. But their performance is weaker in nanotechnologies, where Europe scores very close to the world average. European science has, however, higher quality in publications related to industrial sectors, such as aeronautics, new production technologies, other transport technologies and materials. As a whole, the EU-28 has achieved higher scientific quality than the United States in these last two areas.

However, in technological innovation for solving societal challenges, key enabling technologies and industry-related sectors, Europe lags behind the United States and Japan

Over the period 2000–2010, the world produced over one million PCT patent applications in the different thematic areas. The ERA countries taken together produced close to 28 % of these PCT patent applications, comparable to the United States. Nevertheless, when counting the PCT patent applications per billion GDP, ERA countries, taken together, lag behind the United States in all the thematic areas. Europe’s main strengths are in technology development for energy, ICT, materials, new production technologies, materials and automobile, where Europe performs better.

Focussing on technology development in health and energy, both relevant for addressing societal challenges, the findings are slightly different. In health technologies, the greatest producers are Israel, Iceland, Switzerland, the United States, Sweden and Germany. In technology development for energy, Japan takes the lead with the highest number of PTC patents per billion GDP, far above the United States and the world average. Among the countries inside the ERA, Germany, Switzerland, Sweden and Israel contribute the most to technological innovation in energy, followed by countries as Finland, Denmark, Austria and the Netherlands. Europe is also falling behind in technology development for environment, also full of potential when addressing societal challenges. Here it is Japan, the Unites states and South Korea that have taken the world lead. Inside Europe, technological development in environmental research is mainly driven by Germany, Sweden, Finland and the Netherlands.

Another important area of technological development is key enabling technologies, relevant for both established industry and growing markets. In this context, Israel is the only country within the ERA at the top in terms of ICT- and new production technology-related technological innovation, at a level comparable with those of South Korea, Japan and the United States. The European countries with the highest number of ICT and new production technology patent applications per billion GDP are Finland, Sweden, Germany, the Netherlands, Switzerland and the United Kingdom. Within the ERA, the only countries with a high level of technological development in nanotechnologies are the Netherlands, Sweden, Switzerland and Israel. Technological development in other transport technologies is led by Japan and the United States, along with European countries such as Austria, Finland, Sweden or Norway.

Broadly, there is a correlation between scientific quality and technology development. However, there are some differences by thematic priority

Chapter I.1 revealed a relationship between the scientific impact achieved by a country and its ability to apply research to innovation. This correlation can also be observed at sectoral level: many countries with scientific excellence in a specific sector are also achieving a high level of high-impact technology development as measured by the PCT patent application data. However, some differences can be highlighted between thematic priorities and countries. Looking at energy, environment and health, this correlation is better observed in Germany, Switzerland, Denmark, Finland, Japan, the United States, Israel, Belgium and Austria. These countries combine scientific quality in the field with technological development for the global market. On the other hand, catching-up countries (e.g. The Baltic countries, Croatia, Malta and Spain) score very low in terms of patents, despite high levels of scientific impact. This path can also be observed in security, food and biotechnology. ICT and nanotechnologies show similar trends and again countries such as Italy, Spain or Turkey, although performing well in terms of scientific impact, maintain a lower technological innovation capacity. Greece is a particularly striking case in the aeronautical sector, having one of the highest scientific impacts coupled with one of the lowest scores in number of patents ([76]).

New production technologies and other transport technologies show similar trends of correlation and systemic blockages. Nevertheless, these sectors display a particular research performance profile not found in the other sectors: countries with the best technological innovation performance have lower scientific impact in their publications. This is the case for

[76] A more in-depth analysis of science and technology co-development is presented in Chapter II.5.

Finland and Japan regarding other transport technologies, and Austria and Finland for new production technologies. The same is true of aeronautics and automobile sectors for certain countries, such as Germany and France. One possible explanation is the capacity of these countries to source relevant and quality-based science from abroad. However, it may also indicate that technology development does not necessarily have to be based on highly cited science but rather on the right science and combinations of knowledge available.

The United States is a world centre in science and technology ***for health, while in Europe the highest scientific impact is found in Iceland, Switzerland and the Netherlands. The most dynamic technological development is in Sweden and Denmark***

Figure II.2.1 Scientific publications in the field of health, 2000–2010

	Publications			Growth Index	CI	SI	ARC	ARIF	% share of publications (FULL) in the top 10% most cited publications worldwide
	Full counting method (FULL)	Fractional counting method (FRAC)	Trend						
Belgium	78993	54675		1,18 –	1,39 ▲	1,16 ▲	1,39 ▲	1,12 ▲	14,4% ▲
Bulgaria	7011	5220		0,93 ▼	0,78 ▼	0,73 ▼	0,44 ▼	0,60 ▼	3,4% ▼
Czech Republic	36200	29350		1,23 –	0,71 ▼	0,99 –	0,56 ▼	0,57 ▼	4,0% ▼
Denmark	60896	42019		1,19 –	1,29 ▲	1,33 ▲	1,45 ▲	1,15 ▲	15,3% ▲
Germany	437899	346587		1,11 ▼	1,18 ▲	1,15 ▲	1,11 ▲	0,99 –	11,4% ▲
Estonia	3101	1918		1,43 ▲	1,19 ▲	0,63 ▼	1,13 ▲	1,04 –	9,5% –
Ireland	25526	17904		1,60 ▲	1,17 ▲	1,05 –	1,25 ▲	1,12 ▲	12,2% ▲
Greece	44773	36146		1,60 ▲	0,86 ▼	1,07 –	0,88 ▼	0,92 –	7,6% ▼
Spain	181553	150593		1,34 –	0,83 ▼	1,10 –	0,86 ▼	0,84 ▼	7,7% ▼
France	300166	239953		1,08 ▼	1,08 –	1,09 –	0,99 –	0,91 –	9,8% –
Croatia	13541	11480		1,32 –	0,46 ▼	1,06 –	0,40 ▼	0,51 ▼	2,9% ▼
Italy	256775	209538		1,21 –	0,98 –	1,21 ▲	1,05 –	1,01 –	10,1% –
Cyprus	1112	576		2,07 ▲	1,29 ▲	0,44 ▼	0,79 ▼	0,92 –	7,3% ▼
Latvia	1019	571		1,61 ▲	1,16 ▲	0,42 ▼	1,28 ▲	0,99 –	8,0% ▼
Lithuania	2844	1867		1,51 ▲	1,03 –	0,41 ▼	0,85 ▼	0,88 ▼	6,5% ▼
Luxembourg	1307	612		1,73 ▲	1,36 ▲	0,89 ▼	1,07 –	1,03 –	10,9% –
Hungary	24326	17637		1,22 –	1,09 –	0,94 –	0,91 –	0,89 ▼	7,5% ▼
Malta	647	428		2,08 ▲	0,80 ▼	1,18 ▲	1,30 ▲	0,96 –	12,5% ▲
Netherlands	162460	120800		1,28 –	1,29 ▲	1,37 ▲	1,45 ▲	1,25 ▲	15,7% ▲
Austria	55447	39001		1,05 ▼	1,27 ▲	1,20 ▲	1,22 ▲	1,07 –	12,8% ▲
Poland	72130	60297		1,36 –	0,59 ▼	0,91 –	0,56 ▼	0,57 ▼	3,5% ▼
Portugal	21814	15413		1,75 ▲	1,15 ▲	0,67 ▼	0,99 –	0,92 –	9,1% –
Romania	6718	4837		2,83 ▲	0,84 ▼	0,31 ▼	0,68 ▼	0,68 ▼	5,2% ▼
Slovenia	8217	6333		1,39 ▲	0,78 ▼	0,71 ▼	0,72 ▼	0,79 ▼	5,8% ▼
Slovakia	11176	8462		1,05 ▼	0,83 ▼	0,91 –	0,53 ▼	0,53 ▼	3,5% ▼
Finland	46555	34078		1,03 ▼	1,21 ▲	1,05 –	1,47 ▲	1,27 ▲	14,7% ▲
Sweden	107162	76859		1,06 ▼	1,39 ▲	1,28 ▲	1,41 ▲	1,20 ▲	14,1% ▲
United Kingdom	500333	389820		1,13 ▼	1,28 ▲	1,22 ▲	1,29 ▲	1,21 ▲	13,9% ▲
EU (1)	2163762	1911495		1,18 –	:	1,14 ▲	1,01 –	0,99 –	10,1% –
Iceland	2902	1619		1,36 –	1,28 ▲	1,19 ▲	1,81 ▲	1,30 ▲	17,4% ▲
Liechtenstein	143	58		1,95 ▲	1,16 ▲	0,73 ▼	1,40 ▲	1,17 ▲	15,5% ▲
Norway	40267	28399		1,30 –	1,21 ▲	1,13 ▲	1,34 ▲	1,11 ▲	13,0% ▲
Switzerland	105426	68101		1,19 –	1,63 ▲	1,20 ▲	1,45 ▲	1,21 ▲	16,0% ▲
Macedonia (2)	743	546		1,91 ▲	0,67 ▼	0,82 ▼	0,58 ▼	0,60 ▼	5,6% ▼
Turkey	97077	89581		1,49 ▲	0,30 ▼	1,35 ▲	0,52 ▼	0,63 ▼	2,9% ▼
Israel	60493	47427		1,03 ▼	0,97 –	1,19 ▲	1,09 –	1,13 ▲	10,4% –
Russian Federation	48587	40657		0,92 ▼	0,76 ▼	0,39 ▼	0,35 ▼	0,38 ▼	2,6% ▼
United States	1898117	1631625		1,15 –	0,93 –	1,20 ▲	1,38 ▲	1,28 ▲	15,3% ▲
Japan	426107	380218		1,01 ▼	0,60 ▼	1,03 –	0,80 ▼	0,89 ▼	6,7% ▼
China	348359	306564		2,05 ▲	0,62 ▼	0,44 ▼	0,58 ▼	0,70 ▼	4,7% ▼
South Korea	97295	84758		1,99 ▲	0,65 ▼	0,70 ▼	0,88 ▼	0,95 –	7,4% ▼
India	111452	101245		1,69 ▲	0,45 ▼	0,71 ▼	0,49 ▼	0,62 ▼	3,0% ▼
Brazil	118997	101239		2,06 ▲	0,65 ▼	1,11 ▲	0,69 ▼	0,73 ▼	4,8% ▼
Total World	5590402	5590402		1,25 –	:	1,00 –	1,00 –	1,00 –	10,0% –

Source: DG Research and Innovation - Economic Analysis Unit — Innovation Union Competitiveness report 2013
Data: Science Metrix / Scopus (Elsevier)
Notes: (1) EU: Croatia is not included.
(2) The Former Yugoslav Republic of Macedonia.

Health is a large research area, representing a total of 5.6 million publications at the world level. The United States produces the largest number of publications in this field, but ERA countries taken together exceed United States output. The second greatest number of publications is produced by the United Kingdom. The countries with the highest growth index are Romania, Malta and Cyprus. China had the fifth highest growth index and its output has increased substantially faster than that of the world. Focussing on scientific impact, the three countries with the highest percentage of publications in the 10 % most cited publications in health are Iceland, Switzerland and the Netherlands. With the exception of Iceland and the United States, the remaining top 10 countries in terms of scientific impact are members of the European Union.

Figure II.2.2 Patents (1) in the field of health, 2000–2010

	PCT (2)					EPO (2)				USPTO (3)			
	Total 2000-2010	Total per billion GDP (PPS€)	Trend 2000-2010	Growth (4)	RTA (5)	Total 2000-2010	Trend 2000-2010	Growth (4)	RTA (5)	Total 2000-2010	Trend 2000-2010	Growth (4)	RTA (5)
Belgium	1808	1,61		66,0	1,01	1628		66,8	0,86	512		-42,8	1,29
Bulgaria	32	0,00		-3,3	0,77	23		17,5	0,95	0		0,0	0,00
Czech Republic	221	0,26		83,1	1,06	176		65,1	1,16	53		-24,1	1,52
Denmark	2567	2,97		90,4	1,53	2092		76,4	1,69	515		-56,2	2,37
Germany	15592	2,05		58,3	0,73	16557		55,6	0,70	4867		-34,4	1,00
Estonia	31	0,29		24,7	0,77	18		17,7	1,00	6		-75,8	2,67
Ireland	786	1,45		92,4	1,47	578		58,8	1,69	205		-15,0	1,62
Greece	171	0,16		45,0	1,21	134		37,3	1,23	38		-73,0	2,00
Spain	1991	0,32		125,7	1,21	1645		127,1	1,29	362		-45,4	1,97
France	8088	1,40		51,3	0,92	7494		45,9	0,83	2400		-44,7	1,34
Croatia	161	0,86		169,1	1,79	113		102,9	3,00	54		-69,5	6,56
Italy	4108	0,75		69,2	1,26	4390		54,3	1,06	1119		-48,5	1,61
Cyprus	23	0,05		83,3	1,42	17		110,5	1,18	1		66,7	0,66
Latvia	86	0,69		152,3	2,32	62		101,8	2,88	19		-57,1	6,85
Lithuania	11	0,06		135,0	0,55	9		1.550,2	0,69	3		-50,0	0,39
Luxembourg	41	0,30		119,9	0,53	33		79,4	0,26	10		-41,0	0,37
Hungary	415	0,62		61,0	1,30	305		50,9	1,59	98		-29,3	2,75
Malta	2	0,11		0,0	0,32	3		100,0	0,42	1		0,0	0,73
Netherlands	3073	1,55		70,2	0,63	2579		66,0	0,64	825		-50,4	1,06
Austria	1216	1,31		67,9	0,81	1236		56,5	0,79	341		-43,3	1,18
Poland	211	0,11		36,4	0,96	145		90,2	0,92	66		-15,2	2,02
Portugal	135	0,13		162,1	1,11	113		91,2	1,20	28		-65,4	2,52
Romania	34	0,02		70,6	0,59	22		302,1	0,70	5		-47,6	0,39
Slovenia	221	0,62		198,1	1,85	216		288,2	2,27	26		-38,8	2,91
Slovakia	48	0,08		38,8	0,72	29		18,6	0,69	8		-70,6	1,50
Finland	612	1,50		14,0	0,29	537		34,4	0,35	223		-52,0	0,53
Sweden	3726	3,44		49,6	0,98	3012		36,4	1,15	975		-66,9	1,68
United Kingdom	10543	1,51		44,8	1,15	8279		32,4	1,22	2550		-57,3	1,31
EU (6)	51238	1,13		58,9	0,88	47142		52,2	0,86	13889		-46,3	1,19
Iceland	124	7,13		49,1	1,74	89		64,1	2,13	62		-24,1	4,34
Liechtenstein	25	:		154,6	1,04	87		53,4	2,11	38		-33,9	3,55
Norway	555	0,57		32,4	0,59	418		35,2	0,82	123		-59,9	0,85
Switzerland	5320	5,21		92,8	1,61	5239		73,7	1,46	1530		-38,8	2,18
Macedonia (7)	4	0,00		0,0	0,89	0		0,0	0,00	0		0,0	3,65
Turkey	153	0,02		135,7	0,70	78		100,9	0,69	19		-16,7	1,14
Israel	3978	8,56		88,7	1,52	2670		77,2	2,00	1337		-43,1	1,84
Russian Federation	1006	0,07		75,3	0,92	405		84,4	1,20	163		-39,8	1,06
United States	79425	5,15		89,4	1,29	54158		53,0	1,46	57448		-33,2	1,19
Japan	15377	1,77		87,4	0,58	11880		55,5	0,53	5893		-42,7	0,35
China	3264	0,06		98,9	0,64	1024		174,8	0,72	463		34,7	0,69
South Korea	3067	0,73		94,4	0,53	1252		74,9	0,33	803		-32,7	0,25
India	2585	0,20		207,8	1,66	1271		106,1	1,89	633		-14,3	1,37
Brazil	530	0,05		134,5	1,10	239		94,6	1,17	83		-69,8	1,18
Total World	162946	:		79,5	1,00	121195		55,6	1,00	81258		-36,1	1,00

Source: DG Research and Innovation - Economic Analysis Unit

Innovation Union Competitiveness report 2013

Data: University Bocconi (Italy), Eurostat, OECD

Notes: (1) Full counting method.

(2) Patent applications.

(3) Patents granted.

(4) Growth: Growth rate in the number of patents between 2000-2002 and 2003-2006.

(5) RTA: Revealed Technological Advantage index in the period 2000-2010.

(6) EU: Croatia is not included.

(7) The Former Yugoslav Republic of Macedonia.

Germany and the United Kingdom produce the largest absolute number of PCT in health, but Denmark and Sweden have a higher number of PCT per GDP. Of all countries, the United States and Japan have the greatest concentration in PCT patents in health, while Israel and Iceland have the highest number of PCT applications per billion GDP. India and China, emerging global players, already have great outputs in terms of total number of patents in health. Patents and scientific impact seem to be correlated, although certain countries are weak in terms of patents, despite high levels of scientific impact in publications (e.g. Spain).

China produces most scientific publications in the field of energy worldwide, but with a lower impact, while Japan has the highest rate of technology development in energy

Figure II.2.3 Scientific publications in the field of energy, 2000–2010

	Publications			Growth Index	CI	SI	ARC	ARIF	% share of publications (FULL) in the top 10% most cited publications worldwide
	Full counting method (FULL)	Fractional counting method (FRAC)	Trend						
Belgium	2928	2003		1,62	1,56	0,66	1,19	1,32	11,7%
Bulgaria	711	478		1,42	1,42	1,04	1,45	1,41	13,8%
Czech Republic	1093	759		2,07	1,28	0,40	1,33	1,47	12,1%
Denmark	2121	1540		1,72	1,30	0,76	2,03	1,48	22,2%
Germany	16212	11731		1,27	1,62	0,61	1,55	1,30	16,0%
Estonia	569	489		1,98	0,68	2,51	1,23	1,34	12,4%
Ireland	917	670		1,79	1,15	0,61	1,52	1,50	16,7%
Greece	2474	2085		1,93	0,79	0,96	1,51	1,44	15,0%
Spain	7477	5912		1,97	1,22	0,67	1,86	1,64	20,1%
France	14056	10525		1,51	1,50	0,74	1,46	1,41	15,8%
Croatia	633	529		1,11	0,66	0,76	0,77	1,07	8,2%
Italy	8873	7133		1,50	1,13	0,64	1,41	1,37	14,6%
Cyprus	155	92		1,95	1,38	1,10	2,20	1,56	23,2%
Latvia	165	106		1,97	1,24	1,23	0,63	1,32	4,3%
Lithuania	708	621		2,09	0,55	2,12	0,86	1,09	6,4%
Luxembourg	42	27		1,55	0,99	0,63	:	1,28	:
Hungary	915	673		1,30	1,14	0,56	1,30	1,43	12,6%
Malta	20	10		:	:	:	:	:	:
Netherlands	4384	3157		1,76	1,41	0,56	1,34	1,28	14,0%
Austria	1758	1164		1,38	1,53	0,56	1,22	1,23	12,4%
Poland	3116	2499		1,63	1,02	0,59	1,44	1,62	14,2%
Portugal	1779	1345		2,22	1,27	0,91	1,78	1,56	20,4%
Romania	1344	1058		4,29	0,99	1,06	0,92	0,92	8,8%
Slovenia	748	599		1,41	0,88	1,04	1,29	1,44	13,8%
Slovakia	306	200		1,26	1,38	0,33	0,90	1,37	8,7%
Finland	1998	1520		1,23	1,14	0,73	1,20	1,23	13,9%
Sweden	5500	4354		0,99	1,10	1,13	1,19	1,09	13,3%
United Kingdom	16628	12274		1,37	1,52	0,60	1,28	1,23	13,8%
EU (1)	84448	73026		1,50	:	0,68	1,38	1,34	14,5%
Iceland	58	35		2,64	1,20	0,40	1,66	1,44	17,2%
Liechtenstein	2	1		:	:	:	:	:	:
Norway	2900	2066		2,25	1,19	1,28	1,06	1,05	9,7%
Switzerland	3707	2506		1,47	1,65	0,69	1,88	1,37	20,6%
Macedonia (2)	84	55		0,98	1,24	1,28	1,30	1,63	14,3%
Turkey	4228	3866		2,29	0,47	0,91	1,63	1,27	17,8%
Israel	1205	948		1,07	1,08	0,37	1,85	1,74	22,1%
Russian Federation	14018	12168		1,26	0,60	1,81	0,38	0,41	3,0%
United States	74683	62516		1,40	0,92	0,72	1,11	1,05	11,4%
Japan	30229	27178		1,08	0,67	1,15	1,23	1,25	12,1%
China	98354	93269		2,28	0,31	2,09	0,76	0,70	7,1%
South Korea	11623	10249		1,67	0,75	1,32	1,39	1,55	15,5%
India	11730	10658		1,69	0,50	1,17	0,92	1,08	8,4%
Brazil	5706	4830		1,78	0,78	0,82	1,17	1,35	12,0%
Total World	370758	370758		1,65	:	1,00	1,00	1,00	10,0%

Source: DG Research and Innovation - Economic Analysis Unit — Innovation Union Competitiveness report 2013
Data: Science Metrix / Scopus (Elsevier)
Notes: (1) EU: Croatia is not included.
(2) The Former Yugoslav Republic of Macedonia.

China leads among the 42 selected countries based on number of publications in energy research, and actually produced more scientific publications than all EU Member States taken together. This is a relatively large field, with a total of 371 000 publications at world level. At the country level, the United States and Japan have the next largest outputs, ahead of three large Member States (Germany, France and the United Kingdom). Iceland, Romania, the Czech Republic and Lithuania have a greater growth rate but an overall lower level of scientific publications in energy. Nevertheless, China and Turkey both have high output and strong growth. Looking at scientific impact, Cyprus has the greatest percentage of its publications in the 10 % most-cited publications. This is far superior to that of the main producers of energy-related publications, including the United Kingdom, Japan and the United States. On the other hand, impact scores for the largest producer, China, are consistently below the world average.

Figure II.2.4 Patents (1) in the field of energy, 2000–2010

	PCT (2)					EPO (2)				USPTO (3)			
	Total 2000-2010	Total per billion GDP (PPS€)	Trend 2000-2010	Growth (4)	RTA (5)	Total 2000-2010	Trend 2000-2010	Growth (4)	RTA (5)	Total 2000-2010	Trend 2000-2010	Growth (4)	RTA (5)
Belgium	621	0,92		16,9	0,70	885		21,7	0,70	293		-33,6	0,71
Bulgaria	34	0,10		56,7	1,64	20		345,3	1,25	8		119,1	0,58
Czech Republic	127	0,27		84,4	1,24	111		85,8	1,10	55		-4,2	1,51
Denmark	1040	1,56		66,2	1,25	960		55,5	1,16	271		-24,2	1,21
Germany	16292	3,15		45,9	1,54	21364		29,2	1,35	7460		-35,2	1,48
Estonia	21	0,19		44,1	1,07	10		21,6	0,89	4		-25,0	1,55
Ireland	202	0,40		95,9	0,76	148		78,3	0,65	56		-12,8	0,43
Greece	75	0,05		79,4	1,08	62		54,2	0,85	12		146,5	0,64
Spain	761	0,14		101,5	0,94	780		78,7	0,91	162		-23,6	0,85
France	4799	1,23		74,9	1,10	6417		60,8	1,06	2107		-15,4	1,14
Croatia	36	0,13		-31,2	0,83	23		192,9	0,91	8		-16,7	1,02
Italy	1996	0,70		89,2	1,23	3785		51,9	1,36	1048		-30,6	1,46
Cyprus	8	0,05		140,0	0,99	8		125,0	0,87	1		0,0	0,56
Latvia	16	0,00		190,3	0,88	8		176,5	0,57	0		0,0	0,33
Lithuania	21	0,06		8,8	2,15	6		-45,0	0,75	3		-51,9	0,50
Luxembourg	44	0,66		66,2	1,14	144		90,0	1,63	22		-30,7	0,79
Hungary	105	0,13		100,5	0,67	59		87,3	0,46	21		54,2	0,60
Malta	3	0,00		500,1	1,07	7		140,0	1,51	0		0,0	0,18
Netherlands	1791	1,14		43,7	0,75	1724		27,8	0,64	608		-40,0	0,76
Austria	997	1,60		75,2	1,35	1186		35,3	1,13	418		-43,6	1,40
Poland	128	0,06		13,8	1,18	149		235,7	1,41	35		40,4	1,05
Portugal	62	0,06		137,7	1,04	61		172,7	0,96	12		-23,3	1,07
Romania	35	0,05		44,6	1,19	19		28,5	0,90	13		-50,5	0,98
Slovenia	63	0,33		35,1	1,07	53		27,6	0,83	14		-61,0	1,53
Slovakia	55	0,12		50,7	1,66	49		214,1	1,72	12		-23,2	2,10
Finland	649	1,79		22,6	0,62	664		26,6	0,64	267		-24,1	0,61
Sweden	1772	2,17		15,5	0,94	1512		40,1	0,86	615		-37,1	1,03
United Kingdom	3697	1,10		30,5	0,82	3797		27,2	0,83	1859		-27,5	0,93
EU (6)	33804	1,20		48,8	1,17	42074		37,1	1,12	14722		-31,0	1,20
Iceland	19	0,46		-15,8	0,55	11		-17,3	0,40	4		-79,2	0,29
Liechtenstein	8	:		212,5	0,69	15		-11,4	0,58	7		-60,9	0,64
Norway	456	0,44		46,1	0,98	264		63,7	0,77	96		-44,0	0,64
Switzerland	1444	2,90		55,5	0,89	2285		27,9	0,95	851		-36,1	1,17
Macedonia (7)	4	0,00		-85,0	1,80	0		0,0	0,00	0		0,0	0,00
Turkey	345	0,05		326,3	3,17	203		182,0	2,66	44		-75,1	2,46
Israel	617	2,05		51,0	0,48	331		52,2	0,37	320		-14,0	0,43
Russian Federation	763	0,08		65,1	1,42	272		64,6	1,19	181		-26,1	1,14
United States	22071	3,80		60,5	0,72	18756		19,3	0,75	42393		-4,3	0,85
Japan	17208	6,68		139,0	1,30	17952		33,3	1,18	22255		-13,0	1,30
China	2453	0,11		85,4	0,97	694		165,3	0,72	862		146,2	1,24
South Korea	3163	3,27		157,8	1,11	2904		210,4	1,13	3583		33,6	1,06
India	379	0,07		132,5	0,49	232		112,8	0,51	225		28,4	0,47
Brazil	426	0,07		90,5	1,79	234		74,3	1,70	115		-34,3	1,59
Total World	84255	:		71,2	1,00	85797		37,0	1,00	89320		-8,4	1,00

Source: DG Research and Innovation - Economic Analysis Unit — Innovation Union Competitiveness report 2013
Data: University Bocconi (Italy), Eurostat, OECD
Notes: (1) Full counting method.
(2) Patent applications.
(3) Patents granted.
(4) Growth: Growth rate in the number of patents between 2000-2002 and 2003-2006.
(5) RTA: Revealed Technological Advantage index in the period 2000-2010.
(6) EU: Croatia is not included.
(7) The Former Yugoslav Republic of Macedonia.

The United States leads among the 42 selected countries based on number of PCT patents in energy, followed by Japan, Germany, France, South Korea and the United Kingdom. However, Japan has the best performance in terms of patents in energy per GDP at global level, scoring far above other world regions, including the ERA countries taken together. Inside Europe, Germany remains the best performer, followed by Finland, Austria and Denmark. The Baltic, the Mediterranean and the central and eastern European countries are less able to turn their high scientific impact in the energy sector into technological development.

Japan and the United States hold a strong position in environmental technologies, but Germany, the Netherlands, Sweden and Finland combine high scientific impact with intensive technology development

Figure II.2.5 Scientific publications in the field of the environment, 2000–2010

	Publications			Growth Index	CI	SI	ARC	ARIF	% share of publications (FULL) in the top 10% most cited publications worldwide
	Full counting method (FULL)	Fractional counting method (FRAC)	Trend						
Belgium	7452	4649		1,26	1,29	0,85	1,51	1,24	17,0%
Bulgaria	905	526		1,12	1,15	0,63	0,79	0,91	4,9%
Czech Republic	4823	3511		1,38	0,90	1,02	0,96	0,94	9,2%
Denmark	7296	4427		1,19	1,28	1,20	1,54	1,22	17,4%
Germany	47498	32511		1,22	1,31	0,93	1,30	1,11	14,4%
Estonia	1147	772		1,28	0,89	2,19	1,20	1,08	12,1%
Ireland	2154	1252		1,64	1,17	0,63	1,27	1,25	13,2%
Greece	5580	4202		1,37	0,83	1,07	1,04	1,02	9,6%
Spain	19720	14850		1,59	0,99	0,93	1,18	1,17	12,3%
France	37936	25205		1,26	1,38	0,98	1,33	1,18	14,2%
Croatia	1276	1062		1,22	0,51	0,84	0,56	0,79	3,8%
Italy	23924	17775		1,53	1,03	0,89	1,17	1,13	11,6%
Cyprus	255	123		3,39	1,15	0,81	0,73	0,93	7,7%
Latvia	209	146		1,90	0,66	0,94	0,85	0,79	7,4%
Lithuania	812	659		2,33	0,49	1,24	0,49	0,65	3,5%
Luxembourg	250	114		2,29	1,32	1,43	1,32	1,13	14,6%
Hungary	2849	2038		1,30	0,85	0,93	0,80	0,84	7,8%
Malta	76	38		1,16	0,91	0,92	1,47	0,91	22,8%
Netherlands	16078	10188		1,30	1,32	0,99	1,47	1,25	16,6%
Austria	6039	3414		1,31	1,33	0,90	1,24	1,03	12,6%
Poland	8209	6790		1,50	0,60	0,88	0,63	0,71	4,5%
Portugal	4353	3073		1,97	0,99	1,15	1,09	1,13	10,0%
Romania	1718	1214		4,65	0,83	0,67	0,84	0,90	7,0%
Slovenia	1364	1042		1,77	0,67	1,00	0,80	0,82	7,4%
Slovakia	1781	1331		1,15	0,77	1,23	0,58	0,61	4,4%
Finland	7596	5263		1,11	1,08	1,39	1,36	1,18	14,6%
Sweden	12190	7781		1,15	1,24	1,11	1,46	1,24	15,8%
United Kingdom	53156	35819		1,16	1,34	0,97	1,42	1,24	15,9%
EU (1)	225914	188716		1,31	:	0,97	1,18	1,12	12,2%
Iceland	763	398		1,11	1,27	2,52	1,36	1,25	14,3%
Liechtenstein	13	8		:	:	:	:	:	:
Norway	10151	6304		1,38	1,28	2,15	1,34	1,17	14,1%
Switzerland	13702	8181		1,41	1,42	1,24	1,73	1,32	20,8%
Macedonia (2)	85	44		3,45	1,02	0,61	0,78	0,76	5,7%
Turkey	7190	6219		1,64	0,50	0,81	0,85	0,82	7,3%
Israel	4109	2932		1,18	0,98	0,63	1,14	1,20	10,6%
Russian Federation	24411	20156		1,15	0,69	1,66	0,40	0,41	2,9%
United States	208785	172100		1,20	0,88	1,09	1,27	1,20	14,2%
Japan	31019	24409		1,25	0,92	0,57	0,99	1,06	8,9%
China	77114	68500		2,33	0,59	0,85	0,73	0,71	6,5%
South Korea	8644	6528		1,57	0,92	0,47	0,96	1,04	8,9%
India	22362	20121		1,38	0,39	1,22	0,48	0,61	3,3%
Brazil	10527	7938		1,81	0,90	0,75	0,90	0,96	8,0%
Total World	637303	637303		1,39	:	1,00	1,00	1,00	10,0%

Source: DG Research and Innovation - Economic Analysis Unit — Innovation Union Competitiveness report 2013
Data: Science Metrix / Scopus (Elsevier)
Notes: (1) EU: Croatia is not included.
(2) The Former Yugoslav Republic of Macedonia.

The United States leads for the 2000–2010 period in terms of absolute number of scientific publications in environment. China is the second largest producer, followed by the United Kingdom, Germany, France, Italy, Spain and the Netherlands. Outside of Europe, Japan, Russia and India are also in the top 10 based on number of publications. China, Italy and Spain have a growth index that is superior to the world level, and Romania, FYROM, Cyprus, Lithuania and Luxembourg significantly increased their output over the period.

In terms of scientific impact, many European countries (e.g. Switzerland, Denmark, the United Kingdom, the Netherlands, Belgium, Sweden, Finland, Germany, Luxembourg, Ireland and France), along with the United states, perform above the world average.

Figure II.2.6 Patents [1] in the field of the envronment, 2000–2010

	PCT [2]					EPO [2]				USPTO [3]			
	Total 2000-2010	Total per billion GDP (PPS€)	Trend 2000-2010	Growth [4]	RTA [5]	Total 2000-2010	Trend 2000-2010	Growth [4]	RTA [5]	Total 2000-2010	Trend 2000-2010	Growth [4]	RTA [5]
Belgium	506	0,52		29,3	1,11	584		16,1	1,14	164		-43,4	1,06
Bulgaria	19	0,02		3,8	1,80	8		184,1	1,31	2		-54,9	0,53
Czech Republic	71	0,10		46,6	1,34	55		111,1	1,34	21		24,7	1,53
Denmark	720	0,90		69,5	1,68	651		64,4	1,94	156		-28,4	1,85
Germany	5676	0,85		26,0	1,04	7057		21,7	1,10	2017		-39,4	1,06
Estonia	13	0,14		199,1	1,27	7		105,9	1,59	3		-60,7	3,27
Ireland	109	0,18		24,6	0,80	79		14,0	0,85	25		-40,2	0,52
Greece	60	0,05		96,9	1,66	54		53,8	1,83	11		510,5	1,56
Spain	536	0,08		114,0	1,28	409		118,5	1,18	85		-28,6	1,20
France	2151	0,40		34,1	0,96	2183		33,4	0,89	683		-31,3	0,98
Croatia	21	0,05		5,4	0,92	3		125,0	0,35	3		-70,0	1,16
Italy	881	0,17		77,4	1,06	1208		59,5	1,08	250		-30,1	0,93
Cyprus	10	0,00		140,0	2,52	9		34,5	2,47	0		0,0	0,85
Latvia	6	0,00		20,0	0,71	5		26,1	0,89	0		0,0	0,88
Lithuania	10	0,04		-27,3	2,12	3		-85,7	0,93	2		-63,9	0,99
Luxembourg	20	0,12		-34,3	1,03	35		65,9	1,00	4		-70,0	0,40
Hungary	90	0,06		6,0	1,11	45		-1,3	0,88	10		-32,3	0,74
Malta	1	0,00		0,0	0,62	1		0,0	0,78	0		0,0	0,00
Netherlands	1203	0,62		50,6	0,97	1079		42,7	0,99	328		-48,6	1,08
Austria	435	0,48		27,9	1,14	571		46,0	1,35	125		-52,3	1,11
Poland	84	0,02		35,1	1,49	69		44,4	1,61	13		-61,6	1,07
Portugal	50	0,01		76,7	1,62	30		152,0	1,20	2		-14,3	0,48
Romania	19	0,02		161,3	1,27	9		204,0	1,13	4		94,1	0,84
Slovenia	27	0,05		-1,1	0,90	19		-22,2	0,77	2		0,0	0,78
Slovakia	29	0,03		8,9	1,73	18		84,8	1,60	3		-67,9	1,43
Finland	407	0,71		46,3	0,75	330		34,4	0,79	106		-38,7	0,64
Sweden	770	0,74		22,2	0,79	621		31,0	0,88	211		-40,7	0,93
United Kingdom	2302	0,45		18,0	0,98	1752		4,4	0,95	763		-46,5	1,01
EU [6]	15341	0,38		34,3	1,03	16015		29,7	1,06	4714		-39,0	1,03
Iceland	15	0,46		6,1	0,84	8		-21,1	0,72	4		-59,7	0,78
Liechtenstein	5	:		160,0	0,94	7		23,5	0,71	2		0,0	0,55
Norway	362	0,42		26,4	1,51	213		34,2	1,54	91		-52,1	1,61
Switzerland	630	0,84		30,3	0,75	795		18,2	0,82	247		-49,8	0,91
Macedonia [7]	1	0,00		0,0	1,47	0		0,0	0,00	0		0,0	0,00
Turkey	48	0,00		134,2	0,87	19		31,9	0,62	2		-70,8	0,38
Israel	433	0,98		63,5	0,65	226		50,2	0,63	153		-27,3	0,54
Russian Federation	367	0,04		41,2	1,32	138		37,3	1,50	84		-47,6	1,41
United States	13744	1,59		38,0	0,87	8754		0,1	0,87	17720		-11,2	0,94
Japan	8441	2,13		117,9	1,24	6796		35,8	1,11	7077		-22,6	1,10
China	1272	0,03		28,3	0,97	313		128,9	0,81	243		37,1	0,93
South Korea	1479	1,34		139,3	1,01	955		239,2	0,93	1466		100,8	1,15
India	283	0,04		131,9	0,71	147		72,8	0,81	124		-9,0	0,69
Brazil	152	0,02		200,2	1,23	77		160,9	1,40	40		13,8	1,50
Total World	43454	:		52,3	1,00	34405		27,2	1,00	33300		-14,0	1,00

Source: DG Research and Innovation - Economic Analysis Unit

Innovation Union Competitiveness report 2013

Data: University Bocconi (Italy), Eurostat, OECD

Notes: (1) Full counting method.

(2) Patent applications.

(3) Patents granted.

(4) Growth: Growth rate in the number of patents between 2000-2002 and 2003-2006.

(5) RTA: Revealed Technological Advantage index in the period 2000-2010.

(6) EU: Croatia is not included.

(7) The Former Yugoslav Republic of Macedonia.

The United States and Japan are the world leaders in terms of number of PCT patents in environment for the period 2000–2010, followed by Germany, the United Kingdom, France and the Netherlands. Japan is the country with the highest number of PCT applications per billion GDP, well above other world regions, including all the European Member States together. For this indicator, Germany and the Netherlands remain two of the best performing EU countries, along with Finland and Sweden. In the previous table, Estonia, Malta and Spain were shown to have significant scientific impact in their publications related to environment. However, they remain behind in terms of patents.

China produces the highest number of scientific publications in ICT globally. However, Switzerland, Israel and the United states have the highest scientific impact with their publications, while technology development is most intense in Japan, Israel and South Korea.

Figure II.2.7 Scientific publications in the field of ICT, 2000–2010

	Publications			Growth Index	CI	SI	ARC	ARIF	% share of publications (FULL) in the top 10% most cited publications worldwide
	Full counting method (FULL)	Fractional counting method (FRAC)	Trend						
Belgium	11230	8573		2,08 ▼	1,34 ▲	0,83 ▼	1,40 ▲	1,15 ▲	14,9% ▲
Bulgaria	1587	1191		3,07 ▲	1,11 ▲	0,76 ▼	0,50 ▼	0,71 ▼	4,4% ▼
Czech Republic	7135	5961		3,15 ▲	0,88 ▼	0,92 –	0,78 ▼	0,90 –	7,4% ▼
Denmark	6094	4343		2,17 –	1,47 ▲	0,62 ▼	1,20 ▲	1,00 –	12,7% ▲
Germany	66427	54048		2,20 –	1,27 ▲	0,82 ▼	1,11 ▲	0,93 –	11,6% ▲
Estonia	558	444		3,95 ▲	0,79 ▼	0,67 ▼	0,83 ▼	0,66 ▼	6,7% ▼
Ireland	6659	5207		2,62 ▲	1,15 ▲	1,40 ▲	1,07 –	0,98 –	11,0% ▲
Greece	14192	11773		2,30 –	0,97 –	1,59 ▲	1,06 –	1,17 ▲	11,0% ▲
Spain	36299	30156		2,38 –	1,14 ▲	1,00 –	0,97 –	1,03 –	10,0% –
France	55200	43791		2,18 –	1,41 ▲	0,90 –	1,14 ▲	1,03 –	11,6% ▲
Croatia	1926	1711		2,50 –	0,50 ▼	0,72 ▼	0,43 ▼	0,56 ▼	3,2% ▼
Italy	42688	35270		1,96 ▼	1,17 ▲	0,93 –	1,16 ▲	1,08 –	12,4% ▲
Cyprus	1027	677		3,29 ▲	1,40 ▲	2,37 ▲	0,99 –	1,05 –	11,5% ▲
Latvia	451	406		3,75 ▲	0,36 ▼	1,37 ▲	0,44 ▼	0,53 ▼	6,1% ▼
Lithuania	965	843		2,16 –	0,55 ▼	0,84 ▼	0,69 ▼	0,74 ▼	5,1% ▼
Luxembourg	764	462		8,59 ▲	1,57 ▲	3,16 ▲	0,74 ▼	0,70 ▼	9,2% –
Hungary	4665	3582		2,09 ▼	1,17 ▲	0,87 ▼	0,82 ▼	0,94 –	8,2% ▼
Malta	151	126		7,49 ▲	0,60 ▼	1,59 ▲	0,43 ▼	0,80 ▼	5,5% ▼
Netherlands	20391	15364		2,01 ▼	1,43 ▲	0,79 ▼	1,40 ▲	1,05 –	15,0% ▲
Austria	11141	8628		2,62 ▲	1,25 ▲	1,21 ▲	1,09 –	0,92 –	11,4% ▲
Poland	11894	9984		2,83 ▲	0,86 ▼	0,69 ▼	0,82 ▼	0,77 ▼	7,7% ▼
Portugal	8608	7006		2,89 ▲	1,01 –	1,39 ▲	0,85 ▼	0,86 ▼	8,1% ▼
Romania	5540	4659		6,87 ▲	0,83 ▼	1,37 ▲	0,68 ▼	0,75 ▼	6,5% ▼
Slovenia	2913	2426		1,60 ▼	0,80 ▼	1,23 ▲	0,77 ▼	0,76 ▼	6,1% ▼
Slovakia	2121	1651		3,12 ▲	1,01 –	0,81 ▼	0,72 ▼	0,82 ▼	6,5% ▼
Finland	12211	10011		1,95 ▼	1,00 –	1,40 ▲	1,09 –	1,01 –	10,8% –
Sweden	12624	9570		1,86 ▼	1,34 ▲	0,72 ▼	1,15 ▲	1,11 ▲	11,5% ▲
United Kingdom	66418	51665		1,96 ▼	1,48 ▲	0,74 ▼	1,23 ▲	1,14 ▲	12,5% ▲
EU (1)	367331	327818		2,21 –	:	0,89 ▼	1,07 –	1,01 –	10,9% –
Iceland	464	237		4,63 ▲	1,76 ▲	0,79 ▼	1,15 ▲	1,11 ▲	13,7% ▲
Liechtenstein	30	15		6,43 ▲	1,32 ▲	1,05 –	:	:	:
Norway	6351	4596		3,04 ▲	1,40 ▲	0,83 ▼	1,23 ▲	1,00 –	12,2% ▲
Switzerland	13995	9860		2,03 ▼	1,68 ▲	0,79 ▼	1,93 ▲	1,28 ▲	19,7% ▲
Macedonia (2)	413	335		3,06 ▲	0,70 ▼	2,29 ▲	0,31 ▼	0,49 ▼	2,0% ▼
Turkey	10131	8763		3,26 ▲	0,73 ▼	0,60 ▼	1,10 –	1,30 ▲	11,5% ▲
Israel	12710	9742		1,75 ▼	1,34 ▲	1,11 ▲	1,63 ▲	1,56 ▲	18,2% ▲
Russian Federation	8310	6893		1,85 ▼	0,88 ▼	0,30 ▼	0,42 ▼	0,66 ▼	3,8% ▼
United States	274130	233082		1,51 ▼	1,11 ▲	0,78 ▼	1,55 ▲	1,32 ▲	15,8% ▲
Japan	70198	63037		1,71 ▼	0,66 ▼	0,78 ▼	0,62 ▼	0,74 ▼	5,7% ▼
China	299676	283388		4,22 ▲	0,47 ▼	1,86 ▲	0,72 ▼	0,83 ▼	6,9% ▼
South Korea	48567	43718		2,18 –	0,65 ▼	1,65 ▲	0,73 ▼	0,97 –	7,4% ▼
India	32203	28900		4,22 ▲	0,61 ▼	0,93 –	0,72 ▼	0,93 –	7,2% ▼
Brazil	15343	13138		2,58 –	0,88 ▼	0,65 ▼	0,66 ▼	0,87 ▼	6,5% ▼
Total World	1210542	1210542		2,38 –	:	1,00 –	1,00 –	1,00 –	10,0% –

Source: DG Research and Innovation - Economic Analysis Unit — Innovation Union Competitiveness report 2013

Data: Science Metrix / Scopus (Elsevier)

Notes: (1) EU: Croatia is not included.

(2) The Former Yugoslav Republic of Macedonia.

The world's scientific output in ICT is about 1.2 million publications, with European countries producing about one quarter of these. China produces the highest number of publications in ICT, followed by the United States and Japan. The remainder of the top 10 is rounded off by the United Kingdom, Germany, France, South Korea, Italy and Spain. Luxembourg, Malta, Romania, Liechtenstein and Iceland have the highest growth rates. The countries with the highest percentage of publications in the 10 % most-cited publications were Switzerland, Israel and the United states. As in several other research areas, European countries, here the Netherlands, Belgium and Switzerland, have the greatest impact in terms of most cited publications.

Figure II.2.8 Patents (1) in the field of ICT, 2000–2010

	PCT (2)					EPO (2)				USPTO (3)			
	Total 2000-2010	Total per billion GDP (PPS€)	Trend 2000-2010	Growth (4)	RTA (5)	Total 2000-2010	Trend 2000-2010	Growth (4)	RTA (5)	Total 2000-2010	Trend 2000-2010	Growth (4)	RTA (5)
Belgium	1274	3,56		205,8	0,50	2136		64,9	0,68	1131		5,0	0,64
Bulgaria	52	1,54		129,7	0,87	42		250,9	1,05	124		1.398,9	1,96
Czech Republic	126	0,42		166,8	0,43	121		279,2	0,48	87		0,8	0,56
Denmark	1275	3,25		63,1	0,53	985		23,4	0,48	563		-32,7	0,58
Germany	19675	5,52		35,2	0,64	24837		17,9	0,63	13081		-17,9	0,60
Estonia	61	0,14		576,5	1,04	33		4.100,0	1,13	3		500,0	0,31
Ireland	778	4,95		50,4	1,02	554		26,3	0,98	699		3,3	1,24
Greece	135	0,30		46,5	0,67	141		85,7	0,78	73		81,5	0,87
Spain	1141	0,41		94,0	0,49	1071		38,2	0,50	461		-14,6	0,57
France	10270	3,39		72,5	0,82	13536		41,9	0,90	5822		-28,7	0,73
Croatia	57	0,11		77,4	0,44	27		125,0	0,44	7		-37,9	0,21
Italy	2160	1,13		117,5	0,46	3354		60,0	0,49	1691		-19,7	0,55
Cyprus	17	0,20		-15,9	0,74	18		-59,7	0,76	4		-38,9	0,54
Latvia	16	0,07		87,5	0,31	13		150,0	0,37	2		0,0	0,18
Lithuania	19	0,32		-30,8	0,69	9		-12,5	0,41	15		-15,6	0,45
Luxembourg	56	0,45		62,7	0,51	83		121,8	0,38	15		67,2	0,13
Hungary	392	0,72		61,3	0,86	275		90,4	0,86	115		-26,4	0,73
Malta	4	0,23		100,0	0,50	4		500,0	0,38	2		166,7	0,45
Netherlands	9990	6,24		15,8	1,44	8873		-11,1	1,33	3328		-20,8	0,96
Austria	1631	3,26		84,5	0,77	1635		66,1	0,63	851		-5,2	0,67
Poland	180	0,14		47,9	0,57	154		266,4	0,59	84		12,7	0,58
Portugal	109	0,14		363,9	0,63	117		429,0	0,75	30		-10,6	0,60
Romania	113	0,35		464,9	1,34	70		207,1	1,34	86		387,6	1,41
Slovenia	56	0,29		-33,1	0,33	58		-26,4	0,37	12		-69,0	0,32
Slovakia	51	0,07		219,6	0,54	44		282,9	0,62	7		1.600,2	0,32
Finland	5959	17,18		67,0	1,97	4904		25,1	1,92	2557		-26,0	1,36
Sweden	6609	7,20		41,4	1,22	4792		54,4	1,10	2042		-42,2	0,79
United Kingdom	11381	4,39		49,9	0,87	10495		23,8	0,93	7436		-29,0	0,86
EU (6)	69548	3,12		46,5	0,83	74560		24,6	0,80	38347		-22,5	0,73
Iceland	47	4,26		18,4	0,47	36		-20,1	0,51	37		-72,8	0,58
Liechtenstein	18	:		-18,0	0,52	19		-18,8	0,28	8		-52,8	0,19
Norway	701	1,56		44,5	0,52	477		53,0	0,56	338		12,2	0,52
Switzerland	1952	4,98		34,0	0,42	2684		14,9	0,45	1462		-18,7	0,47
Macedonia (7)	4	0,00		200,0	0,65	3		0,0	2,68	0		0,0	0,00
Turkey	153	0,06		311,7	0,49	132		385,2	0,70	49		-2,9	0,64
Israel	4626	25,39		63,2	1,24	2497		42,0	1,12	3967		-13,6	1,23
Russian Federation	974	0,25		87,1	0,63	381		55,7	0,68	535		9,7	0,78
United States	90664	18,76		134,9	1,03	62970		46,3	1,02	209053		-1,7	0,97
Japan	44032	26,55		96,3	1,16	49257		32,8	1,31	88418		-18,1	1,20
China	13695	0,45		641,6	1,87	4635		507,9	1,95	3624		185,5	1,21
South Korea	13077	20,52		263,1	1,59	13850		285,7	2,19	22515		47,6	1,55
India	1552	0,74		465,4	0,70	813		208,3	0,73	2359		113,6	1,15
Brazil	231	0,06		115,6	0,34	82		80,3	0,24	104		56,9	0,33
Total World	239868	:		100,0	1,00	212406		45,8	1,00	387823		-3,5	1,00

Source: DG Research and Innovation - Economic Analysis Unit
Innovation Union Competitiveness report 2013
Data: University Bocconi (Italy), Eurostat, OECD
Notes: (1) Full counting method.
(2) Patent applications.
(3) Patents granted.
(4) Growth: Growth rate in the number of patents between 2000-2002 and 2003-2006.
(5) RTA: Revealed Technological Advantage index in the period 2000-2010.
(6) EU: Croatia is not included.
(7) The Former Yugoslav Republic of Macedonia.

The United States produces the largest number of PCT patents for this research area, more than in the EU. However, at international level, Japan, Israel and South Korea have the best performance in terms of patents in ICT per GDP. The European country with the largest number of PCT patents in ICT is Germany, followed by the United Kingdom, France and the

Netherlands. Nonetheless, Finland has the best performance in terms of PCT per GDP. Again, the relatively high scientific impact of Turkey, Italy, Greece or Spain has not resulted in high technological development.

Nanoscience is a small but growing research area in which all larger countries are active, and Israel, the Netherlands, the United States, Germany, Austria and Switzerland have the highest scientific impact. However, technology development is more intensive outside Europe, in particular in Japan, the United States and South Korea.

Figure II.2.9 Scientific publications in the field of nanosciences and nanotechnologies, 2000–2010

	Publications			Growth Index	CI	SI	ARC	ARIF	% share of publications (FULL) in the top 10% most cited publications worldwide
	Full counting method (FULL)	Fractional counting method (FRAC)	Trend						
Belgium	1021	658		1,86	1,36	0,84	0,97	1,09	8,9%
Bulgaria	130	85		1,86	1,07	0,70	0,45	0,75	2,2%
Czech Republic	409	262		2,00	1,23	0,53	0,59	0,80	3,7%
Denmark	594	413		1,81	1,13	0,78	1,26	1,25	13,0%
Germany	6951	4975		1,87	1,30	0,99	1,35	1,23	15,1%
Estonia	48	32		1,59	0,87	0,63	0,74	1,16	9,4%
Ireland	607	420		2,61	1,11	1,47	1,23	1,17	10,8%
Greece	520	355		2,53	1,13	0,63	0,85	0,88	8,3%
Spain	2442	1764		1,92	1,19	0,77	1,18	1,11	10,5%
France	4370	3025		1,65	1,30	0,82	1,11	1,13	11,2%
Croatia	25	9		:	:	:	:	:	:
Italy	2608	1960		2,09	1,07	0,68	0,90	1,05	7,2%
Cyprus	32	21		6,89	1,01	1,30	:	:	:
Latvia	24	11		:	:	:	:	:	:
Lithuania	64	48		1,70	0,88	0,63	0,64	0,80	4,9%
Luxembourg	12	3		:	:	:	:	:	:
Hungary	262	168		1,64	1,15	0,53	0,66	0,76	4,6%
Malta	3	2		:	:	:	:	:	:
Netherlands	1808	1287		1,95	1,22	0,87	1,53	1,34	16,4%
Austria	593	376		2,42	1,27	0,69	1,51	1,15	12,5%
Poland	810	543		1,16	1,13	0,49	0,69	0,70	3,6%
Portugal	502	371		2,15	1,09	0,96	0,80	0,81	5,6%
Romania	362	236		2,32	1,13	0,90	0,56	0,65	2,4%
Slovenia	159	117		1,32	0,86	0,78	0,78	0,92	6,9%
Slovakia	79	50		1,36	1,06	0,32	0,28	0,82	0,0%
Finland	488	353		2,52	0,99	0,65	0,95	1,08	10,0%
Sweden	1160	814		2,01	1,15	0,81	1,27	1,25	14,3%
United Kingdom	5439	4042		1,69	1,16	0,76	1,27	1,24	12,2%
EU (1)	26251	22389		1,85	:	0,79	1,12	1,12	11,0%
Iceland	4	1		:	:	:	:	:	:
Liechtenstein	6	3		:	:	:	:	:	:
Norway	226	138		3,34	1,20	0,33	0,75	0,91	5,2%
Switzerland	1832	1232		2,22	1,28	1,30	1,28	1,27	14,3%
Macedonia (2)	4	2		:	:	:	:	:	:
Turkey	359	260		4,71	0,90	0,23	0,77	0,74	4,1%
Israel	792	622		2,11	0,82	0,93	1,55	1,50	20,4%
Russian Federation	1598	1100		1,17	1,24	0,63	0,49	0,70	3,1%
United States	27010	23121		2,09	0,77	1,02	1,41	1,27	15,8%
Japan	10776	9405		1,44	0,63	1,52	0,67	0,84	6,1%
China	17137	15212		3,97	0,58	1,31	0,85	0,83	8,1%
South Korea	6775	5826		2,71	0,66	2,88	0,73	0,86	7,1%
India	3134	2689		3,53	0,63	1,13	0,74	0,68	4,7%
Brazil	827	658		1,44	0,73	0,43	0,63	0,74	4,6%
Total World	91395	91395		2,27	:	1,00	1,00	1,00	10,0%

Source: DG Research and Innovation - Economic Analysis Unit — Innovation Union Competitiveness report 2013
Data: Science Metrix / Scopus (Elsevier)
Notes: (1) EU: Croatia is not included.
(2) The Former Yugoslav Republic of Macedonia.

Nanosciences and nanotechnologies represent a relatively small but growing research field with only 91 000 scientific publications produced worldwide between 2000 and 2010. The 10 largest producers are the United States, China, Japan, Germany, South Korea, the United Kingdom, France, India, Italy and Spain. Cyprus, Turkey and China have the highest growth index. Israel is the country with the highest scientific impact, followed by the Netherlands, the United States, Germany, Austria and Switzerland. The scientific impact of the EU average in this research sector is slightly above the world average.

Figure II.2.10 Patents [1] in the field of nanosciences and nanotechnologies, 2000–2010

	PCT [2]					EPO [2]				USPTO [3]			
	Total 2000-2010	Total per billion GDP (PPS€)	Trend 2000-2010	Growth [4]	RTA [5]	Total 2000-2010	Trend 2000-2010	Growth [4]	RTA [5]	Total 2000-2010	Trend 2000-2010	Growth [4]	RTA [5]
Belgium	54	0,08		348,1	0,88	66		91,6	1,03	25		-12,2	0,81
Bulgaria	2	0,00		-50,0	1,70	2		100,0	2,35	0		0,0	0,00
Czech Republic	5	0,00		1.425,1	0,82	5		1.200,1	0,99	1		375,0	0,69
Denmark	36	0,07		-13,9	0,62	20		-17,5	0,49	12		-73,5	0,72
Germany	654	0,10		109,8	0,88	591		70,3	0,73	238		-29,0	0,62
Estonia	1	0,00		0,0	1,05	1		0,0	1,60	0		0,0	0,00
Ireland	18	0,06		279,0	1,02	10		456,3	0,85	8		5,5	0,81
Greece	8	0,01		67,9	1,66	4		-45,0	1,14	3		9,1	2,55
Spain	44	0,01		97,4	0,78	34		70,3	0,78	11		-35,7	0,80
France	288	0,06		108,1	0,95	304		92,6	0,98	110		-31,2	0,79
Croatia	0	0,00		-33,3	0,27	0		0,0	0,38	0		0,0	0,77
Italy	66	0,02		87,7	0,59	76		40,9	0,54	31		-55,2	0,58
Cyprus	1	0,00		0,0	1,74	1		-60,0	3,50	0		0,0	3,17
Latvia	1	0,00		0,0	1,17	1		0,0	2,00	0		0,0	0,00
Lithuania	0	0,00		0,0	0,00	0		0,0	0,70	0		0,0	0,83
Luxembourg	0	0,03		0,0	0,19	1		400,0	0,44	1		0,0	0,61
Hungary	2	0,01		-73,3	0,26	3		6,7	0,59	1		66,7	0,47
Malta	0	0,00		0,0	0,00	0		0,0	0,00	0		0,0	0,00
Netherlands	171	0,14		231,6	1,02	109		182,4	0,79	74		37,0	1,21
Austria	44	0,05		408,1	0,87	44		273,3	0,82	13		-23,5	0,61
Poland	10	0,01		76,3	1,32	7		123,1	1,37	4		-80,6	1,77
Portugal	3	0,00		-22,2	0,75	3		0,0	0,91	0		0,0	0,55
Romania	4	0,01		0,0	2,02	2		-33,3	2,35	2		0,0	1,85
Slovenia	4	0,00		-27,3	1,13	4		22,2	1,41	0		0,0	0,70
Slovakia	1	0,00		50,0	0,72	1		-25,0	0,79	0		0,0	1,52
Finland	28	0,03		131,3	0,39	19		113,1	0,36	5		-55,8	0,16
Sweden	78	0,11		40,5	0,60	60		38,0	0,67	32		-25,9	0,72
United Kingdom	294	0,06		48,0	0,93	225		33,5	0,96	98		-7,9	0,65
EU [6]	1694	0,05		98,7	0,84	1488		71,7	0,77	638		-20,3	0,68
Iceland	2	0,12		-78,6	1,15	2		-45,5	1,95	1		0,0	0,91
Liechtenstein	0	:		0,0	0,59	1		0,0	0,70	0		0,0	0,00
Norway	17	0,02		99,0	0,54	15		163,3	0,90	5		-19,4	0,48
Switzerland	84	0,19		85,1	0,75	91		66,0	0,74	56		-15,2	1,02
Macedonia [7]	1	0,00		0,0	5,93	0		0,0	18,41	0		0,0	0,00
Turkey	7	0,00		0,0	0,96	6		0,0	1,74	2		300,0	1,84
Israel	81	0,17		88,4	0,91	42		113,5	0,91	27		-30,7	0,48
Russian Federation	37	0,01		71,2	1,00	24		54,8	2,08	20		28,0	1,72
United States	2437	0,33		148,1	1,14	1521		66,0	1,19	3667		4,9	0,96
Japan	1115	0,51		127,1	1,21	959		41,1	1,23	1703		-19,4	1,31
China	74	0,01		178,3	0,42	34		135,7	0,71	71		209,8	1,35
South Korea	221	0,35		589,0	1,11	197		168,4	1,50	379		74,1	1,47
India	37	0,01		438,6	0,69	22		360,0	0,95	21		8,6	0,59
Brazil	14	0,00		116,7	0,84	9		154,2	1,40	3		-55,6	0,59
Total World	5676	:		130,0	1,00	4247		65,0	1,00	6573		-1,0	1,00

Source: DG Research and Innovation - Economic Analysis Unit

Innovation Union Competitiveness report 2013

Data: University Bocconi (Italy), Eurostat, OECD

Notes: (1) Full counting method.

(2) Patent applications.

(3) Patents granted.

(4) Growth: Growth rate in the number of patents between 2000-2002 and 2003-2006.

(5) RTA: Revealed Technological Advantage index in the period 2000-2010.

(6) EU: Croatia is not included.

(7) The Former Yugoslav Republic of Macedonia.

Japan and the United States are the largest producers of PCT patents in nanotechnologies, and along with South Korea are also the countries with the highest rates in terms of PCT patent applications per GDP, far above the European Union. The second largest number of PCT patents in this research field is produced by the European Union: the United Kingdom, France and the Netherlands are large producers of PCT patents in nanotechnology. However, only the latter performs relatively well in terms of PCT patents per billion GDP, along with Iceland, Switzerland and Israel.

3. Capitalising on research collaboration in the ERA[77]

Highlights

Intensified cooperation within Europe coupled with collaboration with partners outside Europe may increase research excellence

Scientific collaboration is growing, both within the European Research Area and with countries outside of Europe. The vast majority of EU Member States, as well as Iceland, Liechtenstein, Norway and Switzerland, show higher co-publication rates with other European countries than with third countries. The scientific impact of international co-publications is consistently well above the world level, whereas that of domestic-only co-publications is generally close to world level. The results suggest that scientific excellence may benefit from an intensification of transnational cooperation within Europe, coupled with collaboration with partners outside of Europe.

For most research areas, cooperation within Europe is crystallising around a few central nodes; eastern European research teams are outside of core networks

However, not all research areas and not all European regions benefit equally from increased collaboration. Over the period 2000–2011, Europe's stronger science and technology centres were reinforced, with increasingly crystallised cooperation networks. For most research areas, the cooperation links between these central nodes were intensified, while links to less advanced science and technology centres remain weak and new nodes have not appeared. Some variations can be found by region and sector. Regions in Southern Europe have increased their integration in most scientific priority areas, while Eastern Europe remains predominantly outside of central networks. Research teams in health, energy and environment have increased their cooperation outside of core networks, while researchers in nanotechnologies, ICT and new production technologies have reinforced the main network nodes.

There is a positive correlation between success in framework programme (FP) participation and scientific strengths

Besides scientific and technological collaborations, the European Framework programmes have the capacity to leverage science and technology performance at national level. In general, there is a positive correlation between success in FP participation and scientific strengths, although this relation varies across research fields; national strategies for a successful FP participation are tie in with both sector specialisation and national scientific strengths.

[77] This chapter analyses research collaboration patterns in EU Member States and associated countries. The term European Research Area (ERA) refers to the countries actively involved in the implementation or ERA policies.

Introduction

Reforms of national research and innovation system go beyond national borders. European countries have the opportunities to capitalise on the ERA, benefiting from knowledge spillovers, economies of scale and scope, and top-up investments in strategic areas. The consolidating ERA offers opportunities to hook in to cross-country cooperation networks in science and technology development. These networks are the result of a comprehensive integration process in the research community both inside Europe and internationally. They offer new forms of cooperation between both European and non-European colleagues.

The large range of specific policy instruments constructed since the launch of the ERA in 2000 ([78]), coupled with incentives from the single market, reinforce opportunities for European countries to integrate within networks and benefit from knowledge spillovers. The ERA also offers opportunities for economies of scale and scope through pan-European research infrastructures and networked specialisation. Thematic objectives have been identified at the European level for the EU framework programmes and European Strategy Forum on Research Infrastructures (ESFRI) roadmap, as well as in European Innovation Partnerships (eips) and Joint Technology Initiatives (jtis). They have also been identified in public–private partnerships, lead market initiatives, Knowledge and Innovation Communities of the European Institute of Innovation and Technology (EIT), and for the upcoming Horizon 2020. Most of these objectives are also closely related to other European policy areas, such as environmental policy, energy policy, transport policy, agricultural policy and public health policy. The supply of science and technologies in the ERA is linked to demand measures at European, national and regional levels, increasing the effectiveness of research in terms of economic and societal impact. The ERA offers opportunities to enhance investments and capacity building at national and regional levels, mainly through Horizon 2020 and the Structural Funds, strategically reinforced through smart specialisation strategies.

This chapter will provide a first analysis of the extent to which European countries capitalise on research collaboration inside the ERA and the opportunities to step up this strategy. Being an evidence-based analysis, it is limited to the areas where solid data are available. The chapter will first focus on the actual use of scientific and technological cooperation networks in view of gaining knowledge spillovers. It will then analyse the extent to which European countries have been able to increase excellence through FP7, reinforcing strengths, specialisation profiles and transformation potential in fast-growing science and technology fields.

[78] ERA progress report, 2013.

3.1. Fostering collaborative research to enhance excellence in science

Cooperation is an important part of the science and innovation structures. There is a trend towards more international co-publications, both within and beyond Europe. Accessing complementary expertise, addressing trans-border challenges or achieving critical mass are some of the underlying rationales for cooperation. The evidence presented in this chapter covers all scientific cooperation between European researchers, independently of funding instruments. Most collaborative research is funded by national sources. European instruments, in particular FP7, contribute to a limited extent to this funding. They gain leverage by focussing on creating European added value, sponsoring research projects whose participants are located in different European countries. They also encourage the mobility of skilled workers over national borders by offering fellowships where this is a mandatory requirement ([79]). This section aims to provide evidence of collaborative research and its effect on scientific quality. It provides in-depth analyses of European countries' collaboration patterns as well as those of a selected set of comparable countries outside the ERA. The analysis relates scientific collaboration to scientific impact/excellence. The following section presents a descriptive analysis of the evolution of scientific collaboration within the ERA by key sectors between 2000 and 2011 ([80]).

The following indicators ([81]) have been used to characterise collaboration patterns over the 2000–2011 period:

- Pubs (FULL): total number of publications.
- CI: the collaboration index is a scale-adjusted measure of the propensity of a country to co-publish its papers with international partners. It is calculated by taking the ratio of a country's observed number of international co-publications over its expected number of international co-publications given the size of its scientific output. When the CI is above one, a country collaborates more with international partners than expected given the size of its production. When it is below one, the opposite is true.
- SAP: total number of single author publications per country.
- SCCP: total number of domestic-only (i.e. Single-country) co-publications.
- ICP: total number of international co-publications involving the given country and at least one author from another country.
- ERACP: total number of international co-publications involving at least one author in the given country and at least one author from the EU-27, the European Free Trade Association (EFTA) or candidate countries.

[79] The mobility of highly skilled people is also analysed in the chapter on knowledge circulation enhancing the economic impact of knowledge (see Chapter II.4).

[80] The results are based on a longitudinal study performed by Science-Metrix and financed by the European Commission, DG RTD. The study was launched in 2010, when Croatia was not a member of the European Union As in previous chapters, this section will present a selection of key fields relevant for the upcoming Horizon 2020. A full set of data on collaboration classified by all sectors can be found in the Statistical annex in this report.

[81] Detailed information about indicators is provided in the Methodological annex.

– EU27CP: total number of international co-publications involving the given country and one or more EU-27–only authors.
– Non-EU27CP: total number of international co-publications involving the given country and one or more non-EU-27–only authors.
– EU27 & Non-EU27 CP: total number of international co-publications involving the given country, at least one author from an EU-27 country and at least one author from a non-EU-27 country.

Figure II.3.1: Scientific collaboration patterns for all scientific priorities (2000–2011)

Country	Pubs (FULL)	CI Score	CI GI	SAP %	SAP GI	SCCP %	SCCP GI	ICP %	ICP GI	ERACP %	ERACP GI	EU27CP %	EU27CP GI	EU27CP Trend	Non-EU27CP %	Non-EU27CP GI	Non-EU27CP Trend	EU27 & Non-EU27 CP %	EU27 & Non-EU27 CP GI
EU27																			
Austria	107.569	1,30	1,06	11,7	0,85	40,1	0,91	45,8	1,14	36,1	1,17	22,4	1,11		12,2	1,03		11,1	1,32
Belgium	150.988	1,38	1,03	10,4	0,82	40,8	0,93	46,7	1,10	35,7	1,12	22,8	1,07		12,4	1,06		11,4	1,23
Bulgaria	16.013	0,92	0,99	14,3	0,92	42,7	1,05	40,3	1,05	32,8	1,09	23,6	1,00		9,1	0,95		7,7	1,35
Cyprus	5.189	1,16	1,00	16,1	0,90	24,8	1,06	57,9	0,99	41,8	1,12	28,8	1,04		18,8	0,82		10,3	1,26
Czech Republic	77.820	0,78	0,97	16,7	0,91	52,7	1,00	28,5	1,03	21,7	1,06	14,9	0,99		7,6	0,98		6,0	1,19
Denmark	110.363	1,30	1,02	11,2	0,89	40,1	0,95	45,8	1,09	33,1	1,10	18,5	1,05		15,4	1,08		11,9	1,19
Estonia	9.022	0,97	0,99	13,0	0,99	41,0	1,02	45,1	0,99	38,6	0,97	26,3	0,90		7,8	1,12		11,0	1,13
Finland	100.537	1,10	1,05	10,7	0,89	48,4	0,93	39,2	1,13	27,8	1,15	16,7	1,09		13,0	1,09		9,6	1,25
France	598.502	1,22	1,03	15,0	0,90	47,6	0,95	35,2	1,13	20,5	1,14	12,0	1,08		16,4	1,11		6,8	1,26
Germany	816.294	1,25	1,03	14,0	0,81	48,4	0,97	34,6	1,13	21,7	1,19	12,3	1,14		15,7	1,06		6,6	1,29
Greece	99.057	0,88	1,04	7,9	0,94	58,8	0,95	31,3	1,11	22,3	1,14	15,4	1,09		10,0	1,04		5,9	1,28
Hungary	49.870	1,00	0,97	16,8	1,15	42,9	0,92	38,5	1,03	27,6	1,10	18,2	1,01		12,1	0,94		8,2	1,25
Ireland	56.697	1,12	1,04	11,8	0,87	44,0	0,95	42,4	1,09	30,1	1,09	20,4	1,03		13,2	1,09		8,7	1,25
Italy	462.763	1,04	1,05	7,7	0,96	58,9	0,93	30,8	1,14	20,6	1,18	12,8	1,14		11,6	1,08		6,4	1,25
Latvia	3.528	0,81	0,72	13,7	1,16	42,5	1,48	42,7	0,70	35,5	0,70	23,1	0,66		8,6	0,70		11,0	0,78
Lithuania	11.945	0,62	0,82	17,9	1,19	53,1	1,04	28,2	0,83	22,8	0,84	16,0	0,79		6,5	0,80		5,8	0,98
Luxembourg	3.819	1,36	1,04	10,5	0,80	18,7	1,05	70,0	1,02	64,3	0,99	46,2	0,93		7,8	1,23		16,0	1,24
Malta	1.433	0,78	0,86	22,1	0,91	32,3	1,38	44,8	0,84	41,5	0,84	27,2	0,81		4,0	0,78		13,5	0,91
Netherlands	295.610	1,33	1,03	9,3	0,81	46,5	0,94	41,7	1,11	29,5	1,13	18,4	1,07		13,7	1,07		9,5	1,25
Poland	151.288	0,65	0,93	16,7	1,01	58,8	0,99	21,8	1,00	14,9	1,06	10,0	0,98		7,5	0,90		4,3	1,24
Portugal	65.816	1,11	0,99	6,9	0,88	50,0	1,00	41,3	1,03	29,5	1,01	21,2	0,97		12,7	1,07		7,5	1,13
Romania	31.694	0,76	0,65	15,8	1,05	51,7	1,36	30,7	0,63	24,1	0,63	17,7	0,60		7,7	0,65		5,3	0,72
Slovakia	25.784	0,84	0,98	16,7	0,82	46,8	1,04	34,8	1,04	29,1	1,06	21,3	1,08		6,7	0,92		6,7	1,02
Slovenia	24.881	0,75	1,04	16,6	0,92	51,0	0,97	31,2	1,08	24,4	1,09	14,7	1,04		10,6	1,08		6,0	1,20
Spain	371.526	0,95	1,08	8,4	0,96	60,0	0,93	29,1	1,16	18,6	1,18	12,3	1,13		11,3	1,14		5,6	1,29
Sweden	195.617	1,33	1,05	12,0	0,83	42,4	0,90	43,7	1,14	30,1	1,18	16,9	1,11		16,6	1,10		10,2	1,27
United Kingdom	976.359	1,30	1,04	18,8	0,90	43,9	0,92	35,3	1,14	18,9	1,19	11,3	1,13		17,9	1,10		6,1	1,31
Candidates																			
Croatia	30.193	0,49	1,03	16,5	0,99	60,2	0,99	20,1	1,07	14,5	1,06	9,9	1,01		6,4	1,05		3,8	1,26
Macedonia	2.574	0,87	0,75	12,2	1,19	40,1	1,29	46,3	0,80	28,9	1,18	14,6	1,20		23,9	0,54		7,8	1,25
Turkey	184.626	0,41	0,99	10,1	1,17	74,3	0,97	13,4	1,06	6,2	1,18	4,2	1,10		7,5	0,98		1,7	1,36
EFTA																			
Iceland	6.367	1,32	1,04	10,7	0,97	23,4	0,81	64,2	1,06	49,2	1,01	24,2	0,95		19,5	1,17		20,5	1,11
Liechtenstein	406	1,12	1,15	11,3	0,29	15,8	0,73	71,9	1,27	64,8	1,34	31,8	1,16		22,7	0,88		17,5	2,64
Norway	92.199	1,24	1,05	13,1	0,88	40,5	0,93	44,4	1,11	31,5	1,13	20,7	1,10		13,8	1,07		9,8	1,18
Switzerland	190.956	1,60	1,02	10,5	0,79	34,9	0,91	52,6	1,10	38,3	1,13	26,1	1,08		14,8	1,05		11,7	1,23
ERA																			
Israel	113.342	1,00	1,02	12,8	0,96	49,8	0,93	34,8	1,11	15,4	1,19	8,2	1,14		20,4	1,05		6,1	1,27
Asia																			
China	1.620.092	0,51	0,96	5,0	1,06	80,2	1,00	13,1	1,00	3,6	1,01	2,6	0,96		9,7	1,00		0,9	1,09
India	320.513	0,48	0,95	8,1	0,84	74,8	1,03	14,8	0,99	5,3	1,03	3,4	0,94		9,8	0,99		1,6	1,18
Japan	841.660	0,65	0,99	7,2	1,04	71,1	0,97	18,2	1,11	5,5	1,14	3,2	1,07		13,0	1,09		2,0	1,27
Rep. of Korea	295.238	0,73	0,94	4,5	0,94	70,9	1,01	23,0	0,99	3,6	1,15	1,8	1,05		19,7	0,97		1,6	1,27
Others																			
Brazil	248.474	0,68	0,86	5,6	1,04	67,7	1,03	21,6	0,89	10,6	0,95	7,3	0,94		11,3	0,84		3,0	0,99
Russia	158.973	0,75	0,82	16,9	1,04	56,0	1,07	25,2	0,89	15,8	0,90	10,7	0,86		10,1	0,89		4,5	0,98
United States	3.739.514	0,93	1,03	17,0	0,87	58,0	0,99	21,7	1,16	11,0	1,12	7,7	1,05		11,6	1,20		2,4	1,35

Source: DG Research and Innovation – Economic Analysis Unit   Innovation Union Competitiveness report 2013
Data: Computed by Science-Metrix using Scopus
Note: The tables were commissioned in a service contract to the European Commission in 2010, when Croatia was still a candidate country.

International collaboration is becoming increasingly important in science, inside Europe and beyond; collaboration inside Europe is growing, although eastern European countries tend to participate less than statistically expected.

The proportion of publications in the European Union signed by a single researcher ranges from 7 % in Portugal to 20 % in Malta. Outside of the European Union, those rates are lowest for Brazil. Single author publications (saps) are on a downward trend for most countries, with the exception of Hungary, Latvia, Romania, FYROM and Turkey. Domestic collaborations are still highly important for Asian countries, with rates above 70 %.

Western European countries tend to have a higher Collaboration Index (CI), whereas eastern European countries tend to collaborate less internationally than expected given the size of their production ([82]). Of the remaining countries among those selected, only EFTA states, which are part of the ERA, collaborate more internationally than expected considering the size of their publication output; for example, Liechtenstein has 12 % more international co-publications than expected, Norway has 24 % more, Iceland has 34 % more and Switzerland has 60 % more. Asian countries, Brazil, Russia and the United states collaborate less internationally than expected, whereas Israel collaborates on an international scale as much as could be expected given the size of its output.

With the exception of the United Kingdom, France and Germany, all EU Member States produce a greater share of their papers exclusively with other Member States than exclusively with non-Member States. Cyprus and Malta publish the largest shares of their output with at least one other EU country, while Poland is the least connected to other Member States. Germany, Italy and the United Kingdom show the highest increases in the share of their production produced through collaboration exclusively with EU partners. Interestingly, all EFTA countries, with the exception of Iceland, present positive growth in their co-publication rates exclusively with EU countries, and collaboration rates are especially high among EFTA states. Turkey co-published only 4.2 % of its output exclusively with EU-27 partners. Asian countries do not collaborate frequently with EU-27 members, with rates ranging between 1.8 % (South Korea) and 3.4 % (India) only. In comparison, the US rate stands at 7.7 % and at 15.8 % for Russia.

European science collaboration is increasingly open to researchers from outside Europe

Collaboration initiatives involving at least one partner from the EU and another from non-EU countries are on the rise, as all countries with the exception of Romania, Latvia, Malta, Lithuania, Russia and Brazil show a Growth Index (GI) above 1. This increase is much stronger if we look at international collaboration with EU partners and with non-EU partners inside the same research team. In sum, the results show that international collaboration in science is becoming increasingly important for all countries, while SAP and single-country

[82] This finding is not only linked to the current research and innovation system capacity of eastern European countries, but also to historical reasons, as these systems are younger than those in Western Europe.

publication are declining. It is therefore relevant to assess if this collaboration leads to improved scientific quality, measured by the citation impact of the publications.

Collaboration in Europe and beyond increases scientific impact, an indicator of scientific quality

Scientific cooperation is broadly recognised as having a positive effect on the scientific impact of publications. To characterise the types of co-publications the most beneficial to scientific quality, scientific impact is measured here using the Average of Relative Citations (ARC) ([83]). The statistical analysis has computed publications/co-publications for European countries (i.e. The 35 countries of the ERA) and a selected set of international countries comparable over the 2000–2008 period.

Single author publications (saps) stand out as being less cited than any other type of co-publication. With the exception of Turkey, where the ARC of saps and of all papers are cited at the same level, papers published without collaboration are always cited less frequently than the corresponding country's average based on all documents. All countries present an ARC below the world level for this indicator, the strongest performances being those of Denmark (0.86), the Netherlands (0.81) and the United Kingdom (0.83). In these cases, saps are cited nearly as often as the average world paper. However, these countries have some of the strongest arcs overall so that, based on all publications, Danish, Dutch and British authors are cited 62 %, 63 % and 48 % respectively, less frequently when publishing papers without collaboration.

Single-country co-publications (sccps) are cited more frequently than saps, but still below the world level for most countries. With an ARC of 1.38, the United States ranks above Switzerland (1.26), the Netherlands (1.26) and Denmark (1.24). All EU candidate countries rank below the world level, as do Asian countries, Brazil and Russia. Russia is again last with a score of 0.23 (similar to the ARC of its saps), its national collaborations being almost three times less cited than those of China (0.62). Finally, all EFTA countries score above the world level for this indicator with the exception of Iceland (0.97), an interesting fact considering that Iceland achieved the highest ARC among selected countries when all publications are considered. This indicates that Iceland's high impact is highly dependent on its international co-publications.

[83] See Methodological annex for a definition of this indicator.

Figure II.3.2: Impact of collaboration on scientific excellence (2000–2008)

Country	Pubs (FULL)	SAP	SCCP	ICP	ERACP	EU27CP	Non-EU27CP	EU27 & Non-EU27 CP
EU27								
Austria	1,20	0,51	0,97	1,66	1,73	1,42	1,43	2,50
Belgium	1,42	0,60	1,13	1,93	2,05	1,57	1,64	3,05
Bulgaria	0,61	0,28	0,35	1,08	1,16	0,90	0,79	2,10
Cyprus	1,05	0,77	0,70	1,28	1,28	1,12	1,27	1,80
Czech Republic	0,70	0,31	0,48	1,40	1,50	1,14	1,11	2,47
Denmark	1,49	0,86	1,24	1,97	2,11	1,65	1,61	3,02
Estonia	1,10	0,58	0,76	1,59	1,68	1,29	1,07	2,73
Finland	1,35	0,76	1,15	1,80	1,97	1,59	1,42	2,72
France	1,08	0,35	0,92	1,67	1,89	1,50	1,39	2,72
Germany	1,14	0,48	1,00	1,72	1,81	1,49	1,56	2,57
Greece	1,01	0,64	0,82	1,51	1,53	1,21	1,46	2,47
Hungary	0,86	0,34	0,55	1,48	1,58	1,17	1,25	2,62
Ireland	1,25	0,79	1,01	1,66	1,72	1,42	1,52	2,50
Italy	1,11	0,61	0,87	1,79	1,89	1,48	1,61	2,83
Latvia	0,91	0,41	0,39	1,47	1,56	1,20	1,07	2,51
Lithuania	0,86	0,48	0,71	1,34	1,43	1,11	0,98	2,50
Luxembourg	1,11	0,51	0,66	1,34	1,36	1,20	1,31	1,83
Malta	1,04	0,55	0,37	1,75	1,77	1,22	1,55	2,97
Netherlands	1,46	0,81	1,26	1,90	2,01	1,63	1,67	2,83
Poland	0,63	0,39	0,42	1,46	1,62	1,12	1,13	2,98
Portugal	1,06	0,56	0,80	1,51	1,56	1,29	1,39	2,38
Romania	0,70	0,43	0,36	1,26	1,24	0,99	1,31	2,16
Slovakia	0,60	0,32	0,33	1,17	1,22	0,97	0,92	2,07
Slovenia	0,80	0,42	0,68	1,27	1,30	1,15	1,00	2,08
Spain	1,00	0,41	0,81	1,66	1,87	1,48	1,34	2,81
Sweden	1,39	0,76	1,20	1,81	1,95	1,59	1,52	2,74
United Kingdom	1,31	0,83	1,20	1,76	1,92	1,56	1,60	2,65
Candidates								
Croatia	0,47	0,15	0,39	1,06	1,17	0,88	0,83	1,99
Macedonia	0,55	0,27	0,34	0,81	1,09	1,06	0,53	1,41
Turkey	0,72	0,76	0,61	1,36	1,51	1,21	1,24	2,41
EFTA								
Iceland	1,64	0,85	1,02	2,07	2,12	1,41	1,81	3,13
Liechtenstein	1,30	0,34	1,67	1,45	1,42	1,39	1,65	n.c.
Norway	1,32	0,74	1,06	1,80	1,96	1,57	1,43	2,86
Switzerland	1,54	0,65	1,26	1,98	2,02	1,70	1,89	2,78
ERA								
Israel	1,25	0,86	1,03	1,76	1,99	1,55	1,59	2,69
Asia								
China	0,71	0,58	0,61	1,46	1,66	1,39	1,39	2,46
India	0,64	0,35	0,58	1,19	1,36	1,12	1,12	1,86
Japan	0,82	0,43	0,74	1,36	1,62	1,30	1,25	2,20
Rep. of Korea	0,92	0,58	0,80	1,38	1,74	1,32	1,32	2,28
Others								
Brazil	0,73	0,34	0,60	1,34	1,54	1,07	1,17	2,71
Russia	0,42	0,18	0,19	1,10	1,21	0,95	0,92	1,89
United States	1,35	0,83	1,38	1,72	1,95	1,79	1,49	2,57

Source: DG Research and Innovation – Economic Analysis Unit, Innovation Union Competitiveness report 2013
Data: Computed by Science-Metrix using Scopus

High quality scientific publications are associated with research teams involving partners from several European countries working with researchers from outside Europe

International collaborations are highly cited overall, with only one country scoring below the world level for this indicator (FYROM, 0.81). With a score of 2.07, the international co-publications of Iceland have the highest impact among those of the selected countries, which confirms their importance regarding the country's strong impact when all its papers are considered. Among the various types of international co-publication analysed, those generally resulting in a stronger impact, with scores above those of all international co-publications in aggregate, include co-publications involving both EU and non-EU partners in first place, and co-publications involving at least one partner from the ERA in second place. Compared to the other two categories of international co-publications, namely co-publications with EU partners only and co-publications with non-EU partners only, they are less restrictive with regard to the partners' location. As such, they are more likely, on average, to result from the work of larger teams of researchers, which might explain their greater impact.

However, other factors may also influence the number of citations received by research publications. Author self-citations are often considered an influential factor. Indeed, the categories with the smallest number of authors scored lowest, and those with the highest number of authors scored highest. This is however probably not the only factor causing the observed increase in the impact of co-publications relative to saps.

Another factor that might explain such an increase is that as publications result from the work of researchers from more countries and/or diverse parts of the world, their citation rates increase due to their greater visibility within the networks of each of their co-authors (i.e. Not only through direct self-citations). Indeed, publications involving researchers from many parts of the world have a higher chance of being cited all around the world, rather than only being cited by local researchers. They may very well be cited by the partners of their own partners, who otherwise would not have cited them if their collaboration networks were unconnected (the farther apart two researchers are, the more likely their collaboration network will be unconnected).

Another possibility — and the main rationale behind scientific policies promoting international cooperation — is that researchers, by pooling diverse and complementary sets of expertise, might manage to tackle challenges that they could rarely have addressed on their own. In turn, this would increase the novelty and quality of their research, as well as the influence/impact of their publications. Given the positive effect of collaboration on scientific impact, it is justified to conduct a more in-depth analysis of scientific collaboration networks within Europe.

3.1.1. Networks of research collaboration in the European Research Area

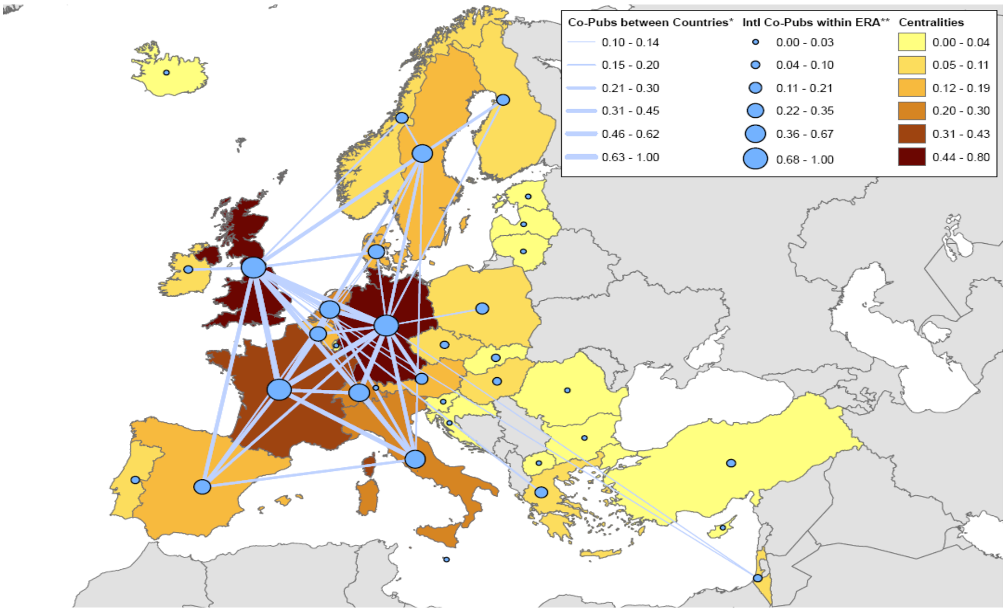
Collaboration networks are displayed below on geographic maps, with countries coloured according to their centrality score (i.e. Eigenvector centrality). The mathematical definition of the eigenvector centrality is such that the centrality score of a node in a network is proportional to the sum of the centrality scores of all nodes that are connected to it. Thus, this indicator offers good appreciation of both the number and quality of an entity's collaborations, since connections to high-scoring nodes (which represent the entities in the network) contribute more to the score of that entity than equal connections to low-scoring nodes. A country scoring high with respect to this indicator operates closer to the core of the network (i.e. It is central and highly important to the network's structure) than a low-scoring country, so the eigenvector centrality provides a good appreciation of the integration of an individual country within a network; that is, the higher the score the more integrated the country.

The level of integration of countries within a collaboration network is reflected by the number of countries to which they are connected, as well as the quality of their collaboration initiatives (i.e. The strength of the links measured by the number of co-authored publications and the importance of the countries to which they are connected in the network). Each link between any two countries on the map is proportional to the number of co-publications between these two countries divided by the maximum number of co-publications observed between any pair of countries within the network. Collaboration links in the network emanate from a bubble (i.e. A country node) proportional to the number of co-publications of a country in the network ([84]). The larger the bubble, the more a country collaborates within the network. The advantage of the collaboration network is that it allows for the rapid visualisation of major 'hubs'; that is, entities for which centrality is highest (i.e. Darker countries on the maps). It also allows rapid visualisation of ties between countries.

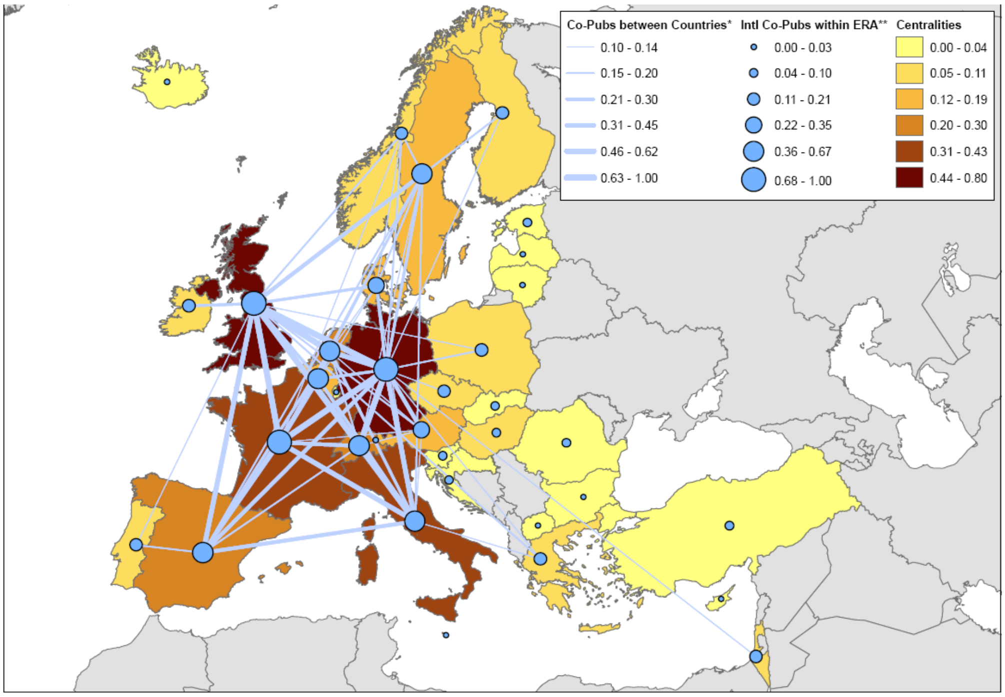
[84] Double-counting of co-publications is avoided; possible values range from 0 % to 100 % for the country with the highest number of co-publications in the network.

Figure II.3.3: Scientific collaboration across the European Research Area covering all areas

2000



2011



Source: DG Research and Innovation – Economic Analysis Unit, Innovation Union Competitiveness report 2011
Data: Computed by Science-Metrix using Scopus

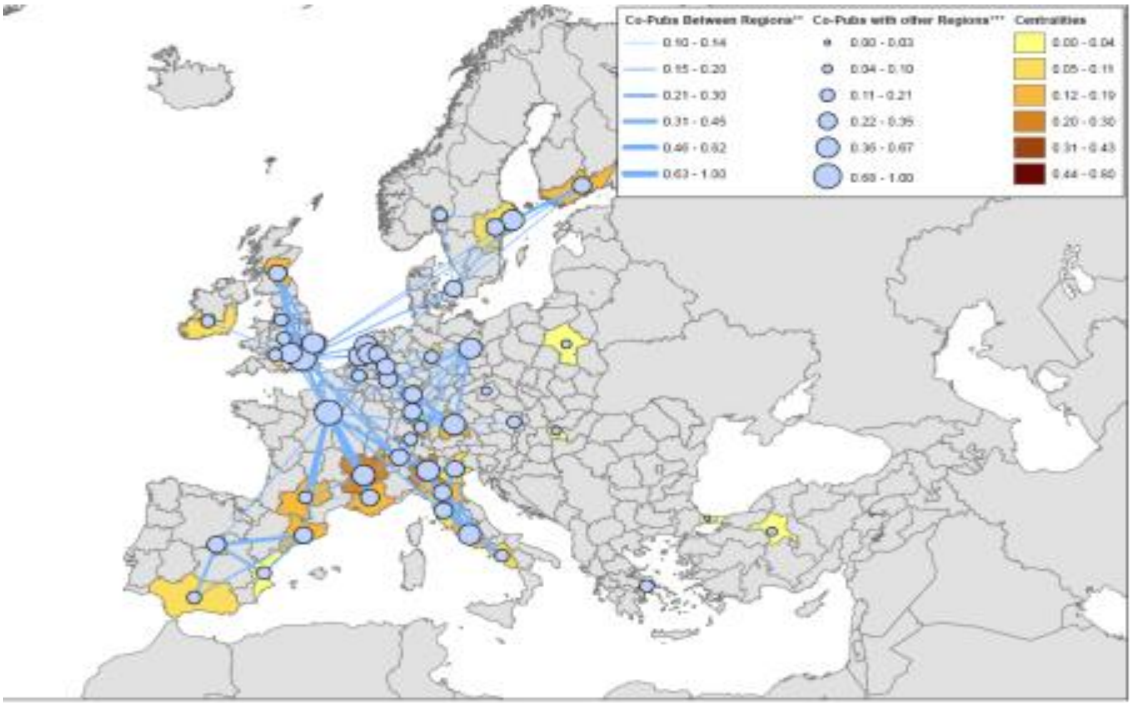
The construction of a European Research Area has enhanced scientific collaboration in Europe. However, eastern European countries are less integrated within European collaboration networks.

The level of integration within overall scientific collaboration in Europe is higher for Western Europe than for Eastern Europe. This is reflected by the centrality scores, the number of countries to which they are connected and the quality of their collaborations. The maps in figure II.3.3 illustrate an increase in countries' centrality scores. However, this increase is not strong and is only really noticeable in the case of Spain and Italy, which show remarkable growth both in centrality and number of co-publications in the network. It seems the catching-up process is making more progress for Mediterranean countries than for Eastern Europe.

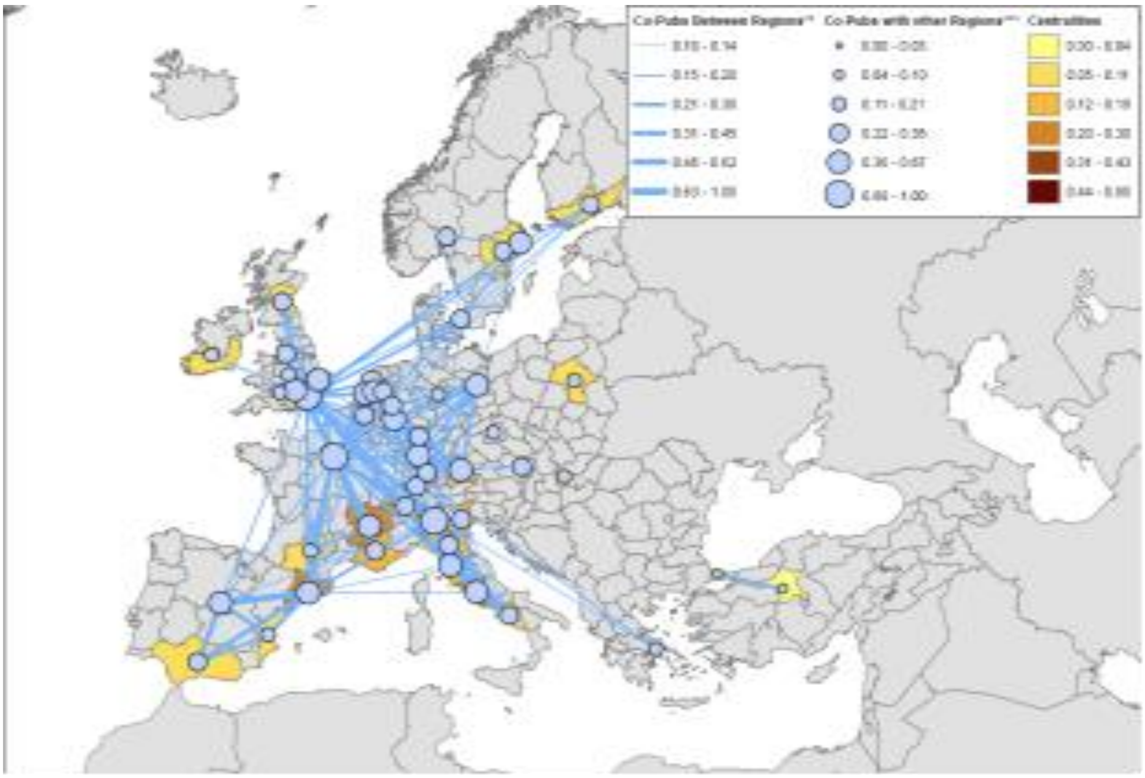
The current situation and the change are more visible at regional level as illustrated in figure II.3.4. The increase in the level of scientific integration in Europe is reinforced by the increase in the number of co-publications involving at least one European country. The links between the centre-nodes are intensified, while the south and north peripheries are slightly better connected to the European core. Strong science nodes are reinforced around large cities, pointing to agglomeration effects. However, the networks reflect lower involvement among eastern European countries, a situation which did not substantially change over the period 2000–2011. The weaker integration of the Member States in Eastern Europe diminishes the chance of knowledge spillover, which would support the catching-up process.

Figure II.3.4: Scientific production in the ERA — all areas in 50 top publishing regions

2000



2011



Source: DG Research and Innovation – Economic Analysis Unit, Innovation Union Competitiveness report 2011
Data: Computed by Science-Metrix using Scopus

Integration in the European Research Area differs depending on scientific field

The integration of European collaboration networks can also be assessed at a thematic level. In each thematic field, the actors are different and so are the incentives to collaborate. Comparing collaboration networks in all the scientific fields ([85]), two main collaboration trends are visible in the ERA: integration and concentration. Integration has been the target of comprehensive policy efforts to construct an ERA ([86]), coupled with the growing share of EU Structural Funds allocated to R&I capacity building. The expected outcomes of these initiatives are increased integration between existing nodes and a simultaneous broadening of the networks to include nodes across all of Europe, including connection to new nodes in catching-up countries. The concentration trend may be more a response to the competitive nature of science-funding tools such as the FP (even though the data on scientific collaboration displayed below represent total scientific publications in Europe, financed by national as well as European funds). For concentration, cooperation links between the central nodes of excellence are reinforced while the links to the less advanced Science and Technology regions are weakened. Previous European Commission studies ([87]) have shown how successive fps have managed to tread a fine line between promoting efficiency and quality in research without sacrificing a cohesive dimension. The result of this effort is reflected through a concentration of FP funds in absolute terms in the main European research hubs, while a large number of peripheral regions have a greater share of European research funds relative to their overall R&D effort.

Research collaboration initiatives in health, energy and environment are increasingly integrated across Europe

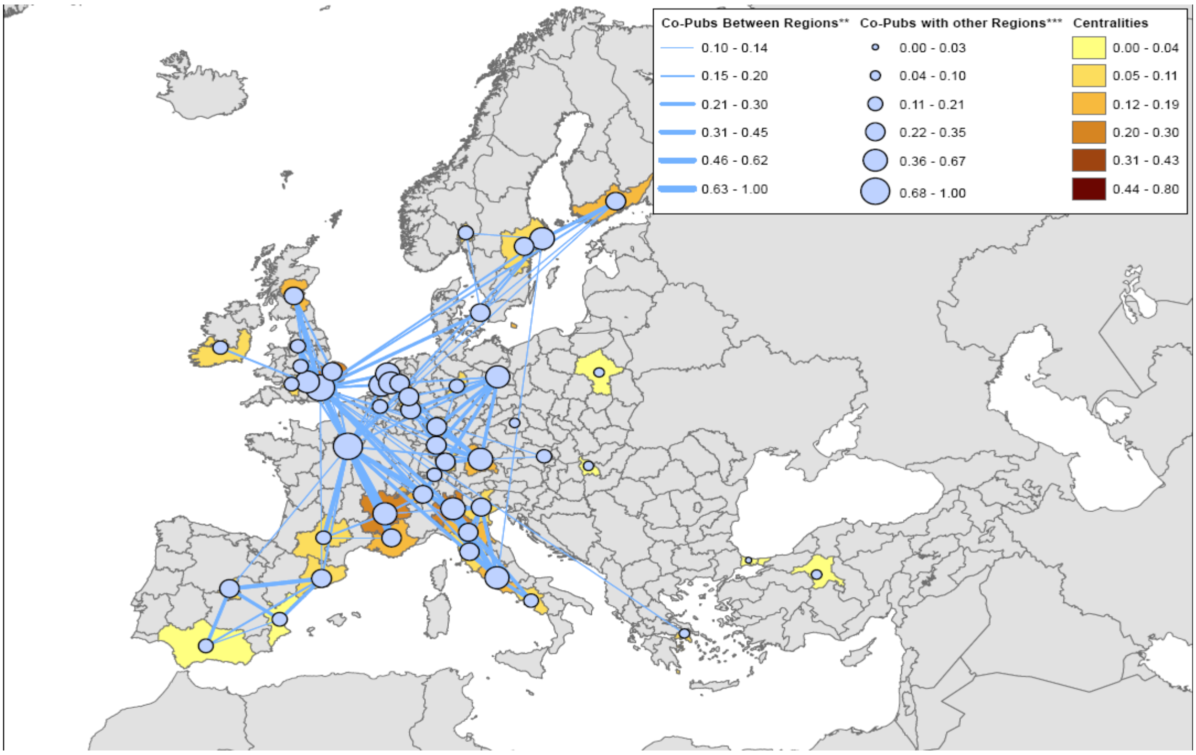
Health is one of the scientific priorities with the highest increase in integration between countries within collaboration networks. This is reflected with a significant increase in three indicators: centrality scores, number of collaboration links between regions and number of co-publications within the network. The maps in figure II.3.5 illustrate how cooperation links between central nodes have been intensified, but also how new links to less advanced research have appeared. Policy efforts have led to increased integration between existing nodes and a broadening of the networks to include new nodes in catching-up countries. This finding is particularly visible for Mediterranean regions in Italy, Spain and Greece.

[85] This chapter presents only a selection of thematic research areas. A complete overview of scientific collaboration networks in all thematic areas can be found in the Statistical annex.

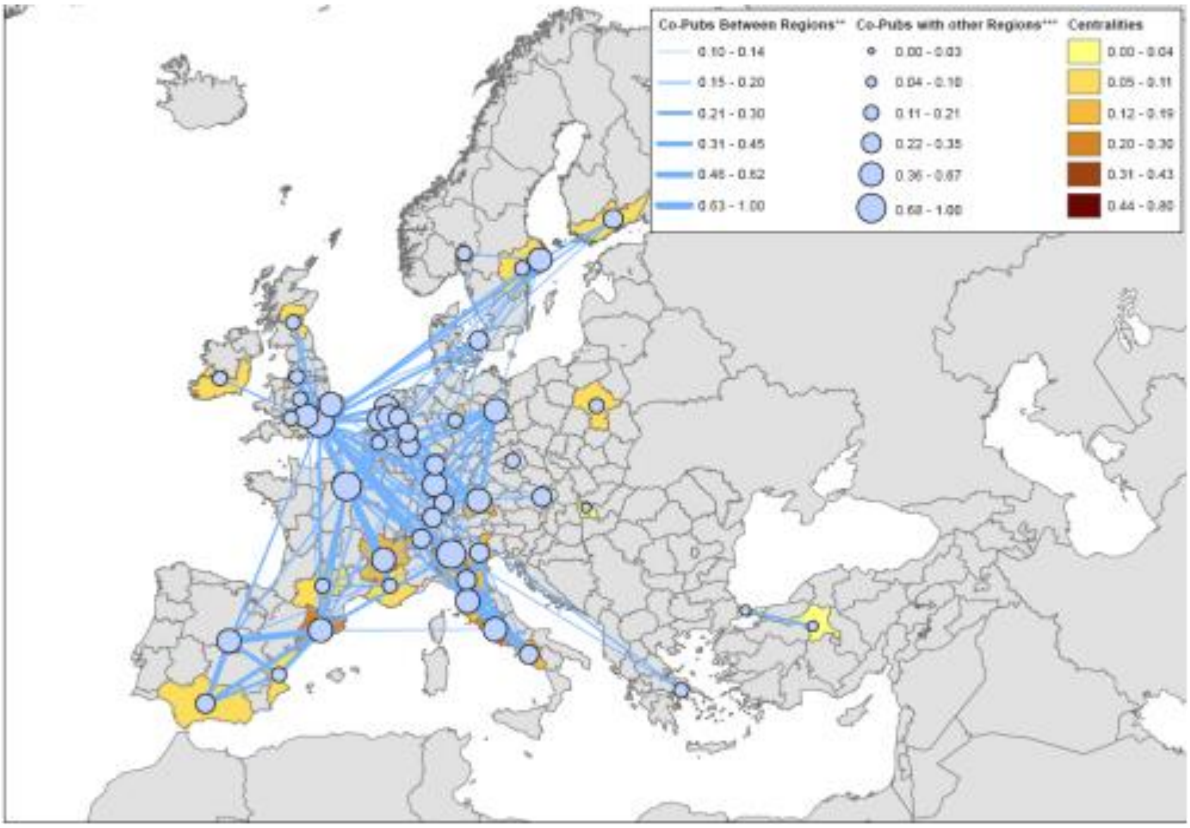
[86] For evidence on the implementation of the policy initiatives for the construction of a European Research Area, see the ERA Progress monitoring report, 2013.

[87] 'Regional analysis of Framework Programme participants from 1987 (FP2) until 2002 (FP5)', prepared for the Directorate-General for Research and Innovation (DG RTD).

Figure III.3.5: Health - scientific cooperation 50 top-publishing regions in Europe, 2000



Health – Scientific co-operation of 50 top-publishing regions in Europe, 2011



Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2011
Data: Computed by Science-Metrix using Scopus

The integration trend visible in health research is also taking place in energy and environmental research. In the field of energy, there has been a strong increase in the number of co-publications involving at least two European countries. Both collaboration links between regions and the overall number of co-publications in the network (bubble size) grew between 2000 and 2011. Centrality scores also grew for certain Mediterranean and a very limited number of eastern European regions. Co-publications showed strong growth in existing nodes, and links between regions outside the network core increased. The integration of European energy research intensified between 2000 and 2011. The links between the centre nodes intensified while the south and north peripheries became slightly better connected to the European core. The networks reflect greater inclusion of some eastern European regions, particularly in Poland, Hungary and the Czech Republic ([88]).

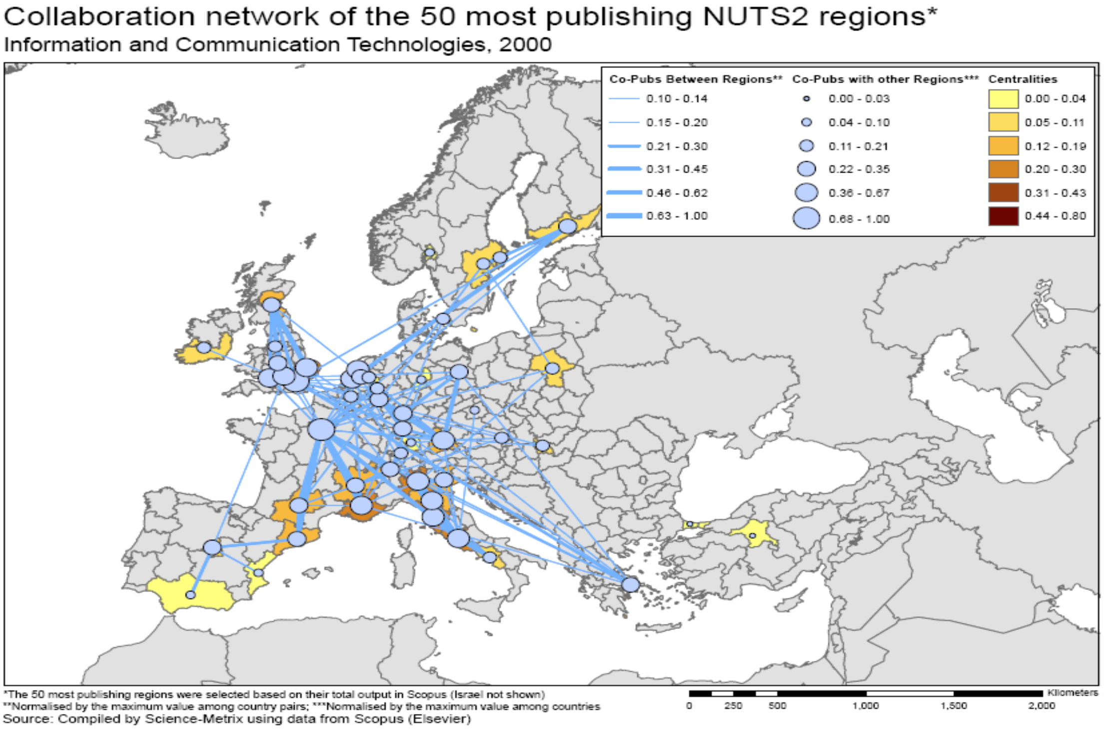
Following a similar evolution, research collaboration for the environment has experienced a noticeable increase as visible in the number of collaboration links between regions and in the number of co-publications within the network. The changes in centrality scores are more visible for certain regions of Ireland and Spain, while other regions remain at the same level as in 2000. Environment networks behave very similarly to those in health or energy. However, contrary to the evolution of the latter, there has not been any visible inclusion of eastern European regions in collaboration networks for environmental research.

Research collaboration in the fields of ICT, nanotechnologies, new production technologies and transport have become more concentrated across major European hubs

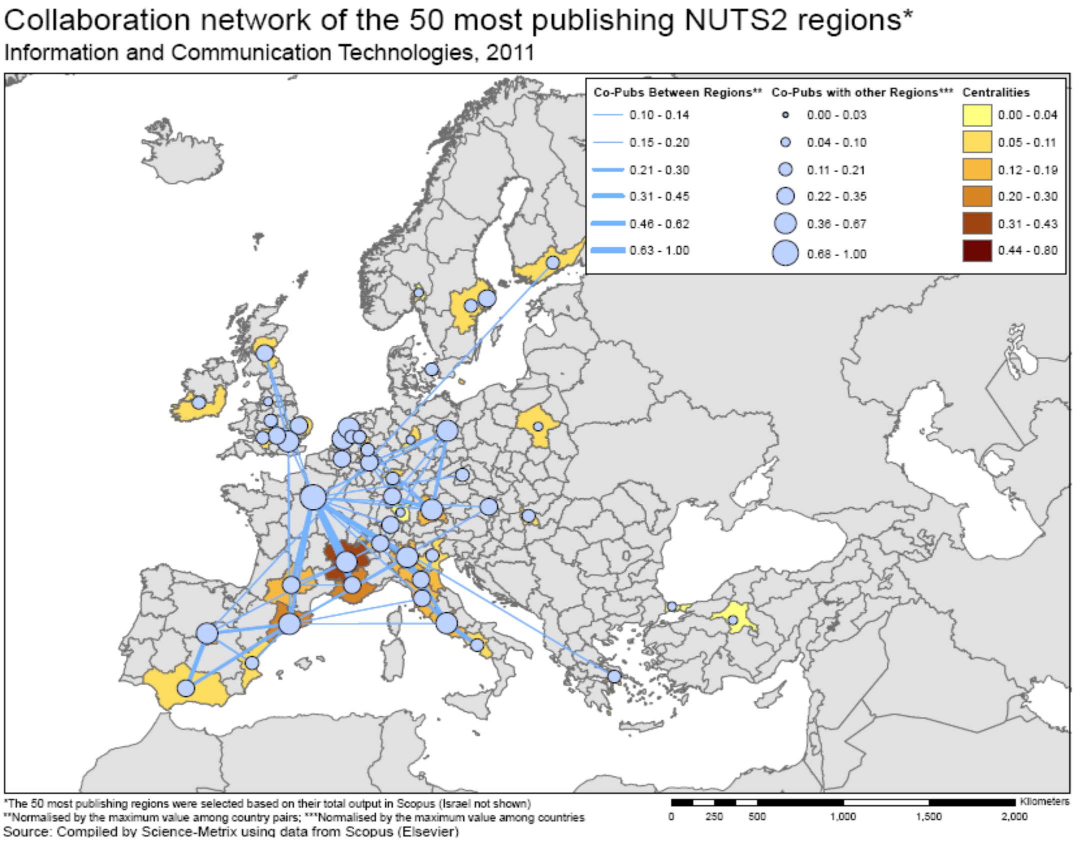
ICT research shows a different pattern of collaboration. The number of collaboration ties between regions seems to have declined while the number of co-publications in ICT inside the ERA increased from 2000–2011. Countries co-publish more but with fewer partners. As previously highlighted, the major hubs in ICT remain the same, while some Mediterranean regions have managed to increase their centrality scores. The networks do not reflect any catching-up among eastern European countries. Strong science nodes are reinforced, pointing to agglomeration effects. Countries publish more, but mainly with the core network, while many links to periphery countries have disappeared.

[88] For a visualisation of the scientific collaboration trends in all thematic areas identified in FP7, see the Statistical annex.

Figure II.3.6: ICT – Scientific co-operation of 50 top-publishing regions in Europe, 2000



ICT – Scientific cooperation between 50 top-publishing regions in Europe, 2011



Source: DG Research and Innovation – Economic Analysis Unit, Innovation Union Competitiveness report 2011
Data: Computed by Science-Metrix using Scopus

A similar trend towards concentration is visible in research collaboration in nanoscience and nanotechnologies. This field is, together with environment, the thematic priority in which collaboration between European countries is the most significant relative to total scientific production in Europe. In this field, as in ICT, the number of ties between regions has been shrinking, despite an increasing number of co-publications in Europe. Stronger science and technology centres in Europe have been reinforced cooperation networks have increasingly crystallised around them. The result is the disappearance of ties outside the core of the network. As in other fields, some Mediterranean regions (i.e. In Spain and in Italy) have improved their centrality scores.

The same concentration trend can be found in science relevant for new production technologies. The major hubs are reinforced, and ties between periphery countries have declined. The number of scientific cooperation initiatives has increased, and while certain regions of France, Italy and Spain gained centrality, northern regions from Finland and Sweden to Eastern Europe have lost centrality. The evolution visible in the maps points to a process of reinforcement around the core network. However, as unlike other research fields, research collaboration for new production technologies does include several nodes in the eastern European countries ([89]). Regions in Poland, Hungary, the Czech Republic, Slovakia, Greece and Turkey are connected to the core of the network, situated between Germany, southern France and northern Italy. A possible explanation for this better integration of regions in Eastern Europe may be found in the trans-European production networks capitalising on the single market ([90]).

In contrast to scientific publications, there is no clear growth in international co-patenting among European countries

Figure II.3.7 illustrates international collaboration in technology development (patenting) in 2000 and 2010. Luxembourg, Latvia, Estonia, Romania, Cyprus, Belgium and Switzerland show the highest share of PCT patent applications, with at least one foreign co-investor. There is no clear growth trend in international co-patenting. Some countries (e.g. Cyprus, Estonia, Luxembourg, Poland, Croatia, Finland and Sweden) have increased their international co-patenting, while others (such as Latvia, Portugal, Greece, Iceland, the Czech Republic, the United Kingdom, Austria, Spain and Slovenia) have shown a decrease. Overall, European countries' international co-patenting has not grown between 2000 and 2010. The sectors where European countries have the highest intensity of international co-patenting are material technologies, aeronautics and technologies for automobiles, with an intensity level above the world average ([91]).

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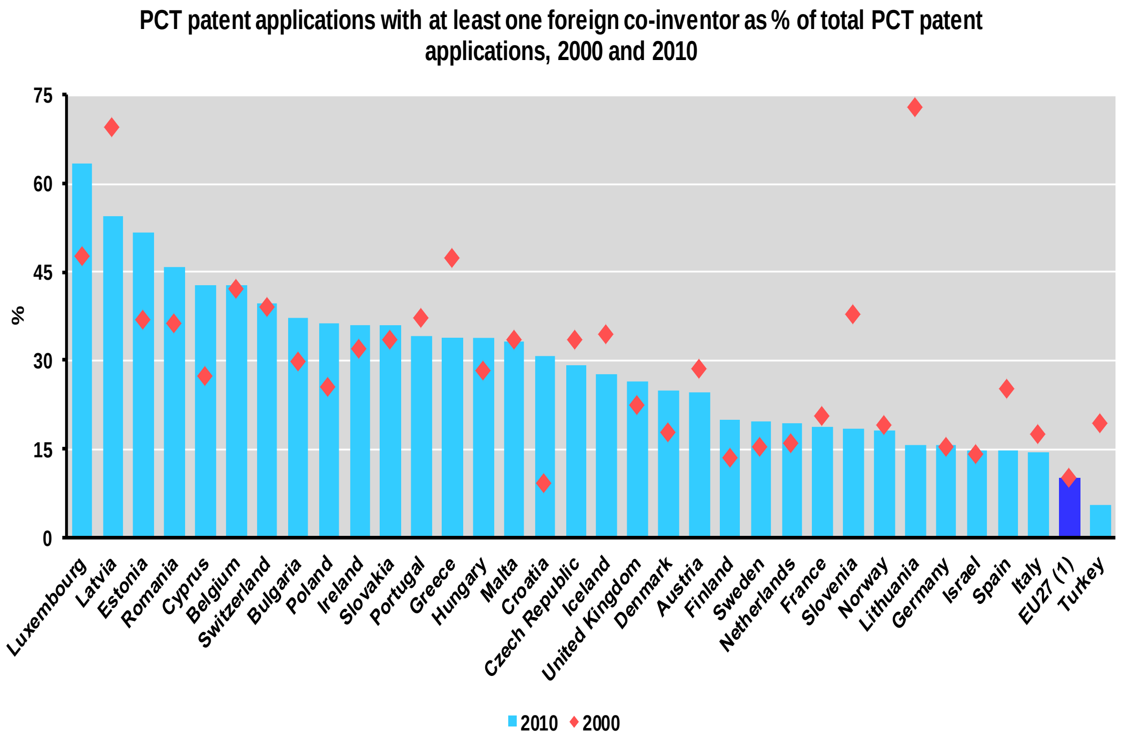
[89] This pattern is also visible in research relevant for transport technologies.

[90] See also Chapter III.4.

[91] A more detailed overview of international co-patenting at sector and country level can be found in the Statistical annex.

Figure II.3.7. International co-patenting of European countries, 2000 and 2010



Source: DG Research and Innovation - Economic Analysis Unit
Data: OECD

Innovation Union Competitiveness Report 2013

Note: (1) EU27 is treated as one country - intra-EU cooperation is excluded.

3.2. Using the Seventh Framework Programme to enhance excellence at national level

Besides scientific and technological collaboration initiatives, European funding instruments are capable of leveraging science and technology performance at the national level. For catching-up countries, Structural Funds are also crucial for improving science quality in domains where the technology is already well developed, as well as for fostering science and technologies capabilities in fields where other latent comparative advantages (e.g. Raw materials) exist.

FP7 and the future Horizon 2020 programme will act both as top-up funding sources and as well as facilitators for participation in European networks. This ensures access to scientific excellence and collaboration with top European researchers. On the one hand, framework programs can be used as a shortcut for improving scientific capabilities within catching-up countries, particularly in research fields that have already reached a high degree of quality at national level, enabling researchers to participate in FP7 programmes. On the other hand, the critical mass and the strategic and global nature of the FP and its successor Horizon 2020 have the potential to support innovation-driven countries in their transformative science and technologies efforts in converging technologies, aiming through their topics and programmes to address pressing societal challenges as well as to promote frontier research.

3.2.1. Correlation between national science and technology strengths and participation in FP7

The table in Figure II.3.8 shows a relative correlation between science and technology capabilities at national level and the use of funding from FP7 for a number of fields. The field of health displays the greatest correlation between science and technology national strengths and financial success in FP7. Other fields present also an overall correlation of FP success, with the technological strengths at national level. These are: food, agriculture and fisheries; biotechnology; materials (excluding nanotechnologies); and security. Finally, for nanosciences and new production technologies there is a noticeable correlation between scientific strengths at national level and participation in FP7.

Figure II.3.8: Overall correlation of national science and technology strengths and participation in FP7

Health	**Index of financial success in FP** (EC contribution / GDP)		**Index of participation in FP** (number of participants / GDP)	
All	***correlation***	***r2***	***correlation***	***r2***
Scientific strength	***0.705***	0.496	0.553	0.306
Technology strength (per inventor)	0.587	0.345	0.462	0.214
Technology strength (per applicant)	**0.632**	0.399	0.500	0.250

Information and Communication Technologies	**Index of financial success in FP** (EC contribution / GDP)		**Index of participation in FP** (number of participants / GDP)	
All	***correlation***	***r2***	***correlation***	***r2***
Scientific strength	0.577	0.333	0.285	0.081
Technology strength (per inventor)	0.442	0.196	0.239	0.057
Technology strength (per applicant)	0.449	0.202	0.257	0.066

Food, Agriculture and Fisheries	**Index of financial success in FP** (EC contribution / GDP)		**Index of participation in FP** (number of participants / GDP)	
All	***correlation***	***r2***	***correlation***	***r2***
Scientific strength	0.516	0.267	0.233	0.054
Technology strength (per inventor)	**0.728**	0.531	0.380	0.144
Technology strength (per applicant)	**0.682**	0.466	0.350	0.123

Environment	**Index of financial success in FP** (EC contribution / GDP)		**Index of participation in FP** (number of participants / GDP)	
All	***correlation***	***r2***	***correlation***	***r2***
Scientific strength	0.350	0.123	0.202	0.041
Technology strength (per inventor)	0.454	0.206	0.142	0.020
Technology strength (per applicant)	0.431	0.186	0.156	0.024

Energy	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	***correlation***	***r2***	***correlation***	***r2***
Scientific strength	0.397	0.158	0.148	0.022
Technology strength (per inventor)	0.580	0.337	0.082	0.007
Technology strength (per applicant)	0.578	0.334	0.134	0.018

Biotechnology	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	***correlation***	***r2***	***correlation***	***r2***
Scientific strength	0.087	0.007	-0.185	0.034
Technology strength (per inventor)	**0.885**	0.784	**0.795**	0.632
Technology strength (per applicant)	**0.856**	0.732	**0.751**	0.564

Nanosciences and Nanotech	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	***correlation***	***r2***	***correlation***	***r2***
Scientific strength	**0.666**	0.444	0.473	0.223
Technology strength (per inventor)	0.580	0.336	0.471	0.222
Technology strength (per applicant)	0.583	0.340	0.487	0.237

Materials (excluding nanotech)	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	***correlation***	***r2***	***correlation***	***r2***
Scientific strength	0.575	0.330	0.076	0.006
Technology strength (per inventor)	**0.789**	0.623	0.312	0.097
Technology strength (per applicant)	**0.756**	0.572	0.333	0.111

New Production Technologies	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	***correlation***	***r2***	***correlation***	***r2***
Scientific strength	**0.624**	0.389	0.351	0.123
Technology strength (per inventor)	0.529	0.280	0.222	0.049
Technology strength (per applicant)	0.561	0.315	0.287	0.082

Construction and Construction Technologies	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	***correlation***	***r2***	***correlation***	***r2***
Scientific strength	0.492	0.242	-0.079	0.006
Technology strength (per inventor)	0.550	0.303	0.081	0.007
Technology strength (per applicant)	0.477	0.228	0.068	0.005

Sustainable surface transport	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	*correlation*	*r2*	*correlation*	*r2*
Scientific strength	0.467	0.218	0.035	0.001
Technology strength (per inventor)	0.434	0.188	0.087	0.008
Technology strength (per applicant)	0.425	0.180	0.127	0.016

Aeronautics and air transport	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	*correlation*	*r2*	*correlation*	*r2*
Scientific strength	0.273	0.075	0.024	0.001
Technology strength (per inventor)	0.334	0.111	-0.076	0.006
Technology strength (per applicant)	0.341	0.116	-0.075	0.006

Other Transport Technologies	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	*correlation*	*r2*	*correlation*	*r2*
Scientific strength	0.058	0.003	-0.201	0.040
Technology strength (per inventor)	0.138	0.019	-0.112	0.013
Technology strength (per applicant)	0.133	0.018	-0.023	0.001

Security	Index of financial success in FP (EC contribution / GDP)		Index of participation in FP (number of participants / GDP)	
All	*correlation*	*r2*	*correlation*	*r2*
Scientific strength	0.017	0.000	-0.392	0.153
Technology strength (per inventor)	**0.625**	0.390	0.048	0.002
Technology strength (per applicant)	**0.644**	0.414	0.065	0.004

Source: DG Research and Innovation – Economic Analysis unit
Data: Science Metrix – Canada, based on Scopus data; Univ. Bocconi - Italy, based on WIPO-PCT applications

Correlation between science and technology strengths at national level and participation in FP7 varies depending on the sector and the country

Some countries have managed better than other to correlate the science and technology strengths with the participation in FP7. There are also sector differences. Extensive data by field show that whereas there is a great correlation between science at home and participation in FP7 for most European countries in the field of health, in other domains the correlation is less significant, with differences between countries. There is a clear correlation scientific strength in health and participation in the FP. In this sense, Estonia, Slovenia and the Netherlands have taken advantage of their scientific strengths and have high participation levels. In the field of food, agriculture and fisheries, Denmark and Finland, as well as the Netherlands, Belgium and Ireland, show a particularly effective use of national technological resources, leveraging higher participation in FP7. The same goes for the field of biotechnologies, broadly with the same top countries: Finland, the Netherlands, Belgium and

Ireland, as well as Slovenia. For nanosciences and nanotechnologies (see statistical annex) , the Nordic countries (Finland, Sweden and Denmark), but also Switzerland, Ireland, Belgium, Slovenia and the Czech Republic build successfully on their domestic scientific capacity when participating in FP7. Finally, in the field of materials (excluding nanotechnologies) are several countries have achieved more successful participation in FP7 in comparison to the technological strengths at home: Switzerland, Belgium, Denmark, Slovenia, Ireland, Italy and Spain are among these countries.

Figure II.3.9: Correlation between scientific strengths and FP success — Health

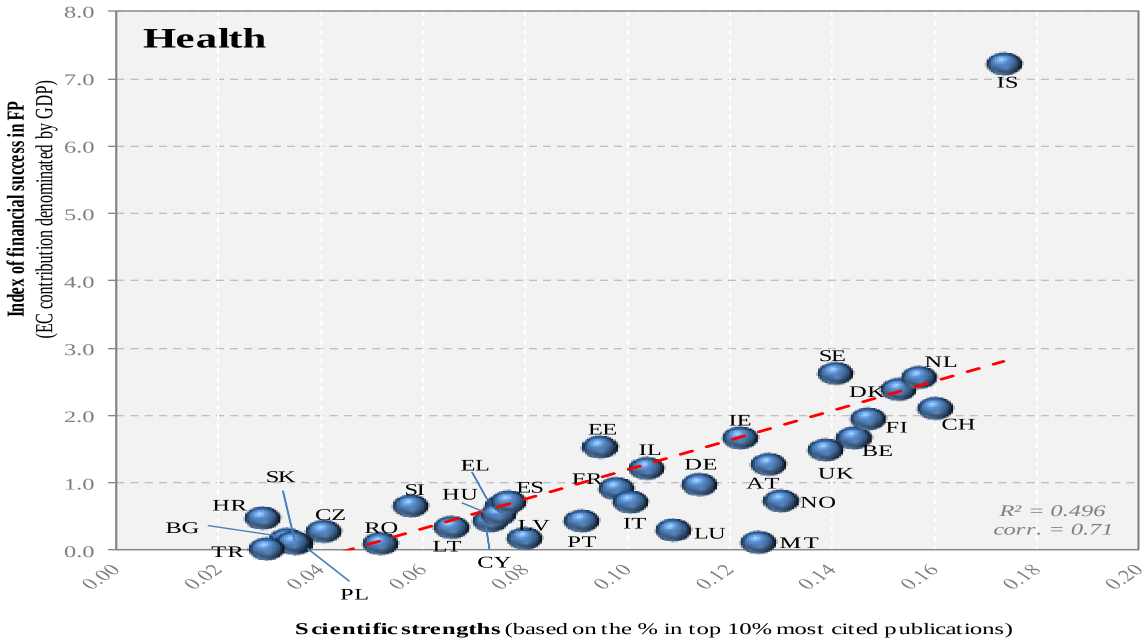


Figure II.3.10: Correlation between scientific strengths and FP success — Food, Agriculture, Fisheries

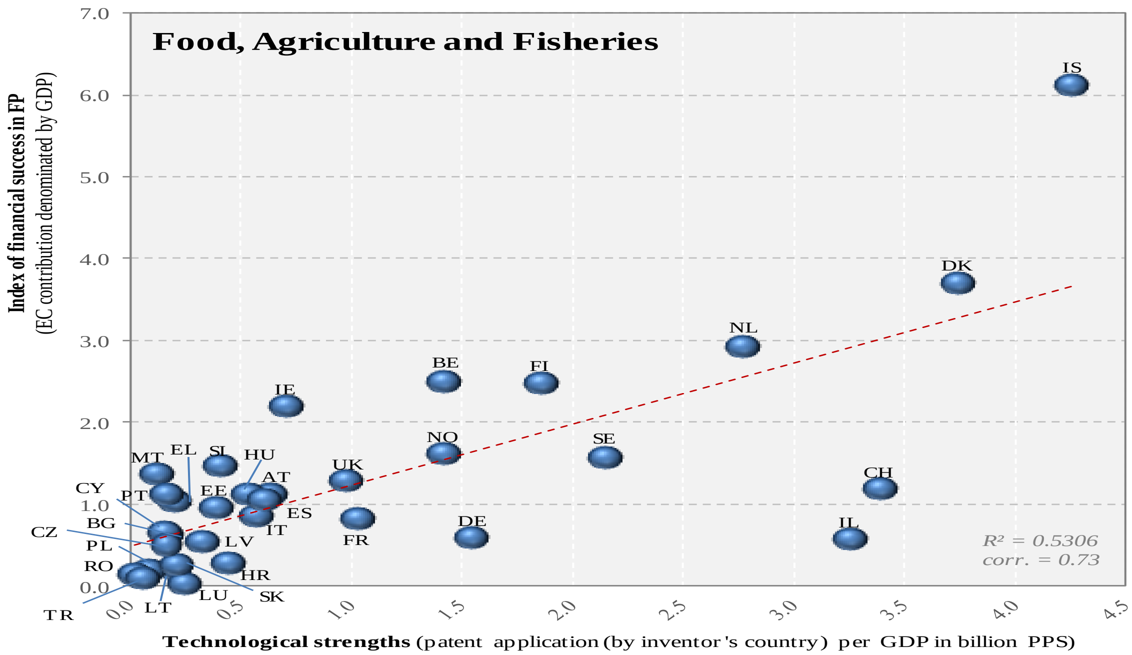


Figure II.3.11: Correlation between scientific strengths and FP success — Biotechnology

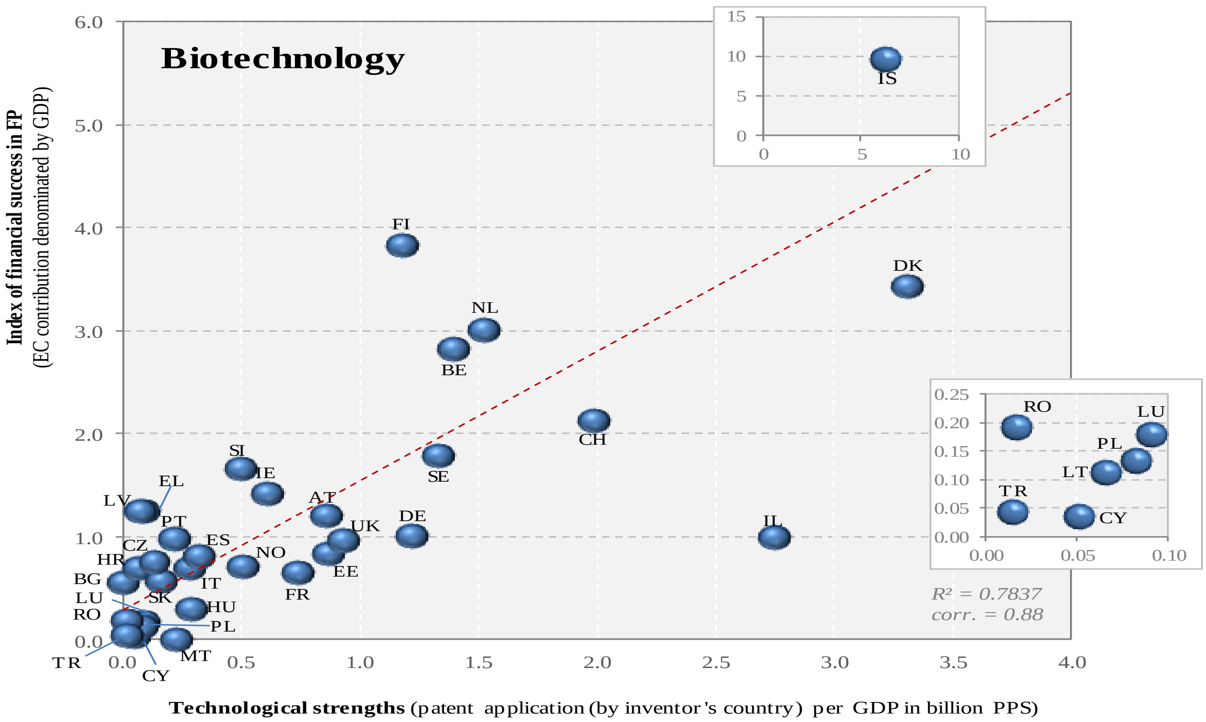
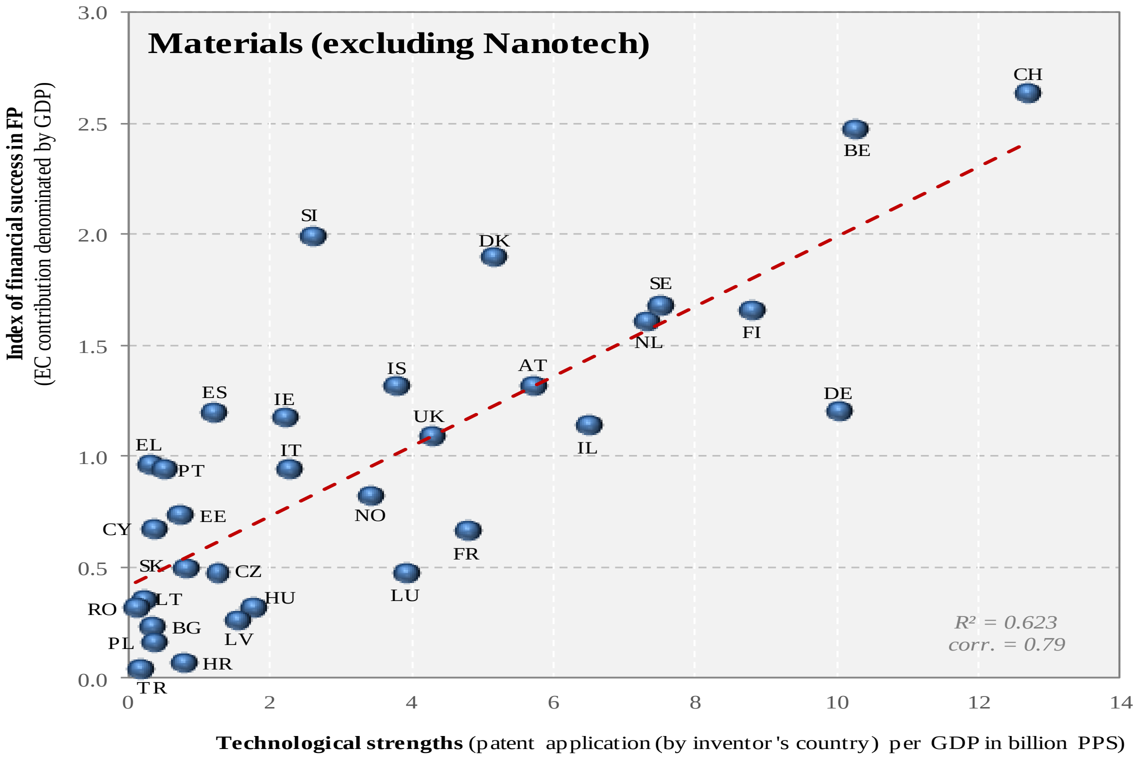


Figure II.3.12: Correlation between scientific strengths and FP success — Materials



3.2.2. The role of country characteristics in successful FP participation

The correlation between national science and technology strengths and FP participation can be analysed in more detail based on country characteristics. For this propose, this section has chosen two main groups of countries have been chosen based on the country groupings presented in the Innovation Union Competitiveness report 2011 The first group is formed by countries with a high knowledge capacity, including Germany ([92]), specialised in high-tech manufacturing and the United Kingdom, France, Austria and Belgium, with a mixed economic structure. The second group is formed by low knowledge capacity systems with specialisation in low knowledge-intensive sectors: Romania, Bulgaria, Poland, Turkey and Croatia.

Germany, the United Kingdom, France, Belgium and Austria have high knowledge capacity systems, coupled with a high rate of participation in FP7

The overall high quality of research in this group of countries (reflected by the high impact of publications) is matched by an overall high rate of participation in FP7. Large countries such as the United Kingdom and France each participate in over 50 % of all FP7 thematic priority

[92] The 2011Innovation Union Competitiveness report separates Germany from the group of the United Kingdom, France, Belgium and Austria, mainly due to distinct economic structures. However, since knowledge capacity is high in all countries, this analysis has merged the five countries into one.

projects, and Germany in over 40 %. The smaller countries of the group — Austria and Belgium — participate in over 25 % of these projects. In some fields, the participation rises to 80 %; this is the case for Germany in nanomaterials and new production technologies and for the United Kingdom in socioeconomic sciences and humanities. In other fields, participation rises to 60–70 %. This is the case for the United Kingdom in the fields of health and food (over 70 %), as well as for France for the fields of transport and food (over 60 %). Although a small country, Belgium also has very good participation rates in the field of transport (being a part of 46 % of the projects); the same holds true for Austria in the field of environment (participating in 29 % of FP7 projects in the field).

National science and technology strengths and successful participation in European funding programmes are mutually reinforcing, contributing to a further increase of quality and performance at national level. This is also confirmed by data at institutional level, showing for instance that most publishing universities in these countries are very well connected in international networks with universities abroad.

The process of 'smart' specialisation in knowledge-based sectors would benefit from taking into account first and foremost the domains in which there is already an established co-specialisation in both science and technology: environment for the United Kingdom, France and Austria; health for the United Kingdom, France and Belgium; construction for the United Kingdom and Belgium; automobiles for Germany and Austria; security for the United Kingdom; new production technologies for France; materials for Germany; and food & agriculture for Belgium.

It is also relevant to consider the technological sectors with the highest growth dynamics over a given period of time because it is very likely that these sectors will become part of future specialisation constellations. Between 2000 and 2010, the highest growth of technologies has been in the field of aeronautics for France, Germany and, to a slightly lesser extent, the United Kingdom. As a result, all these three countries are already well specialised in aeronautics in terms of technologies. However, this is not (yet) matched by a similar specialisation in science. Whereas the quality of science in aeronautics is very good, increased specialisation as reflected by the number of publications will need to be further fostered if absorption and economic impact are to increase in the aeronautics industry in all the three concerned countries.

Another technological sector with a high growth dynamics over the last 10 years is nanotechnologies for Belgium and Austria, Germany was also particularly active in FP7 in this field. Further specialisation in this field is likely in the next years if the technological trend proves e sustainable.

A third avenue to co-specialisation in science and technology is science dynamics. A high increase in the number of ICT publications of all five countries within the group over the last decade is supported by considerable success in FP7: Germany participates in 73.14 % of FP7 ICT projects, the United Kingdom in 58.29 %, and France in 50.79 %. The two smaller countries also have a good participation rate in ICT projects (Belgium at 26.97 % and Austria at 22.35 %). In addition, publications in the field of security increased spectacularly in France, Germany and Austria over the last decade, also accompanied by substantial success in FP7 (participation in over 60 % of FP7security projects for Germany and France, and over 30 % for Belgium). A further use of this latent comparative advantage can be fostered by unleashing competitive advantages in industries that would likely use technologies developed in these fields.

Figure II.3.13: Countries with high knowledge capacity systems with specialisation in high-tech manufacturing (Germany) and a mixed economic structure (Belgium, the United Kingdom, France and Austria)

Country	*Specialisation in science and technology 2000-2010*	*Fields with significant growth rates in science and technology 2000-2010*	*Excellence in science*	*Five most successful fields in FP7*
Germany	*Co-specialisation in S&T* **Automobiles** **Materials**	**Nanoscience and Nanotechnologies** **Aeronautics** Security (mainly publications) **ICT** (mainly publications) **New production technologies** (mainly publications) **Aeronautics**	Most fields	**Nano-materials-new production technologies-**construction **ICT** **Transport** Environment
Belgium	**Food & agriculture** Health Construction **Humanities**	Nanoscience and nanotechnologies ICT **Aeronautics** (mainly science)	Most fields	**Food, agriculture** and biotechnology **Transport** Socio-economic sciences and **humanities**
United Kingdom	Construction **Health** **Environment** **Security** **Socio-economic sciences and humanities** (only publications)	ICT Nanoscience and nanotechnologies Aeronautics	All fields	**Socio-economic sciences and humanities** Food, agriculture and biotechnology **Environment** **Health** **Security**
France	Health **Environment** New production technologies Humanities (only in publications)	Nanoscience and nanotechnologies ICT **Security** New production technologies Construction **Aeronautics** (mainly	Most fields	**Transport** **Environment** Food, agriculture and biotechnology **Security** Space

Country	*Specialisation in science and technology 2000-2010*	*Fields with significant growth rates in science and technology 2000-2010*	*Excellence in science*	*Five most successful fields in FP7*
		in patents)		
Austria	Automobiles **Environment**	Nanoscience and nanotechnologies **Security** (mainly publications) **ICT** (mainly publications)	Most fields	**Environment** Socio-economic sciences and humanities **Security** **ICT**

In contrast, Bulgaria, Romania, Poland, Turkey and Croatia have a low knowledge-intensive economy, while participation in FP7 is rather modest

These countries do not benefit from an overall correlation between science and technology domains, most probably due to their specialisation in low knowledge-intensive economic sectors, accompanied by rather weak overall scientific quality. Maybe with the exception of Poland, foreign direct investment (FDI) for more knowledge-intensive activities (kias) is generally lacking in these countries. Improving the overall framework conditions for business innovation becomes therefore instrumental in order to attract foreign capital for R&I-related activities and to foster the creation of local innovative companies.

The overall participation of these countries in FP7 is rather modest, with variations within the country group due to the size of the country: Poland's participation in European projects varies between 10 % and 25 % by FP7 field, followed by Romanian participation between 4 % and 14 %. Similarly, Bulgarian participation is between 2 % and 13 %, for Turkey it is between 3 % and 25 %, and for Croatia between 1 % and 5 %, varying yet again by FP7 field. National participation rates are highest for the environment for Romania and Bulgaria; food, agriculture and biotechnologies for Turkey and Croatia; and security for Poland.

The sectors in which there is co-specialisation in both science and technology are good candidates to start the smart specialisation process. These are food and agriculture for Bulgaria, Poland, Turkey and Croatia, with Turkey registering a high growth rate for food sector-related technologies. Interestingly enough, the only country not specialised in food and agriculture in this group is Romania, despite its evident potential; however, whereas technological developments continue to remain weak (only 4 patents in Romania over 10 years), there is high growth in both number and quality of the scientific publications in this field.

Other fields where these countries are co-specialised in Science and Technology are energy for Romania, Bulgaria and Turkey, construction for Poland and Turkey, ICT and new production technologies for Romania, other transport technologies and health for Croatia, and materials in the case of Poland.

The second avenue is to boost scientific strengths in fields where there is a positive technology dynamic within industry, with a view to improving knowledge transfer and economic impact. Relative technology growth is evident in the field of automobiles for three countries in this group, namely Bulgaria, Romania and Turkey. Romania and Turkey already show clear specialisation in this field, while the same is expected in Bulgaria soon if the growth trend is sustained. The field of construction technologies recorded relative growth in Bulgaria over the last decade; it is, however, not accompanied by any correspondent science results.

This positive dynamic in technology development is not backed up by a similar specialisation/quality of science in any of these countries. The publications are few and in addition there is room for improvements in quality. One avenue to reinforce national strengths would be increased participation in Horizon 2020 in this field.

In terms of science, positive dynamics have however been taking place in the last decade, and there is clear growth in research for ICT and security. However, the participation in FP7 in the field of ICT is not high for any of these countries. Participation is higher in the fields of security than in ICT. In Romania substantial growth in publications is also observed in the fields of biotechnology, construction, and food and agriculture.

Figure II.3.14: Low knowledge capacity systems with a specialisation in low knowledge intensity (Bulgaria, Romania, Poland, Turkey and Croatia)

Country	*Co-specialisation in science and technology 2000-2010*	*Fields with significant growth rates both in science and technology 2000-2010*	*Excellence in science*	*Most successful fields in FP7*
Romania	ICT **New production technologies** Energy **Nanosciences and nanotechnologies** **Humanities** (only publications)	ICT Security Biotechnologies (only publications) Construction (only publications) Automobiles (mainly patents)	Food & agriculture Other transport technologies Security Energy (is increasing quality)	Environment Socio-economic sciences and **humanities** Security Transport **Nano**-materials-**new production technologies**-construction
Bulgaria	Energy **Food & agriculture** Aeronautics	ICT **Security** Automobiles (only patents) Construction (mainly patents)	Energy Other transport technologies Aeronautics	Socio-economic sciences and humanities Environment **Food, agriculture** & biotechnology Space **Security**
Poland	**Food & agriculture** **Materials** **Construction** **Humanities** (only	**Security** **Biotechnology** ICT	Energy **Aeronautics** **Security Materials**	Socio-economic sciences and **humanities** **Security**

Country	*Co-specialisation in science and technology 2000-2010*	*Fields with significant growth rates both in science and technology 2000-2010*	*Excellence in science*	*Most successful fields in FP7*
	publications)			**Transport** Space **Food, agriculture** & **biotechnology** Nano-**materials-** new production technologies-**construction**
Turkey	**Food & agriculture** Construction Energy	ICT Energy **Security** Automobiles **Food & agriculture** (mainly patents) Nanosciences and nanotechnologies (only publications)	**Security** Energy Other transport technologies New production technologies ICT Construction Materials	**Food, agriculture** & biotechnology Socio-economic sciences and humanities Environment **Security**
Croatia	**Food & agriculture** **Other transport technologies** Health **Humanities** (only publications)	ICT New production technologies Security Health Materials **Biotechnology**	Security **Energy**	**Food, agriculture** & **biotechnology** Environment Socio-economic sciences and **humanities** **Energy** **Transport**

4. Circulation of knowledge throughout the economy

Highlights

European enterprises use a wider range of channels for knowledge circulation

Wider and faster circulation of knowledge can be facilitated by a large range of market- and non-market–driven channels, which can be classified under three interrelated mechanisms: sourcing of knowledge, exploitation of knowledge and co-creation for knowledge-based innovation. Surveys of European firms reveal that companies use an increasing number of channels for knowledge circulation. Recruitment of skilled workers, research and innovation collaboration and patent technology licensing are among the most preferred.

Knowledge circulation throughout Europe is intensifying

The empirical data in the chapter, collected from a large variety of sources, point at a growing intensity of knowledge circulation in Europe, visible both in the number of channels available to firms and in the extent to which these are utilised. The European single market appears to facilitate knowledge circulation within the EU, as evidenced by data on mobility, licensing, exports and research collaboration patterns. However, the internationalisation of knowledge dissemination beyond Europe is also expanding.

Firms and organisations in countries with lower absorptive capacity access very few knowledge channels

However, the analysis also shows that not all EU Member States benefit equally from the knowledge spillovers emerging from knowledge circulation. The main distinctive barrier to broad participation in European knowledge circulation is absorptive capacity. Firms and organisations in countries with lower R&D intensities can only participate marginally in the different mechanisms for knowledge circulation. Their main channel for accessing knowledge for innovation is the acquisition of machinery and equipment. The low R&D-intensive countries benefiting from higher income levels are also able to participate actively in the sourcing of information for innovation, and to a certain extent in international research collaboration between firms and public research institutions. By contrast, highly R&D-intensive firms and organisations are actively utilising all available knowledge circulation channels, inside Europe as well as in the US, Asia and other countries.

Lifting barriers would spur knowledge circulation and enhance economic impact

In- and out-licensing activities are hampered by market failures, technology mismatch and informational asymmetries; the innovation effect of recruiting skilled employees is reduced by excessively restrictive non-compete agreements (NCAs), while research collaboration between firms and public research institutions (including universities) is challenged by deficient organisational coordination mechanisms and sociocultural divergence between actors. Empirical evidence also indicates the importance of taking into consideration the specific challenges facing small and medium-sized enterprises (SMEs) in relation to knowledge circulation, since their needs and capacities differ from those of large firms.

4.1. Mechanisms for knowledge circulation and absorptive capacity

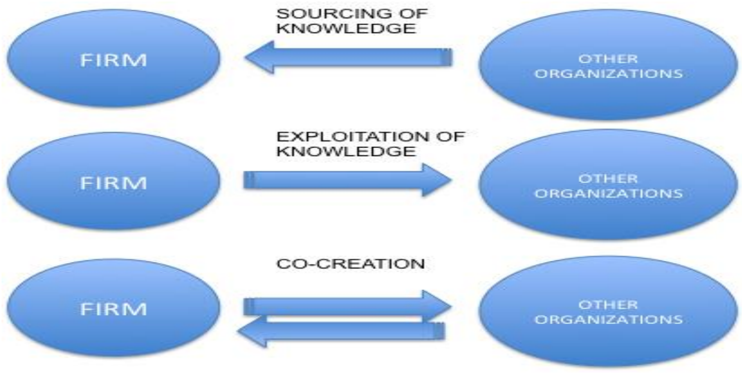
Knowledge circulation is the process by which existing and new knowledge is disseminated throughout the economy and taken up by firms. Knowledge transfer between public and private actors is part of this process. The capacity of a given system of innovation to circulate knowledge across the different actors depends, at least, on the amount of knowledge ready to be distributed, as well as the availability of channels for the dissemination of that knowledge (David and Foray, 1994). The amount of knowledge available in the system has been presented in other chapters of this report (R&D intensity, human resources, publications, patents, innovative firms). This chapter will focus on the channels for the circulation of knowledge as well as the barriers for the dissemination and use of knowledge relevant for innovation.

Firms and other organisations access knowledge for innovation using a variety of market and non-market mechanisms, from the acquisition of machinery or human resources (embedded knowledge) to the development of new knowledge through open innovation or the commercial exploitation of knowledge through for instance, a spin-off company or licensing.([93]) Different mechanisms, in turn, reflect different strategies for accessing knowledge (knowledge exploiting and knowledge seeking) that are also related to different technological capabilities (Cohen and Levinthal, 1991; Tidd et al., 2002). Organisations with higher technological capabilities tend to use more sophisticated strategies for accessing and using knowledge and, as a consequence, engage in different mechanisms for knowledge creation and acquisition. Open source strategies are not exclusively a mechanism of R&D-intensive firms (OECD, 2012a), but the absorptive capacity will determine the variety of channels that are available to them.

This chapter distinguishes between three major mechanisms for knowledge circulation (Archibugi and Michie, 2005): sourcing of knowledge, exploitation of knowledge, and innovation and co-creation of knowledge.

[93] Directorate-General for Research and Innovation (DG RTD), 'Expert group report on indicators on Knowledge Transfer' (autumn, 2011).

Figure II.4.1: Mechanisms for knowledge circulation



The external **sourcing of knowledge** refers to the purchase of embodied knowledge through a variety of mechanisms, including the acquisition of machinery and components for innovation, the outsourcing of R&D (extramural R&D), the mobility of skilled human capital, particularly in S&T, and the purchase of patents and other intangible assets, both nationally and internationally. It also includes the search for information related to innovation, which often takes place using more informal, non-market mechanisms ([94]).

The **exploitation of knowledge and innovation** refers to the commercialisation of innovations in national but also international markets. It embraces mainly market mechanisms such as exports of new products, patent licensing and licensing agreements. It also includes the exploitation of innovative ideas via spin-offs, both academic and corporate. The exploitation of innovations requires more advanced technological capabilities as it implies the development of technological innovations that can be further commercialised.

The **co-creation of knowledge** alludes to the joint development of know-how or innovation with the participation of external partners. In contrast with the previous two mechanisms, co-creation involves shared efforts, risks but also gains in terms of knowledge. This collaboration may take a variety of forms, including R&D collaboration, which may conclude in a joint patent application (co-patenting). In recent decades, scholars have collected abundant evidence of the increasingly international character of knowledge flows, particularly of the exploitation of innovation and research collaboration (Chesnais, 1988; Narula and Hagedoorn, 1999).

The different mechanisms are not mutually exclusive and, more often than not, they co-exist ([95]). However, as indicated earlier, they reflect a certain level of absorptive capacity and technological capability, so we may expect to find a larger variety of channels in countries,

[94] Naturally, what is knowledge sourcing in one organisation is knowledge exploitation in another — for example, the transfer of highly qualified professionals from university to industry is exploitation of knowledge for the university and sourcing of knowledge for the firm.

[95] This implies that there is not a one-to-one correspondence between activities and mechanism for knowledge transfer. For example, the investments in extramural R&D can be considered both sourcing and co-creation.

sectors and organisations with higher technological capabilities than with lower ones. Given the heterogeneity of European countries in terms of R&D intensity and availability of knowledge, differences in the use of various mechanisms for knowledge sharing are to be expected. The engagement in different mechanisms for knowledge sharing is positively related to the innovation performance of firms. At country level, high knowledge transfer policy intensity ([96]) tends to be found together with high national innovativeness and competitiveness. However, also countries with low R&D intensity can benefit positively from engaging in knowledge sharing, even if it is more difficult for them to participate in certain mechanisms or channels for knowledge circulation. In order to optimise the use of each mechanism, any barriers hampering knowledge circulation for innovation should also be addressed. The importance of different barriers depends on the characteristics of each country in terms of R&D intensity and available knowledge.

The following sub-chapters analyse in more detail each mechanism and their relevance for different types of countries.

4.2. Sourcing of knowledge

Acquisition of machinery is essential for countries with low R&D intensity

Expenditure on the acquisition of machinery is significant and positively related to innovation performance (new products and new processes) both in manufacturing (Gracia et al., 2008) and in services (Silva et al., 2012). It is probably one of the mechanisms for knowledge exchange that demands less in terms of absorptive capacity from the recipient firm or country. Countries with low overall R&D intensity rely more heavily on the acquisition of machinery than any other group. It is, in fact, one of the most important mechanisms for knowledge acquisition in these countries. As observed in Figure II.4.2, Latvia, Lithuania, Bulgaria and Poland spend more than 70 % of their innovation expenditure on acquiring machinery, whereas this number in Denmark or Austria is less than 10 %.

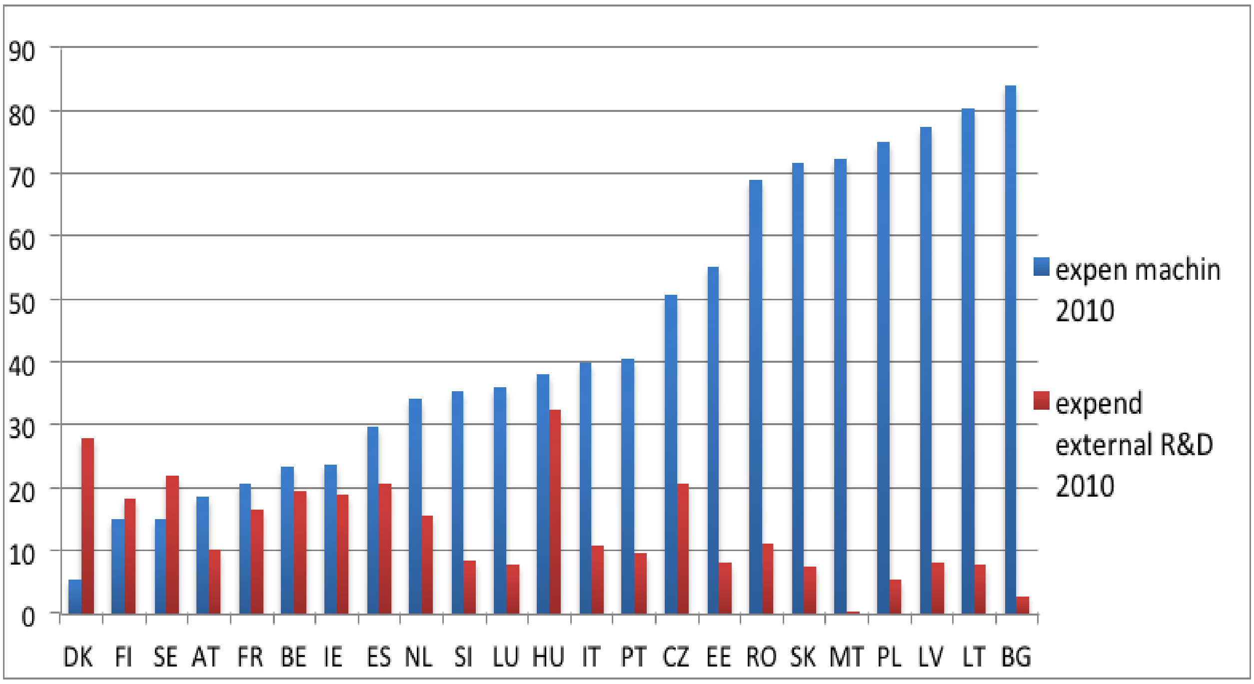
Extramural R&D is growing but requires a higher absorptive capacity

Extramural R&D is positively associated with innovation performance (in terms of turnover due to new products) (Frenz and Ietto-Gilles, 2009). But in contrast to the acquisition of machinery, engaging in extramural R&D requires higher absorptive capacity. Firms need to be able to understand, monitor and often integrate the R&D outsourced with their own internal R&D. The ratio of extramural R&D to intramural R&D has increased in recent years in European countries, which suggests a higher propensity to procure external R&D services (OECD, 2012a).

[96] 'Knowledge Transfer study 2012' p. 8.

A quick look at the data in Figure II.4.2 reveals differences between countries both in terms of acquisition of machinery and for external R&D. In the highest range of the spectrum we find Hungary, Denmark and Sweden, while Bulgaria and Malta are investing less in external R&D. The ANOVA test confirms that low overall R&D-intensity countries are spending significantly less than firms in R&D-intensive countries.

Figure II.4.2: Percentage of innovation expenditure spent on acquisition of machinery and extramural R&D (2008-2010)



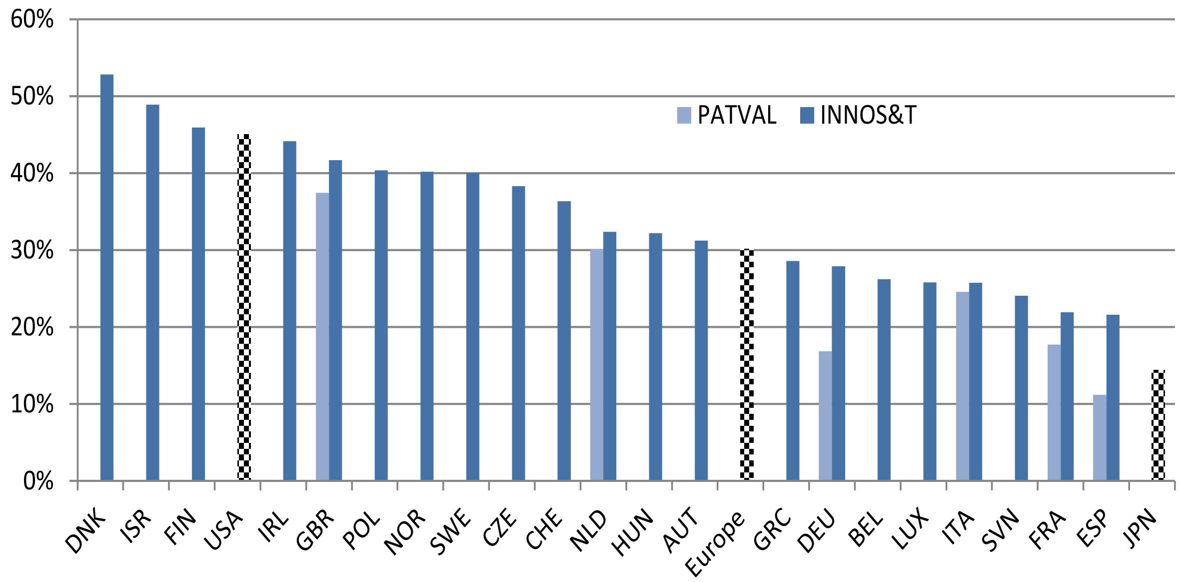
Source: DG Research and Innovation – Economic Analysis Unit, Innovation Union Competitiveness report 2013
Data: Eurostat, Community innovation survey (2010)

Recruitment of skilled workers is considered one of the most important sources of knowledge. Non-compete agreements block this mobility.

Employee mobility and particularly the mobility of skilled workers is one of the most important mechanisms for knowledge dissemination across firms and other organisations (OECD, 2012d). Job mobility is markedly lower in EU countries compared to non-EU OECD countries (OECD, 2012d). But there are also significant differences across European countries. Taking the average tenure years as an indicator of labour mobility in Europe reveals clear differences between countries. In 2011, Denmark, Estonia and the United Kingdom had an average of 8.5 to 9.3 years of tenure while Greece, Portugal and Italy had between 13 and 14 years. Not all profiles are equally important for innovation and, in that respect, most recent efforts to link human capital mobility with innovation have focused on the mobility of inventors, doctorate holders, 'star scientists' or tertiary-level graduates.

From an innovation perspective, the mobility of patent inventors is an important dimension of knowledge circulation. OECD data show that inventors are more mobile in the United States than in Europe. Denmark, Israel and Finland have the highest mobility rate for inventors, while Japan, Spain and France have the lowest.

Figure II.4.3: Inventors who moved jobs in the five years prior to the invention, shown as a percentage of reporting inventors



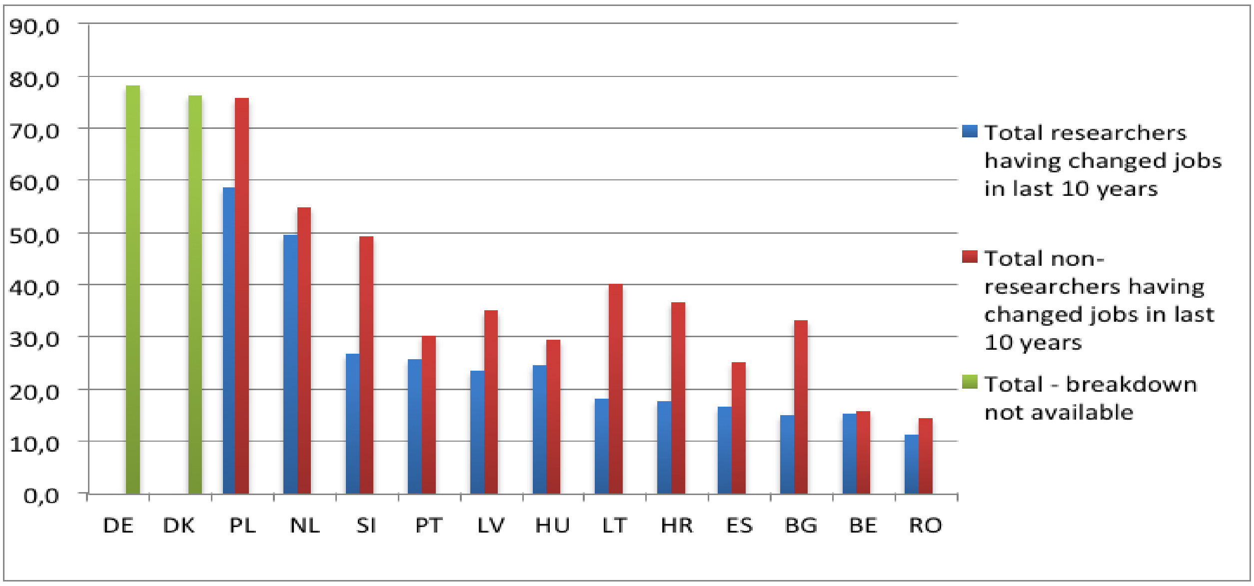
Source: OECD; DG Research and Innovation, Innovation Union Competitiveness report 2013
Data: OECD, based on INNO S&T and PATVAL studies.
Note: For PATVAL 2, EPO priority date 2003-2005 and for PATVAL 1, EPO patents with priority date 1993-1997. INNO S&T EPO priority dates between 2003 and 2005

The OECD analysis of knowledge flows and the mobility of skilled employees highlight the importance of non-compete agreements and their legal enforcement as a barrier to the mobility of inventors and skilled employees.[97] According to the OECD study, the non-compete agreements were found more frequently in countries with lower inventor mobility. The correlation between inventor mobility and NCA enforceability was estimated at 31 %, suggesting a real but mild correlation between the two indicators. European countries were found more permissive to firms using NCAs, often only requiring economic compensation for the employee.

[97] See OECD analytical paper 'Knowledge flows and the mobility of skilled employees: An international perspective on the role of non-compete agreements and their legal enforcement', Directorate for Science, Technology and Industry, DSTI/EAS/STP/NESTI/TIP(2012)10.

Doctorate holders are another sub-group of highly skilled employees. As Figure II.4.4 shows, the percentage of doctorate holders that have changed jobs over the last 10 years is high in Germany, Denmark and Poland, and much lower in Romania, Belgium and Bulgaria, where on average only 15 % of the doctoral holders working as researchers have changed jobs. The mix of countries that are high R&D intensive and low R&D intensive at both ends of the spectrum indicates that R&D intensity is not a predictor of the mobility of human capital. It is also noteworthy that mobility is systematically lower among PhD holders employed as researchers than in those who are not.

Figure II.4.4: Percentage of doctorate holders that have changed jobs in the last 10 years, 2009



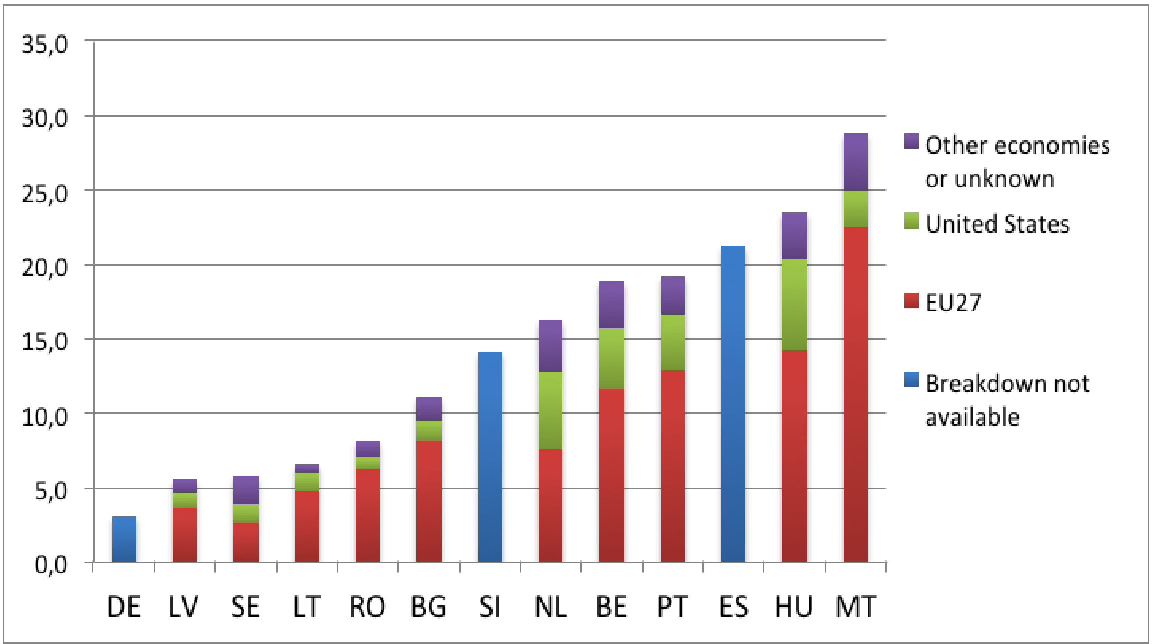
Source: OECD; DG Research and Innovation Innovation Union Competitiveness report 2013
Data: OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010

Inter-sector mobility among PhD holders can be an important mechanism for the transfer of scientific and technological knowledge between university and industry. Data from the OECD/UNESCO/Eurostat survey on doctorate holders show significant differences across countries in the sector distribution of employed doctoral holders. PhD holders are more widely distributed across sectors in Denmark, the Netherlands, Belgium and Slovenia (all technology-intensive countries). On the other hand, in Poland, Portugal, Malta and Bulgaria (all low R&D-intensive countries) PhDs tend to be employed almost exclusively by the government or the higher education sector and only marginally by the business enterprise sector. In Poland, for example, almost 92 % of doctorate holders are employed in the higher education sector.

Doctorate holder mobility is mainly confined to within the EU. This is visible both in highly open and competitive economies, as in the Netherlands and Belgium, and in economies with a lower absorptive capacity.

In the context of the single market, a particularly interesting aspect of PhD holder mobility is its international aspect. The literature on mobility has established the positive impact in terms of knowledge and technology transfer to the firm through the international mobility of PhD holders. So-called brain circulation generates benefits to both home and host countries (Edler et al., 2011). The negative side of higher mobility rates is that they can also indicate higher career instability (OECD, 2012d). From a European perspective, knowledge sourcing through mobile human capital contributes to successful knowledge transfer and an effective single market. Figure II.4.5 shows the percentage of national citizens with a PhD degree that have lived or spent time abroad in the past 10 years. Doctorates with PhDs from Malta, Hungary or Spain are the most internationally mobile, while doctorate holders in Germany, Latvia and Sweden are the least. Mobility takes place mainly within Europe. It is interesting to compare Figure II.4.4 and Figure II.4.5. Doctorate holders in Germany are more mobile, but this mobility appears to take place mainly within the country, responding economic demand and absorptive capacity. By contrast, doctorate holders in Spain are less mobile, but when they move, their mobility is international.

Figure II.4.5: International mobility of doctorate holders by last destination, 2009



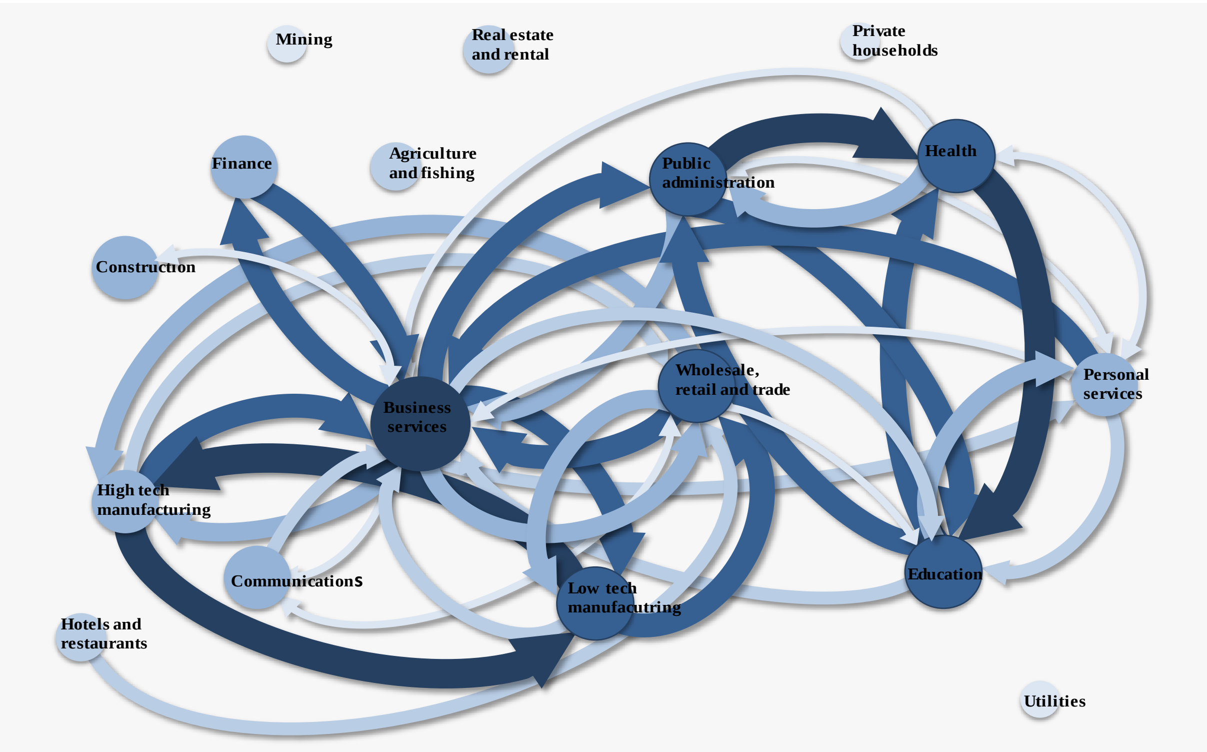
Source: OECD; DG Research and Innovation, Innovation Union Competitiveness report 2013
Data: OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010.

Using data on the mobility of star scientists, Trippl (2011) provides evidence of a positive relationship between their mobility and knowledge networks in the host region, as well as between the host and the home regions. Star scientists are engaged in academic collaboration, research projects with firms, co-patenting or licensing to local firms more often than non-mobile researchers, although some of these collaborations are sporadic.

Mobility between public and private sector is limited and mainly channelled through business services

As illustrated in Figure II.4.6, the mobility of employees with a tertiary education level presents different dynamics in the public and private sectors. Employees in the public sector move mainly within the public sector, while mobility in the private sector is concentrated around business services and the value chain (considerable mobility between the high-tech and the low-tech sectors of manufacturing). The main mobility bridge between public and private sectors builds on the broader category of 'business services', a very important category in the European service economy.

Figure II.4.6: Inter-sector mobility among tertiary-level graduates in Europe, 2007



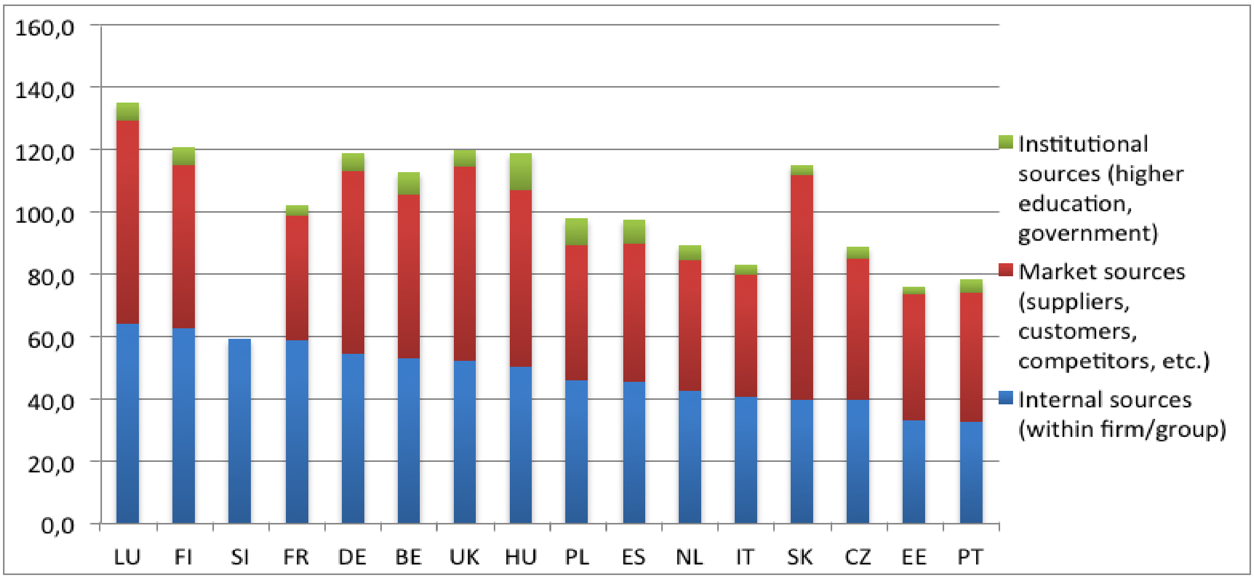
Source: OECD; DG Research and Innovation Innovation Union Competitiveness report 2013
Data: OECD, based on ad hoc tabulations of European Labour Force Surveys 2007
Note: European countries not members of OECD are not included in the calculations

The value chain links are essential sources of information for innovation. Sourcing from universities requires higher absorptive capacity of firms

Searching for external knowledge available beyond 'firm boundaries' has an impact on product development and innovation (Katila and Ahuja, 2002; Rosenkopf and Nerkar, 2001).

The use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, constitutes open innovation ([98]) (Chesbrough, 2006). Firms benefit from having 'open' search strategies that use not only internal resources but also external sources, such as clients, suppliers, competitors, consultants and universities (Laursen and Salter, 2006; Grimpe and Sofka, 2009; Frenz and Ietto-gillies, 2009; Leiponen and Helfat, 2010). In terms of the use of different sources for innovation and particularly the S&T linkages, Community Innovation Survey (CIS) data show that institutional sources (like universities and research centres) are considered to be less relevant for innovation than internal sources or vertical linkages. Less than 10 % of the innovative firms rank them as highly important in their innovation activities (OECD, 2012c).

Figure II.4.7: Main sources of information for innovation by type of partner, 2008-2010



Source: OECD; DG Research and Innovation Innovation Union Competitiveness report 2013
Data: OECD, Eurostat (Community innovation survey) and national data sources, June 2011

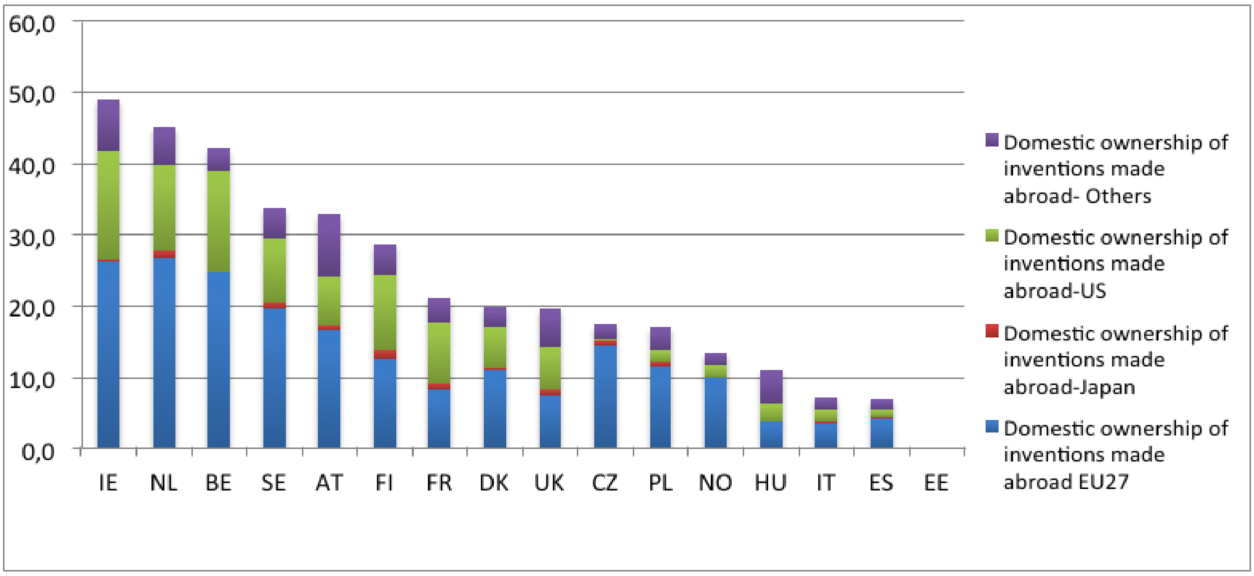
However, with regard to the use of science sources, such as universities or research centres, Callaert et al. (2012) reveal that many innovation leaders (i.e. the United Kingdom, Denmark, the Netherlands, Sweden and Belgium) show high rates of scientific productivity (in terms of publications) and, with the exception of Sweden, high use of science results (publications) in technology development activities (in terms of patents). Hungary, Bulgaria and to a lesser extent Portugal have a low science base but comparatively high use of science results in technology development activities. In general, sourcing from universities has a positive impact on innovation performance in high R&D-intensive countries but not in the low R&D-intensive ones. The latter points to the need to invest in absorptive capacity prior to engagement in different channels of knowledge circulation (Ebersberger et al., 2011).

[98] Chesbrough, H., 2006, 'Open Innovation: Researching a New Paradigm'. This assumes that firms can use external ideas as well as internal ideas, and internal and external paths to market, as they advance their performance.

Many EU Member States acquire patents within the European market and, to a lesser extent, from the United States

Acquiring a patent from a foreign inventor is an important source of knowledge ([99]) and fits within an open innovation strategy. Technology in-licensing feeds the inventive capacity of licensees (see Rigby and Zook, 2002); therefore, in-licensing accelerates the innovation process for licensees (Leone and Reichstein, 2012). In some cases, domestic ownership of foreign inventions can also indicate research collaboration (co-creation) alongside knowledge sourcing. Belgium, Ireland and the Netherlands have higher shares of domestic ownership of foreign inventions. On the contrary, Italy, Spain and Greece have very low shares. For almost all European countries for which data are available, the largest part of foreign inventions are from other EU Member States, followed by the United States.

Figure II.4.8: Domestic ownership of foreign inventions (percentage), 2008



Source: OECD; DG Research and Innovation
Data: OECD Compendium of Patent Statistics

Innovation Union Competitiveness report 2013

Firms investing in patent licensing are driven by a variety of motives

A recent survey of over 300 European firms addressed strategies for in-licensing patents ([100]). It showed that larger firms tend to in-license more than SMEs (61 % vs. 44 % of the sample). The strongest motives were ensuring freedom to operate, followed by an ambition to close the

[99] A survey of highly research-intensive firms reported that in-licensing strategies were considered more important than out-licensing. Companies active in very R&D-intensive sectors reported higher shares of both in-licensing expenditures and out-licensing revenues (see 'The 2012 EU Survey on Industrial R&D Investment Trends', DG JRC–IPTS and Directorate-General for Research and Innovation (DG RTD)).

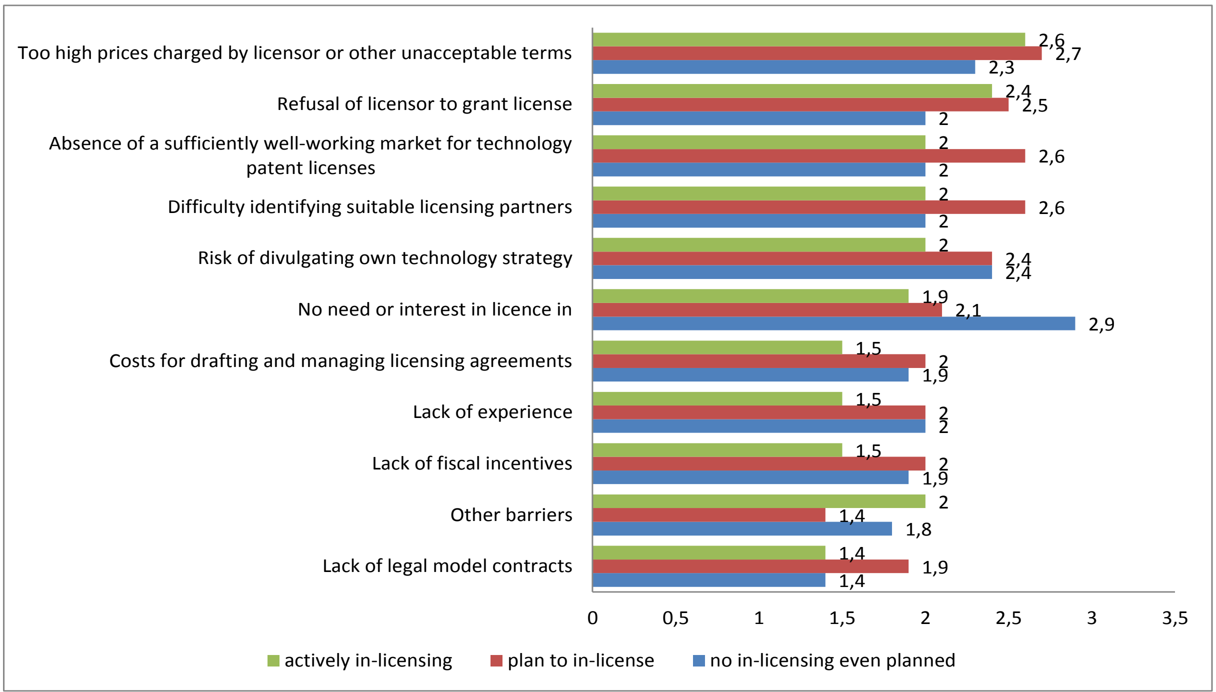
[100] Technopolis group, Radauer, A., and Dudenbostel, T., 'PATLICE Survey – Survey on patent licensing activities by patenting firms', July 2013, Commissioned by the European Commission, Directorate-General for Research and Innovation (DG RTD). Over 300 European firms from 19 European countries provided responses, in particular firms in Germany, France, Austria, Switzerland, the Netherlands, the United Kingdom, Italy, Finland, Denmark and Belgium.

technological gap and speed up time to market. Firms were also motivated by the need to access complementary technology to develop core technology further and to expand business or R&D in new areas. SMEs tend to have more pro-active motives for in-licensing, such as enabling rapid time to market, while large firms are rather reactive, focussing on ensuring their freedom to operate and avoiding possible infringement actions.

Many barriers to in-licensing of patents relate to deficiencies in the supply of technologies

Barriers to in-licensing are usually linked to the supply of technologies, in particular high prices, refusal of licensor to grant license or lack of technology relevance. Some respondents highlight that the technology is interesting but does not fit their needs ([101]). Other relevant barriers are the absence of a sufficiently functioning market for technology patent licences or difficulty in identifying suitable licensing partners. On the other hand, a lack of legal model contracts and fiscal incentives are considered of less relevance.

Figure II.4.9: Barriers to patent in-licensing



Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Technopolis survey, 2013

SMEs are more likely to experience difficulties in finding suitable licensing partners, and meeting the costs associated with drafting and managing licensing agreements. There are also certain differences between industries. While firms active in the healthcare sector stress high prices charged by the licensor and other unacceptable licensing terms, firms in the industrial engineering sector highlight a lack of need or interest in the technologies as a barrier. These differences partly reflect different innovation dynamics. The healthcare industry is open and

[101] A more extensive analysis of the matching between science, technology and industry is presented in Chapter II.5.

experienced in both in- and out-licensing, while the industrial engineering and general industrials sector use patents more internally and are more afraid of divulgating their own technology strategy.

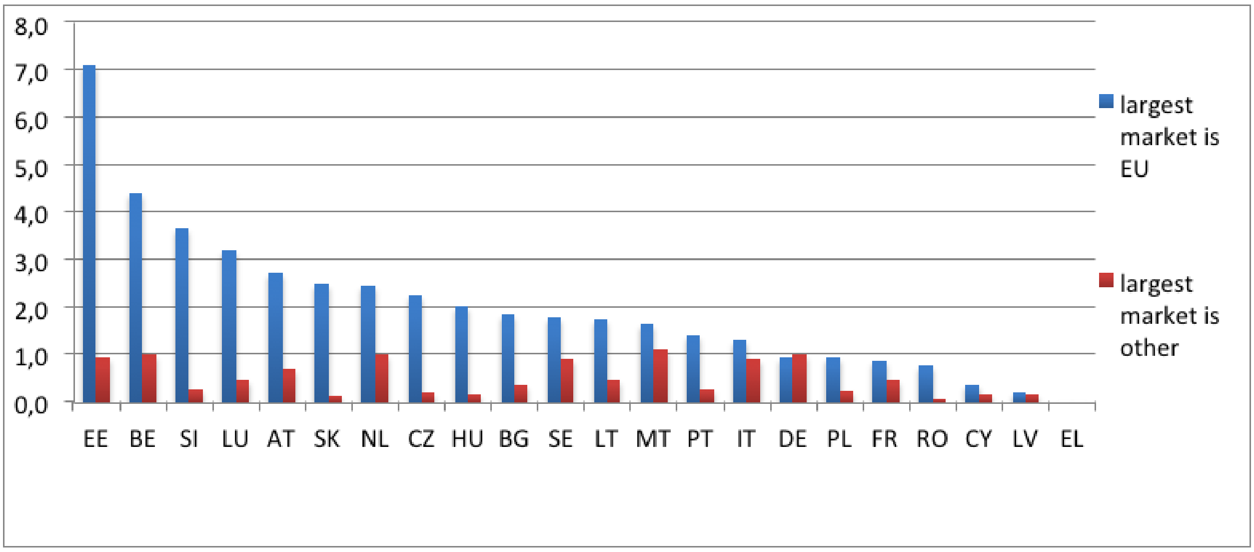
4.3. Exploitation of knowledge and innovation

Knowledge circulation is also about how firms (and other organisations) exploit their inventions or innovations through exports of new products or by licensing patents. Naturally, what is considered the exploitation of knowledge for one firm is the sourcing of knowledge for another. But the required prior absorptive capacity is different as well as the directionality of the knowledge flow.

Sales of innovative enterprises in EU Member States are mainly directed at the domestic market, followed by exports to the EU single market

Exports of new products can be captured by looking at the proportion of exports to turnover. Singling out only innovative firms, provides a proxy of sales and exports in terms of new products. Overall, the largest market for innovative enterprises in EU Member States is still the national domestic market, followed at large by the EU single market. Estonia is a significant outlier with innovative enterprises having large exports into the EU. This is also, to a certain degree, the case for Belgium and Slovenia. Innovative firms in technology-leading countries have the larger share of exports to countries outside the EU. Germany is the only country where innovative firms export more outside the EU than inside the single market.

Figure II.4.10: Percentage of innovative enterprises for which the largest market in terms of turnover is an export market, 2008-2010

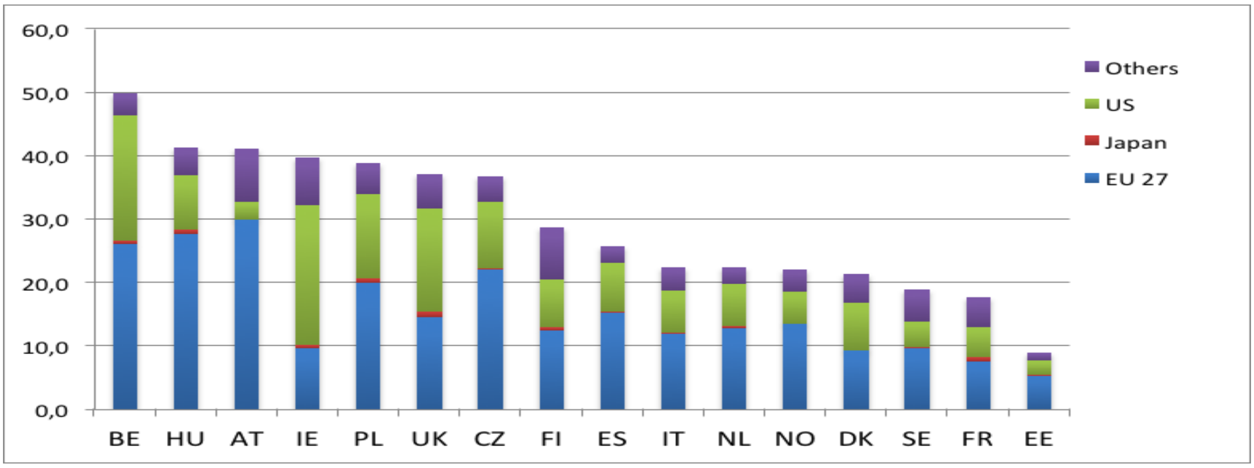


Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Eurostat, Community innovation survey, 2010

EU Member States show very different patterns in terms of international technology exploitation

One of the indicators capturing the exploitation of technology is the ownership of patents, particularly the foreign ownership of domestic patents. On average and compared to other regions, firms in EU Member States owe a large share of patents within the EU. Ireland and the United Kingdom are exceptions, more linked to US ownership of domestic inventions. However, there are important differences between countries concerning foreign ownerships of domestic patents. Technology-leading countries like Austria or Belgium have a higher proportion of foreign ownership of domestic inventions. Denmark, Sweden, France and Estonia on the other hand have lower shares, in particular for EU foreign ownership. One of the arguments often used to explain this result is that most domestic inventions are absorbed at home.

Figure II.4.11: Foreign ownership of domestic inventions (percentage), 2008

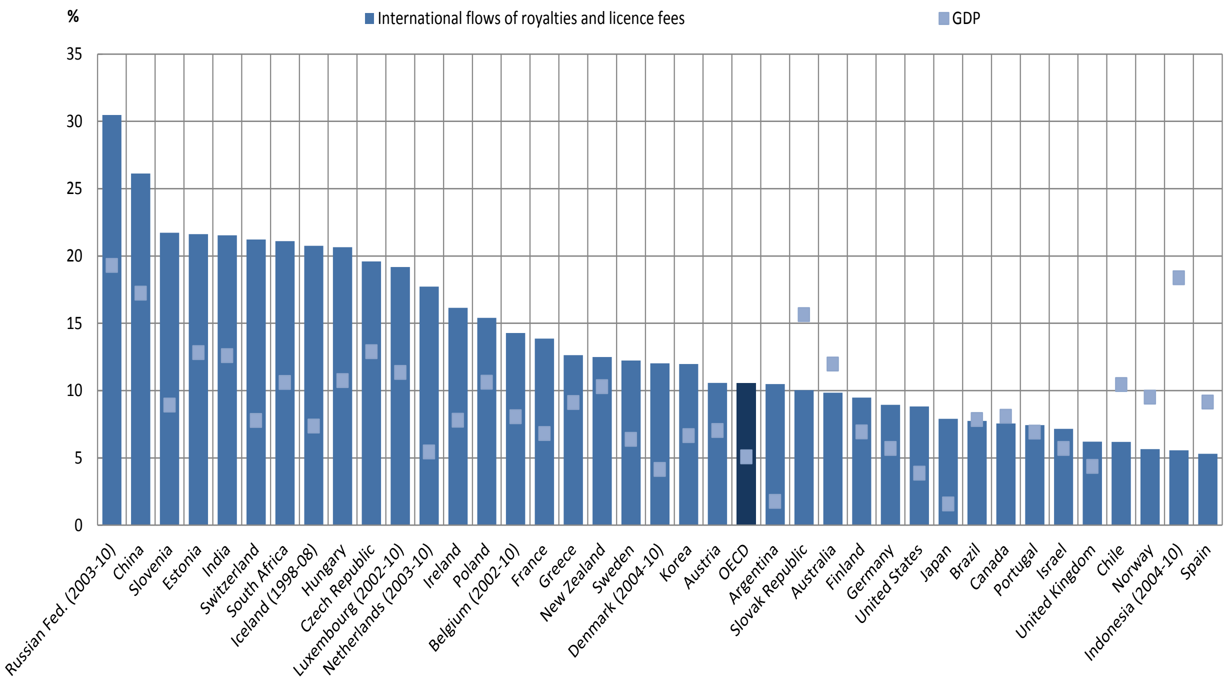


Source: OECD DG Research and Innovation Innovation Union Competitiveness report 2013
Data: OECD Compendium of Patent Statistics

The international market of intellectual property through royalties and licence fees is growing strongly

In almost all countries, international flows of royalties and licence fees for patents grew faster than the economy (GDP) over the period 2000–2010. The growth is highest in catching-up countries but also in technology-leading countries such as Switzerland and the Netherlands. Conversely, Spain, Norway, the United Kingdom and Portugal experienced a lower average annual growth rate.

Figure II.4.12: International IP flows through royalties and license fees, 2000-2010
Average annual growth rate in US dollar, percentage



Source: OECD; DG Research and Innovation Innovation Union Competitiveness report 2013
Data: OECD Technology Balance of Payments database 2012; Trade in services database, March 2012; World Bank, World Development indicators, March 2012; OECD, Annual National Accounts database, March 2012

The importance of patent applications and licensing has increased over the last 10 years. A survey conveyed by the Technopolis group on patent out-licensing and patent in-licensing by European business reports an increasing number of technology licensing deals and increasing license revenues over time ([102]). Over half (56 %) of the patent-active European firms in the survey out-license and another 16 % are considering doing so in the future ([103]). However, the share of patents in the patent portfolio currently out-licensed is still around 5–7 %, depending on firm size and industry dynamics. The survey revealed that European firms tend to out-license mostly in Europe, followed by North America and only thirdly in their home country. Outsourcing to Asian or South American firms is less common. The patents are predominantly out-licensed to competitors and other industries, and less to suppliers and business-to-business customers. SMEs tend to out-license to customers more than large firms.

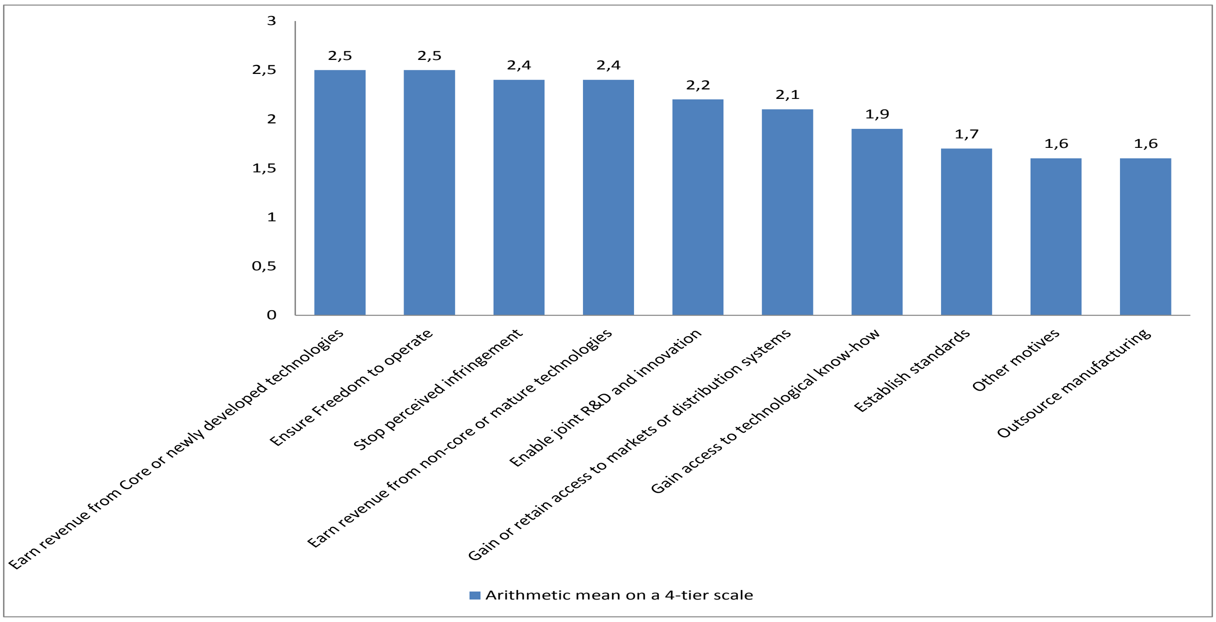
The two most important motives for engaging in patent outsourcing are to earn revenue from core or newly developed technologies and to ensure freedom to operate (with an arithmetic

[102] Technopolis group, Radauer, A., and Dudenbostel, T., 'PATLICE Survey — Survey on patent licensing activities by patenting firms', July 2013, Commissioned by the European Commission, Directorate-General for Research and Innovation (DG RTD).

[103] A previous OECD/EPO survey covering the entire population of patenting firms estimated that 35 % of the firms used out-licensing practices (Zuninga and Guellec, 2009).

mean of around 2.5 on the 4-tier scale used in the survey). Firms also stress the motives of stopping perceived infringement and earning revenues from non-core or mature technologies.

Figure II.4.13: Motives to out-license patents



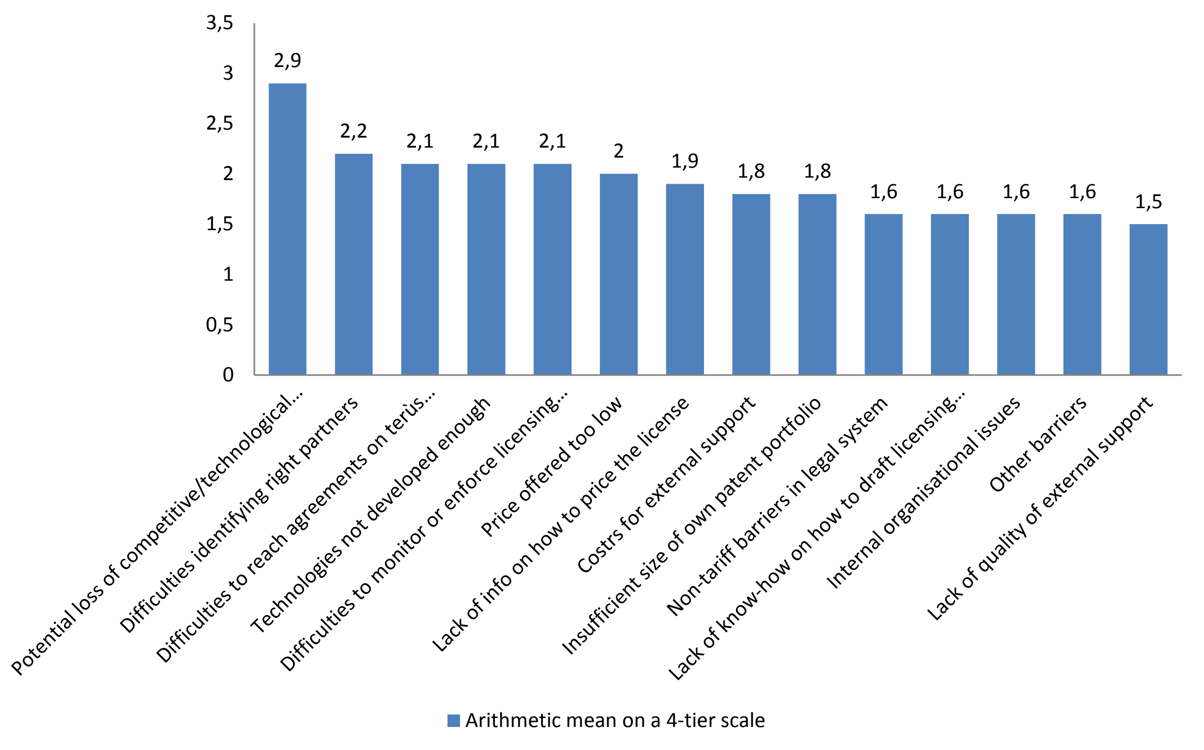
Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Technopolis survey, 2013

Motivation patterns differ between industries. Firms active in the healthcare sector out-license patents mainly to earn revenues from core or newly developed products or to enable joint R&D and innovation. For firms in the ICT sector, almost all motives are of equal importance, while in the consumer goods sector, firms out-license predominantly to ensure freedom to operate or to stop perceived infringement. There are also differences between SMEs and large firms. For SMEs, the strongest motives for out-licensing are earning revenues, enabling joint R&D and innovation, and gaining access to markets or distribution systems. Larger firms out-license more to ensure freedom to operate and stop perceived infringement.

Although barriers to out-licensing discourage firms from exploiting patents, the main hurdles are perceived to be related to IPR enforcement and costs

The survey of European firms also addressed perceived barriers to out-licensing. The most important barrier is potential loss of competitive or technology edge. Other relevant barriers are difficulties in reaching agreements on licensing terms and doubts as to whether the technology for which a licence is sought is considered sufficiently developed for commercialisation.

Figure II.4.14: Barriers to patent out-licensing



Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Technopolis survey, 2013

There are differences in the perception of barriers within industry. Firms in healthcare are more likely to experience insufficiently developed technology and potential loss of competitive technological edge as barriers. Overall, patenting and patent licensing is more frequent in the healthcare industry. Firms in the industrial engineering sector fear the potential loss of competitive edge but also difficulties in reaching agreements on terms other than the price and difficulties identifying the right partners. The barriers lead to a sizable portion of firms declaring they have patents they would be willing to license, but could not license out. Of the firms that are actively out-licensing, 80 % state they have at least one patent that would be available for potential licensees.

However, in general, barriers to licensing are considered less important for knowledge exploitation than problems related to enforcement of intellectual property rights (IPR) or litigation practices in jurisdictions abroad. This aspect was also highlighted by a survey of research-intensive firms ([104]). The conditions for putting intellectual property rights into force, the costs and the time to obtain protection were perceived as harmful to a firm's innovation.

[104] EU R&D survey, 'The 2012 EU Survey on Industrial R&D Investment Trends', DG JRC–IPTS and Directorate-General for Research and Innovation (DG RTD).

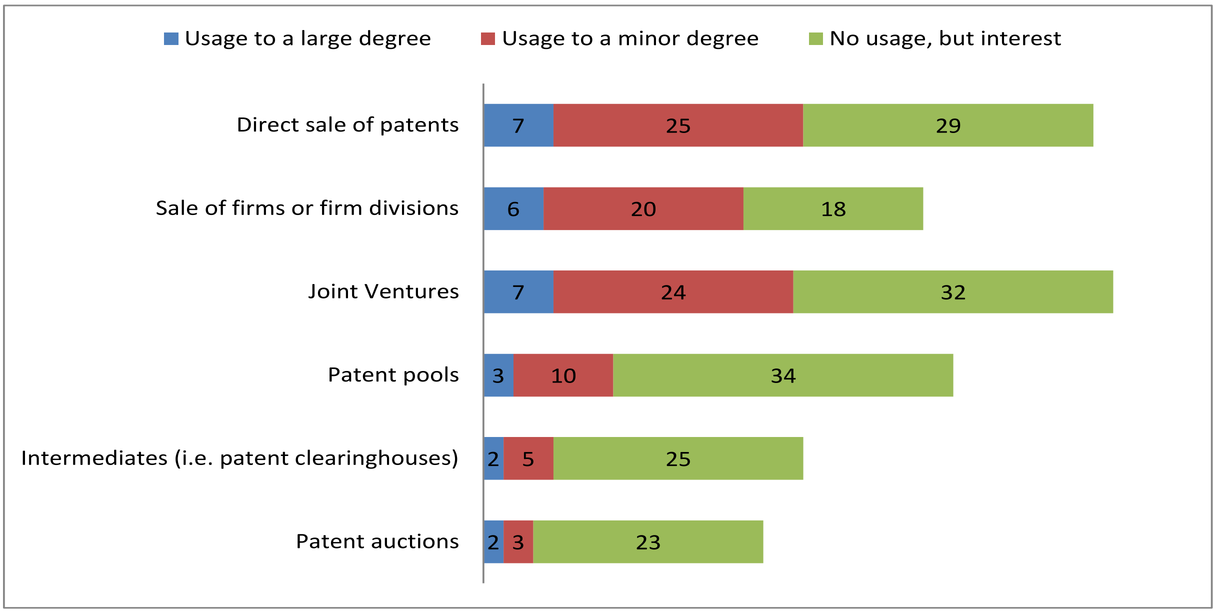
Licensing of technologies is facilitated by bilateral and informal interactions, which is particularly important for SMEs

There are many channels by which an out-licensing firm can get in touch with potential licensees. The most important is informal networks, followed by own research (e.g. in journals, on the Web), being contacted by licensee and at events (e.g. trade fairs or conferences). These channels show that considerable interaction must take place between licensors and licensees, on a bilateral and rather informal level. Other relevant channels are formal networks (e.g. clusters) and research in patent databases. Intermediates searching on the licensor's behalf and technology or licensing exchange platforms are considered less relevant. However, SMEs must be much more active in getting in touch with potential licensees and must utilise all available channels more actively than large firms, in particular informal networks and own research presentations. It is also interesting to note that trade fairs and formal networks are considered important for the firms considering out-licensing for the future.

The dissemination of technology and its exploitation can also be channelled through joint ventures and patent pools

While bilateral out-licensing of patents is the most common strategy for sharing or transfering patents to third parties, there are also other means — in particular, sale of patents and entering joint ventures. Patent pools are used mainly by groups of companies in specific technology fields where standards play an important role. Patent auction events are not considered relevant for the majority of firms in the survey.

Figure II.4.15: Mechanisms other than licensing to share or transfer patents



Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Technopolis survey, 2013

About one in four respondents was potentially interested in using patent pools. To increase the use of patent pools, these firms considered it important to introduce changes to antitrust laws, lower the cost of patenting, increase available and trained staff, enhance tax incentives and introduce the Community Patent.

4.4. Co-creation for knowledge-based innovation

Collaboration initiatives for innovation and international co-patenting are indicators of co-creation. In general, collaboration with external partners in the innovation process is positively correlated with innovation performance (Ebesberger et al., 2012). However, significance is lower for countries with lower R&D intensity (Ebersberger et al., 2011). These countries do not have yet the absorptive capacity to benefit from research collaboration ([105]).

Collaboration agreements for innovation are very important for European R&D-intensive companies.

A survey of the most R&D-intensive firms in Europe and other continents reported that firms consider collaboration agreements an even more important way of knowledge sharing than licensing ([106]). In particular, companies in medium and low R&D-intensive sectors see collaboration agreements with higher education institutions and other public research organisations as very relevant. In contrast to common practice in licensing, the majority of R&D collaboration agreements with other companies are with customers or suppliers, while less than 10 % are made with competitors. The largest numbers of R&D collaboration agreements are found in high-tech sectors such as ICT or biotechnology, which are also the most internationalised. On the contrary, low R&D-intensive sectors have nearly 80 % of their R&D collaboration agreements with companies in the same country or in another EU Member State.

Innovative firms in more R&D-intensive countries collaborate with all partners for innovation

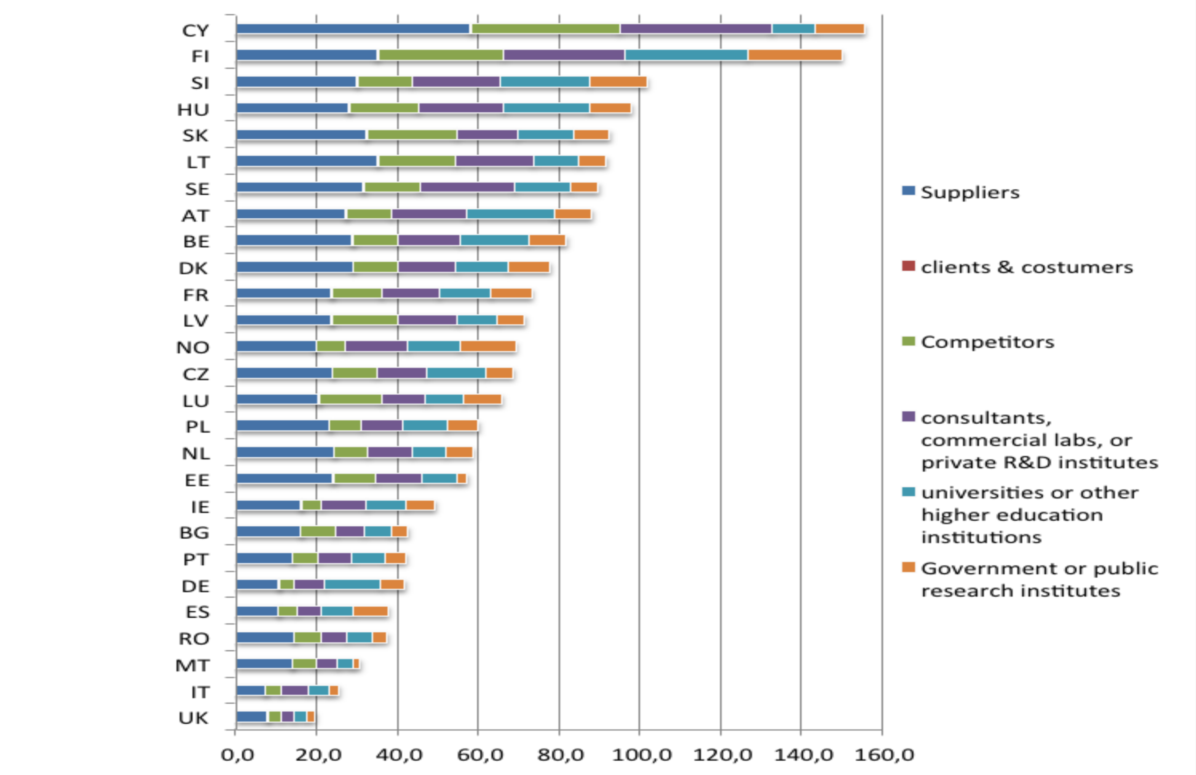
Figure II.4.16 illustrates the percentage of innovative firms that have collaborated with external partners for innovation by partner type. In general, countries that are technology leaders or technology users tend to collaborate more with external partners than countries with low R&D intensity, but the differences are statistically insignificant. Engaging in collaboration requires a minimum absorptive capacity, which we are capturing in this case through R&D intensity. It is interesting to note that during the crisis period, technology users have increased their international collaboration with all partners (the United States, other Member States, China, India) while the low R&D-intensive but high-income countries have

[105] Or the breadth of the network is in fact not providing sufficient variation for innovation.

[106] EU R&D survey, 'The 2012 EU Survey on Industrial R&D Investment Trends', DG JRC–IPTS and Directorate-General for Research and Innovation (DG RTD).

reduced their collaboration with most partners. This is worrying since international collaboration was positively related to innovation performance in those latter countries.

Figure II.4.16: Innovative firms collaborating for innovation, by partner (%) (2008-2010)



Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Eurostat, Community innovation survey (2010)

Collaboration for innovation often takes place within the country and with partners in other European countries. Collaboration with the United States is dominated by technology-leading countries. Collaboration with emerging economies, like China and India, is significant in Sweden, Finland and Luxembourg. Sweden is an interesting case since this trend is also observable in small firms. About 16 % of innovative firms with 10–49 employees report collaborating with China and India for innovation. Firms in technology-leading countries collaborate more internationally as well as with a variety of partners. The lower the R&D intensity, the higher the proportion of firms that collaborate only domestically or with other EU partners. Breadth in particular is an important indicator of the dependency on certain partners for innovation, which may lead to lock-ins and higher risk.

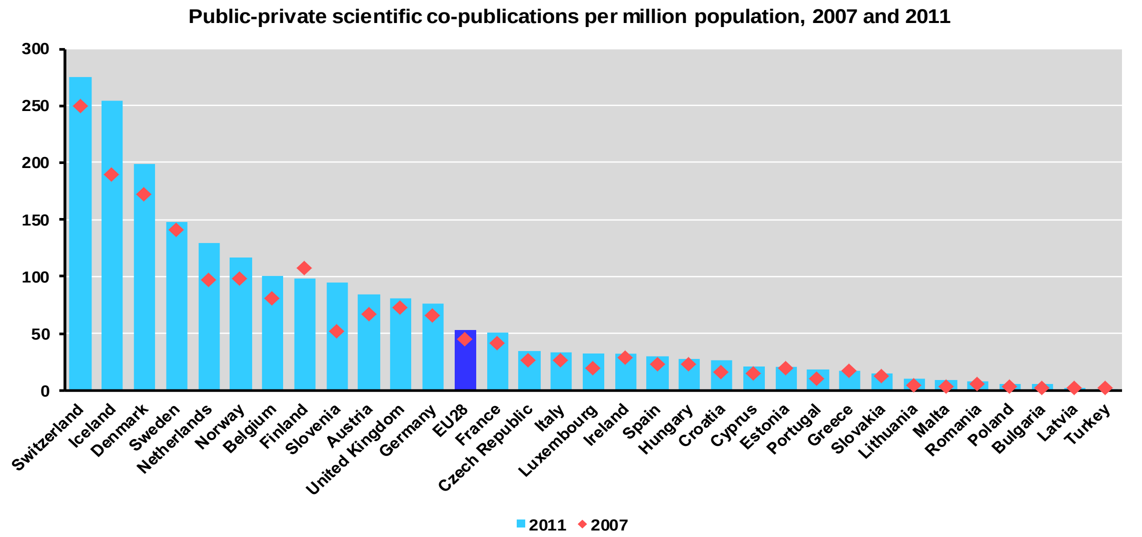
The internationalisation of the research collaboration affects countries very differently. The results reported by Ebersberger et al. (2011) suggest that having international partners is positively related to innovation performance, particularly for technology-user countries, smaller countries and countries with a high income albeit low R&D intensity. On the other hand, firms located in less developed innovation systems and firms that are more dependent on external technology are precisely those that can benefit most from international linkages (Chaminade and Plechero, 2012).

Research collaboration by public and private actors is more frequent and growing in countries with higher R&D intensity

With regard to research collaboration, the aggregated CIS data suggest that in countries with a lower R&D intensity, a higher proportion of innovative firms experience difficulties in finding cooperation partners for innovation (approximately 20 % of innovative firms in Bulgaria, 14 % in Portugal or 12 % in Spain, in contrast with barely 2.62 % in Sweden, 2.77 % in Slovenia and 3.38 % in Finland). In general, the countries that report fewer difficulties in finding a partner are small countries with higher R&D intensity, where the research community is relatively small. An exception to this is Luxembourg, a small country with high R&D intensity in which almost 11 % of innovative firms report having difficulties finding cooperation partners for innovation.

Collaboration between public and private research actors can be analysed using bibliometric data on co-publications. Figure II.4.17 confirms that public–private research collaboration is higher in countries with high R&D intensity and innovation dynamics. It is noteworthy that almost all of these countries, with the exception of Finland, were able to increase their public–private scientific co-publication rate over the period 2007–2011.

Figure II.4.17: Scientific co-publications by public and private researchers, per million population, 2007 and 2011



Source: DG Research and Innovation - Economic nalysis Unit
Data: Eurostat, Innovation Union Scoreboard

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Larger companies in knowledge-intensive industries are increasingly involved in scientific publications with external partners

Larger enterprises have a substantial publication activity. In the period 2007-2011, the most publishing company in Europe, Siemens, produced around 5000 scientific publications. Other companies with a considerable scientific publication activity were firms in the pharmaceutical and biotechnology sector (GlaxoSmithKline, Novartis, AstraZeneca), in the electronics sector (Philips, in the Leisure goods sector (Thales), in the Aerospace & defense sector (STMicroelectronics) and in the Technology hardware and equipment sector. These firms published each 3000-4000 scientific publications over the 2007-2011 period. This publication activity is highly concentrated in six European countries and a few cities. For 80 % of the 100 most publishing European companies, at least 65% of the company's scientific output was produced in only two countries and at least 40% of the company's scientific output was produced in only two cities. The countries in which the companies are publishing most are Germany, the United Kingdom, France, Italy, Switzerland, the Netherlands and Sweden.

Generally, the most publishing firms in Europe publish a great majority of their papers with external partners. Companies co-authored, on average, about 80 % of their publications with at least one external partners. A far greater majority of papers co-published with at least one external partner involved the academic/PRO sector rather than the private sector (69 % versus 22 %. This tendency is broadly similar irrespective of the industrial partner (co-publications with an external partner from a university or other Public Research Organisation is most common in the health care sector (mostly made up of pharmaceutical firms) and in the sector of Basic metals and food producers. The 1OO most publishing companies in Europe collaborated generally more with external partners located within Europe compared to patners located outside Europe. Focusing specifically on co-publications with universities and PROs, 83 % of the companies co-authored with a university or PRO in Europe. The two industry sectors where the firms co-published most frequently with other European firms or research organisations were the aerospace & defense sector and the automobiles & parts sector.[107]

Western European firms cooperate more with public research organisations, both in Europe and beyond

A recent survey of firms and public research organisations involved in knowledge transfer analysed the mechanisms, incentives and barriers for public–private research collaboration in-depth ([108]). Collaboration between academic institutions and industry is facilitated by spatial proximity (Arundel and Geuna, 2004; Audretsch and Stephan, 1996; Jaffe, Trajtenberg, and Henderson, 1993). Hence, practically all companies point to their home countries when asked about the locations of their public research partners (54 out of 55, or 98 %). Cooperation with

[107] Report by Science Metrix, 'Scientific Output and Collaboration of Companies Publishing the Most in the ERA', 2013, analytical report 2.3.5, drafted under a contract financed by the European Commission, DG RTD.

[108] UNU–MERIT, FHNW and Empirica (Arundel, A., Es-Sadki, N., Barjak, F., Perrett, P., and Lilischkis, S.), 'Knowledge Transfer Study 2012-2012. Final report', commissioned by the Directorate-General for Research and Innovation (DG RTD), 2012.

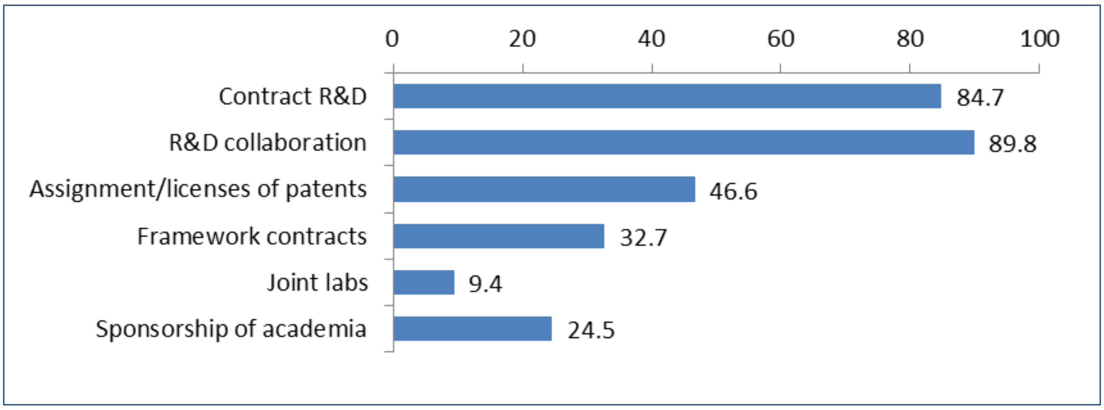
a university or other public research organisations from at least one other European country was also quite usual and found in four out of five companies. Of the firms in the sample, 57 % collaborate with public research organisations in North America, one third collaborate with public research organisations in Asia, and one quarter are involved in partnerships in other world areas. All in all, 31 % of the interviewed companies have partners in the public research sector in Europe and at least two other world areas, making them global players in this respect. Most frequently the interviewees mentioned China (including Hong Kong), Japan, South Korea and India among in Asia, Australia and selected countries in Latin America (Argentina, Brazil, Mexico) among the other countries.

There are notable differences in the global extension of R&D between different types of companies: firms from countries in Western Europe are more often globally active than companies from Southern and Eastern Europe. Only 1 in 12 companies from Southern or Eastern Europe that answered this question had cooperated with an academic partner from Asia, none with partners from Europe and at least two with other world regions. Differences also exist between company sizes — the larger a company, the wider the geographical distribution of its public research partners.

Firms engage in both formal and informal cooperation with public research organisations

Among the formal mechanisms, contract research and collaborative research are clearly the most important mechanisms for obtaining knowledge from the public research sector. A large majority of the companies interviewed had used them recently (see Figure II.4.18). The assignment or licensing of academic patents, sponsorship of academic activities and more long-term framework contracts were only mentioned by a minority of the interviewees. Joint labs are not common ([109]).

Figure II.4.18: Formal mechanisms of knowledge and technology transfer (in %)

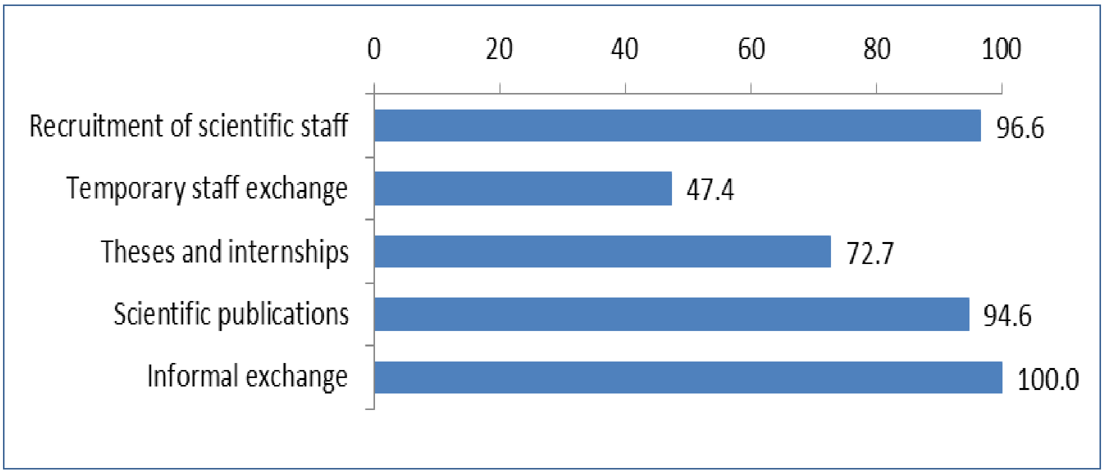


Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: FHNW / Knowledge Transfer Study 2010-2012

[109] Spin-offs were not included among these mechanisms as it was expected that not many of the interview partners would be able to link spin-offs to their company.

Several formal mechanisms were used more often by larger companies in the sample. In particular, assignments/licences of academic patents, framework contracts and sponsorship of academic activities are only common among the largest companies. In addition, contract research is notably more common among large firms. Further variations exist between industries: obtaining technologies by means of purchasing or licensing patents is mainly used in the biotech and pharmaceuticals and hardware sectors; automotive companies and suppliers and software and computer services companies rely on this mechanism less often. Only three companies had no formal links to a university or other public research organisation, all of them companies in the software and computer services industry and all of them employing fewer than 4 000. Informal mechanisms of interaction with the public research sector were not the focus of the interviews but a few issues were picked up in passing. Informal cooperation is widely used across the board (see Figure II.5.19) and was classified by some interviewees as a first step towards cooperation that then becomes formalised. Virtually all interviewed companies see the recruitment of qualified staff, the reading of scientific publications and informal exchanges (at conferences, etc.) as legitimate channels to obtain knowledge. Only temporary staff exchange was less widely used.

Figure II.4.19: Informal mechanisms of knowledge and technology transfer (in %)



Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: FHNW / Knowledge Transfer Study 2010-2012

The survey also highlighted that cooperation with public research institutions is influenced by funding and knowledge transfer office (KTO) Staff. Insufficient KTO funding was repeatedly mentioned in the interviews as a barrier to more transfer success. A general lack of resource stability can have many negative effects. KTOs will limit their activities and focus on the early steps of the KT value chain, the identification and protection of institutional intellectual property (IP), neglecting later steps, in particular technology marketing and scouting in industry.

Incentives for and barriers to cooperation with the public research sector

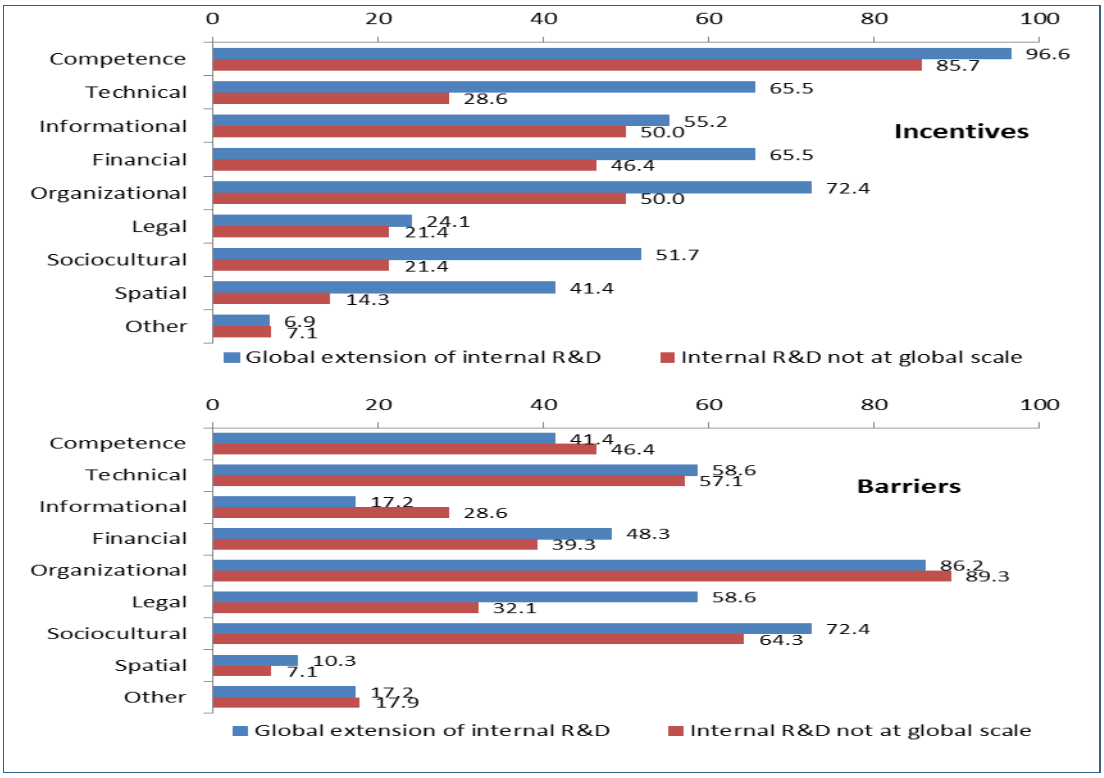
- **Competence**: The main incentive for business enterprises to work with universities and other PROs is their contribution to solving problems that cannot (or not as fast or good enough) be resolved internally or with other partners (Bishop, D'Este, and Neely, 2011; Cohen, Nelson, and Walsh, 2002).
- **Technical**: An uncounted number of studies have looked at the role of technologies and other research results in knowledge transfer. The properties of a technology, such as the innovativeness, degree of codification, development stage, complexity or cost determine whether business enterprises are interested in a transfer and whether the transfer is sticky; that is, needs to overcome many barriers to be successful (Barjak, 2011; Goldhor and Lund, 1983; Szulanski, 1996; Wood and EerNisse, 1992).
- **Informational**: Informational barriers were found to be influential above all for SMEs (Laursen and Salter, 2004; Santoro and Chakrabarti, 2002). They refer to companies' abilities to scout for relevant technologies, monitor their technological and scientific environment, and maintain an overview of potential funding sources for supporting their R&D activities. Informational incentives are for instance discussed in the context of signalling technological capacities to clients and partners (Fontana, Geuna, and Matt, 2006).
- **Financial**: In addition to the direct costs of a technology and technology transfer (Arrow, 1969; Teece, 1977), the indirect costs of doing less basic research and more applied research, services and consultancy have also been in the focus of academic research (Feller, 1990; Larsen, 2011).
- **Organisational**: Interactions between PROs and companies are governed by different types of coordination mechanisms (Amesse and Cohendet, 2001; Bidault and Fischer, 1994): hierarchical mechanisms (e.g. governmental laws and regulations, university by-laws), market mechanisms (e.g. contracts stipulating quantities and prices of the transfer) or characteristics of networks (e.g. trust). Organisational drivers and barriers to technology transfer are related to the costs and risks of a transaction and technology access (Barjak, 2011; Siegel, Waldman, and Link, 2003).
- **Legal**: Previous studies have pointed to the importance of IP regulations (Mowery and Sampat, 2005; Valentin and Jensen, 2007); university regulations on a wide set of issues such as incentives for invention disclosures (Markman, Gianiodis, Phan, and Balkin, 2005); the resources, skills and missions of university administrators and technology transfer intermediaries (Siegel, Waldman, and Link, 2003; Siegel, Waldman, Atwater, and Link, 2003, 2004).
- **Sociocultural**: The partners in university–industry technology transfer are from different sub-systems of society and follow different logics. Dasgupta and David (1994) contrast Polanyi's (1962) term 'Republic of Science' with a 'Realm of Technology', which is different mainly because of its differing reward systems and practices of disclosing results. These cultural differences between universities and firms can create barriers to collaboration and limit transfer success (Rahm, 1994; Siegel, Waldman, Atwater et al., 2003).
- **Spatial**: The empirical evidence that technology transfer happens more often at local and regional than at wider spatial levels is substantial (Jaffe, 1989; Jaffe et al., 1993; Acs, Audretsch, and Feldman, 1991). In particular, informal forms of technology transfer benefit from spatial proximity, whereas it is less important for formal types (Audretsch and Stephan, 1996; Grotz and Braun, 1997).

The most important incentive for collaboration with public research organisations is to access competences and knowledge. Organisational coordination deficiencies and sociocultural divergence are major barriers, and SMEs also suffer informational barriers

By far the most important incentive for collaborating with universities and other public research organisations is access to competencies, knowhow and expertise of scientists and others working in public research institutions. Nearly all interviewed companies pointed to this incentive (see Figure II.4.20). Organisational, financial and information-related incentives are also common. Technical, legal, spatial and sociocultural incentives were mentioned less frequently. However, the picture with regard to barriers is different. Organisational coordination barriers were mentioned most frequently, followed by sociocultural and technical issues. Financial, competence-related and legal barriers are of medium significance; informational, spatial and other barriers are insignificant.

A pattern appears with regard to the geographical extension of the firms' R&D activity (distinguishing between companies with R&D activities both in Europe and at least two other continents ('global')), and those with a more limited geographic R&D spread. In particular, when considering incentives for engaging with universities and other public research organisations, there were clear differences. Larger shares of global R&D players stress the importance of accessing public sector technology, financial drivers (cost reduction), sociocultural incentives (e.g. differing roles of tech transfer in scientists' career models and openness for university–industry cooperation) and spatial incentives (e.g. placement of internal R&D units close to particular competencies in universities or other public research organisations). Companies undertaking R&D globally also highlight legal and sociocultural barriers. It should be noted that the global extension of R&D is correlated with company size.

Figure II.4.20: Incentives and barriers by global extension of internal R&D (in %)



Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: FHNW / Knowledge Transfer Study 2010-2012

5. Matching science with technology and industry

Highlights

There is a strong rationale for improving the match between science/technology and industry

The circulation of knowledge throughout the national and European economies is facilitated by a strong match between science, technology and industry. The absorptive capacity and the competitiveness of an industrial sector are reinforced when the supply of education and science corresponds to industry's technology specialisation and needs. But such a match is often not vigorously pursued at national level.

Both consolidated and more recent innovation systems leave room for improvement in terms of the match between science, technology and industry

The quality of matching between science and technology with industry varies strongly between countries and leaves much room for improvement. This is the case both for more consolidated research and innovation systems, such as that of the United Kingdom, and for systems having gone through a recent transformation process, such as those of the Czech Republic and Romania. A country can have a strong industry base in a sector without any corresponding scientific or technological strengths. This can be caused by FDI (particularly strong in several central and eastern European countries, here exemplified by the Czech Republic), or by the fact that the dynamics of the research system are relatively autonomous from the industry dynamics. The matching of science with technology and industry can be enhanced by a rationalisation process at national level coupled with the exploitation of sectoral knowledge circulation channels at European level, as analysed in Chapter II.4. A certain level of mismatch may also have transformative potential, resulting in the development of latent comparative advantages or new science-based firms.

The matching of science with technology and industry can also be improved through more focused collaboration with European partners

The analysis of specialisation profiles in science, technology and industry across European countries reveals large opportunities for cross-country cooperation that would ensure a better match in most industries. This holds true both for sectors of long-term industrial strength in the European economy (such as the chemicals industry, the motor vehicle industry and aerospace industry), as well as for newer and growing sectors such as the health and ICT industries. Better exploitation of complementary specialisation profiles could provide new opportunities for ICT and health-related industries leading to more radical product and service innovation in these sectors, in which Europe lags behind the United States.

Introduction

The matching of science, technology and industry specialisations is part of the overall strategy to enhance knowledge circulation throughout the economy and the economic impact of research activities and funding. Indeed, the scientific production of a country may not necessarily correspond to its technology specialisation and even technology developments are not always in line with the needs of industry at national level. Stronger matching between the supply and demand of knowledge and technology is possible over time through smart specialisation strategies aimed at rationalising the national R&I system, setting scientific and technological priorities and reallocating scarce resources to ensure higher economic impact. However, there are also limits to this process, as a dynamic economy must be able to adapt to new market opportunities in a global context. In addition, this 'transformative potential' can derive from specific scientific and technological strengths that do not match the needs of industry.

Traditionally, matching or co-developing science, technology and industry is conceived as driving the national strategy. More recently, it has also been contemplated at regional level as part of regional R&I strategies. It could be possible to match opportunities at European level, reinforcing synergies and cooperation between Member States in view of mutual benefit ([110]). This goes in line with the need for accountability of public spending for research and its returns for society and economy, with the more recent focus on the role of R&I for increasing the competitiveness of regions, countries and of Europe as a whole.

All these issues are taken into account by existing policy initiatives at European level. The Innovation Union Flagship Initiative emphasises the need to reinforce the progression of research results from idea to technology and then to the market. In the context of Europe 2020, Member States and the European Commission assess national policies, including how to enhance knowledge circulation from science to technology and industry. Knowledge transfer is also an important dimension of the ERA. The most important European funding instruments for R&I, which are the Framework Programmes and Structural Funds, have explicit segments addressing knowledge circulation, such as the smart specialisation strategies for R&I as an ex-ante conditionality for the next programming period of the Structural and Investment Funds.

This chapter will present a theoretical framework for the co-development of science, technology and industry policies based on empirical evidence at national and European levels.

[110] Related analysis can also be found on networked specialisation in Chapter II.3 and on global value chains capitalising on the EU single market in Chapter III.4.

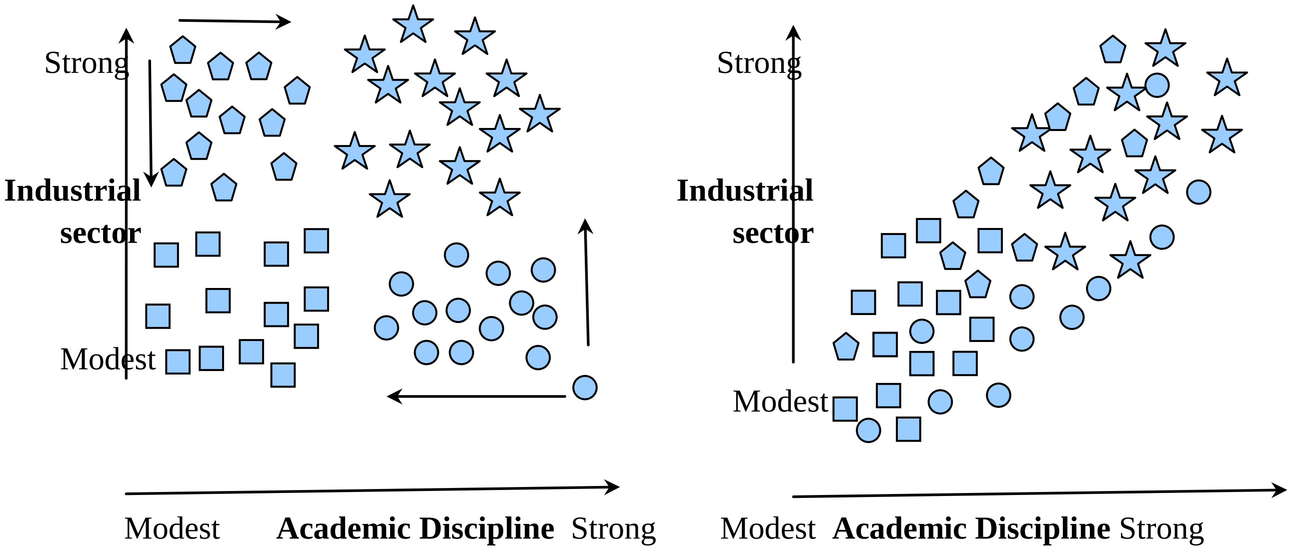
5.1. Co-development or matching of science with technology and industry

Over longer periods of time, a country is likely to become either strong or weak in both science and technology, specifically in industries

Knowledge and science acquire their full economic value when they are exploited. Economic evolution inside a given technology and industrial structure ('paradigm') is pushed by a process of rationalisation, a constant effort by firms and economic actors to allocate and reallocate existing resources to ensure their optimal economic impact. An industry segment is continuously upgraded to reach its competitive edge. Science is an important dimension in this rationalisation process, although science is not equally relevant in all industries.

Some authors (Murmann, 2013) affirm that over longer periods of time, co-specialisation in science and industry at national level occurs naturally in industries with significant input in S&T, even without a specific policy action.

Figure II.5.1: Forces of unstable Academic-Industry complexes at national level at Time T1 **Co-development at national level at Time T2**



Source: J.P. Murmann, 2013

According to this model, government actions to strengthen S&T in specific sectors makes sense mostly in the case of strong science and modest industry, or in the case of strong industry and modest science.

The first case (strong science and modest industry) can be the result of a decline in a technology-based industry that was once strong; in this case, without an eventual policy action. Under this model, the decline in technology will likely trigger a decrease in science specialisation and quality over longer periods of time. Reallocation decisions moving funding between scientific fields may save resources and enhance efficiency. This reflects potential for economic transformation triggered by knowledge or radical innovation. The emergence of fields such as nanosciences or renewable energies in response to the climate change challenge are typical examples in these circumstances. Overall policies addressing societal challenges, challenge-driven innovation and focussing on lead markets are promising avenues for such a transformation, using instruments such as public procurement, advanced regulation and strict standards in the given field.

In the second case (of strong industry and modest science), the role of the government would be to orient science in order to better sustain existing technological and industrial development. This situation is the overall characteristic of the catching-up countries, with a substantial amount of FDI for technology and innovation-related activities. In a situation where both science and industry are strong, the design of policy measures would simply need to take into account whether industry is experiencing growth or decline, which is related to the sustainability of a specialisation. In this case, a better match between science and technology industries could help either maintain a competitive edge in the sector or to regain a competitive advantage by investing in R&D.

Last but not least is the modest-science-and-modest-industry situation, but where policy action would still make sense provided that other comparative advantages are present. An empirical illustration of this potential can be found in the case of the food, agriculture and biotechnology sectors in Romania.

The case of Romania for the fields of food, agriculture and biotechnology

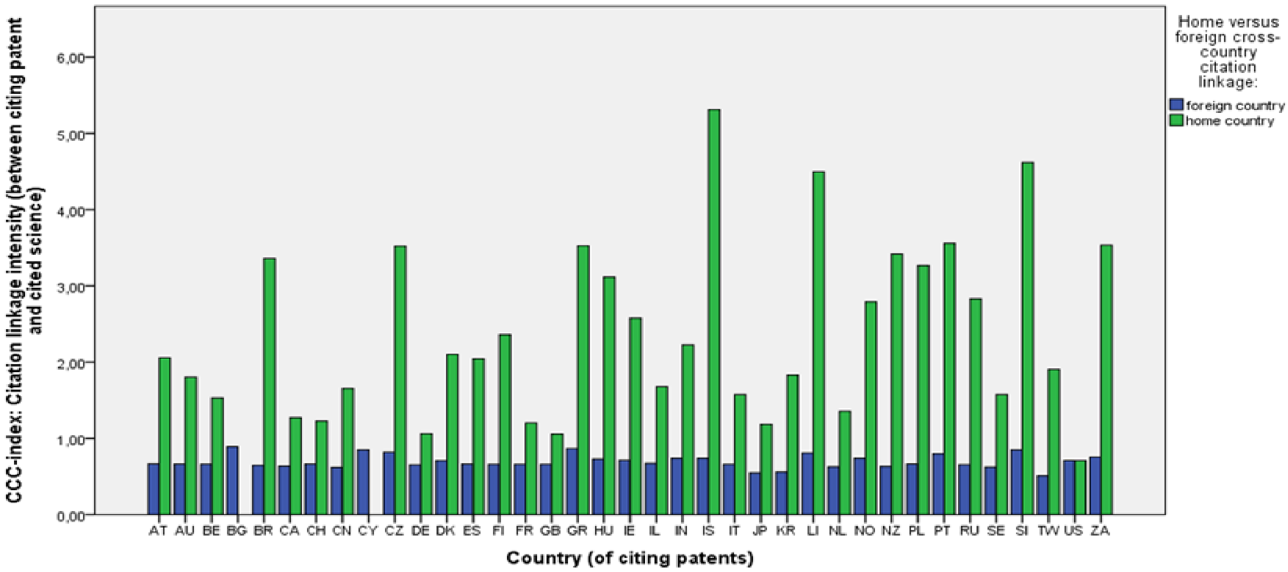
A serious decline in the food and agriculture field after 1990 was coupled with a lack of specialisation in science and industry, despite the existence of massive potential in terms of natural resources and primary production factors. This situation is rather unique in the region as countries with similar economic patterns, such as Bulgaria, Turkey and Croatia, but also Hungary, Slovakia, the Czech Republic and Poland, continued to support the field of food and agriculture after the fall of communism. As developments can often be rebooted bottom-up in the case of existing latent comparative advantages, over the last decade the quality of science in this field rose spectacularly, accompanied by high growth in the number of publications in the field of biotechnologies. However, the country has not yet reached a critical mass of publications to specialise in these fields, and related technologies are not present. In this context, there is room to further boost science in the fields of food, agriculture and biotechnology. This is backed up by a large domestic economy (over 30 % of the population is still employed in the agriculture and food industry) and the potential to upgrade these industries' positions in international value chains.

The co-development of S&T at national level appears to be a characteristic of technologically strong countries (or innovation-driven economies)

The positive effect of co-development in S&T at national level does not exclude the use of foreign S&T for raising a country's technological development. However, research has shown that the leveraging effects of using foreign science for raising technological activities at national level are less decisive for countries with a strong home science base than for countries with smaller domestic scientific capabilities.

One way of verifying this model is to measure the S&T linkages in technology-intensive industries through the use of patent examiner citations of scientific publications in patent applications. This has been done in the context of a study financed by the European Commission ([111]), which concluded that technologically strong countries are empirically correlated with both high levels of scientific productivity and important science–technology relatedness as measured by publications cited in patents. Figure II.5.2 shows the citation intensity of patents to scientific publications comparing national to foreign science references. It reveals that technological development in a country is primarily (but not exclusively) based on the domestic science base (green bars being considerably higher than the blue bars).

Figure II.5.2: Comparison of within-country (home) citation intensity (green) to the average citation intensity in other countries (blue)



Source: J.Callaert et Al., *Patterns of Science-Technology Linkage*, (forthcoming)
Notes: Patent data: *Aggregation USPTO, EPO and PCT patents*, application years 2000-2009; Scientific data: Web of Science (1991-2011)

However, there are country differences in the extent of this home effect. For some countries, the home effect is much less outspoken: they rely on both foreign and domestic science. These are mainly technologically strong countries, such as the Unites States, France, the United Kingdom, Japan and Germany, with capacity to source knowledge globally. Nevertheless, further analysis ([112]) shows that whereas a broader geographical scope in citing science has positive effects on national technological performance, these leveraging effects are not decisive for countries with large scientific capabilities at home but rather for countries with a smaller science base.

[111] Callaert, J. et al., 2013, 'Patterns of science-technology linkage' (forthcoming).
[112] For a more detailed account of these analyses, see the same report 'Patterns of science-technology linkage' (Callaert, J. et al., 2013, forthcoming).

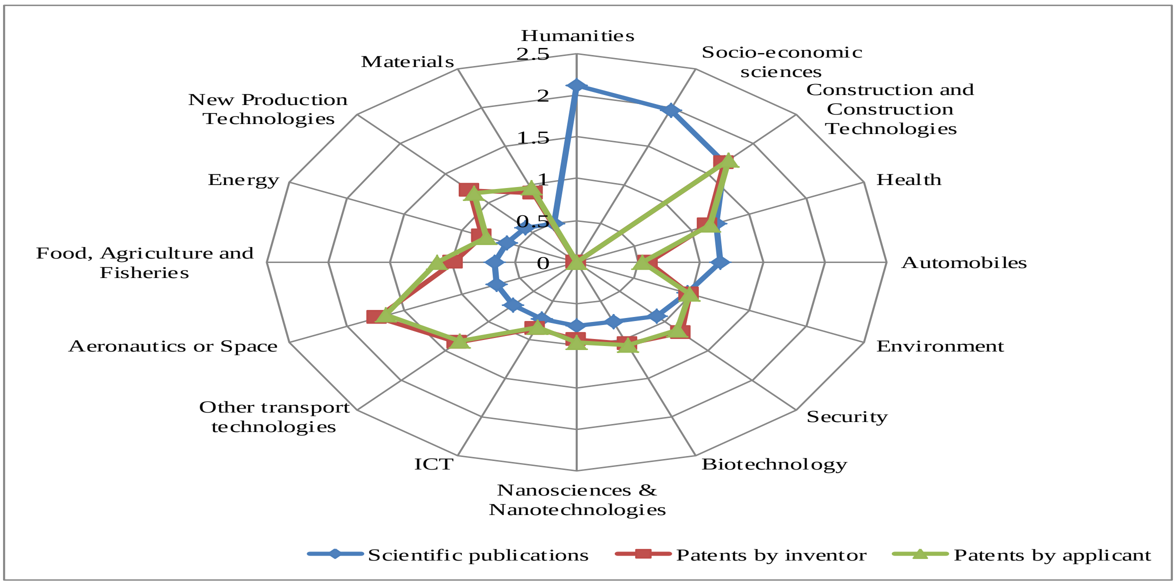
5.2. Possibilities for co-development at national level

The United Kingdom(113) is a country where technology relies on both domestic and foreign science

Figure II.5.3 shows an overall higher level of specialisation in technology compared to science in the United Kingdom, except in the field of automobiles and for the fields of socioeconomic science and humanities, where the comparison does not make sense as there are no correspondent technologies measured by patents in these fields. There is clear technological specialisation in aeronautics and other transport technologies, as well as in new production technologies, although these technology fields are not backed up by any scientific specialisation.

Figure II.5.3: Scientific and technological specialisation profile of the United Kingdom

United Kingdom S&T National Specialisation in FP7 thematic priorities, 2000-2010



Source: DG Research and Innovation - Economic Analysis Unit
Data: Science Metrix - Canada, Univ. Bocconi - Italy
Notes: Values over 1 show specialisation, under 1 lack of specialisation
Patents in "Aeronautics or Space" refers only to "Aeronautics" data.
For the thematic priorities with less than 5 patent applications over 2000-2010, the RTA is not taken into account.

Transformative potential of science — the case of the United Kingdom in the field of automobiles

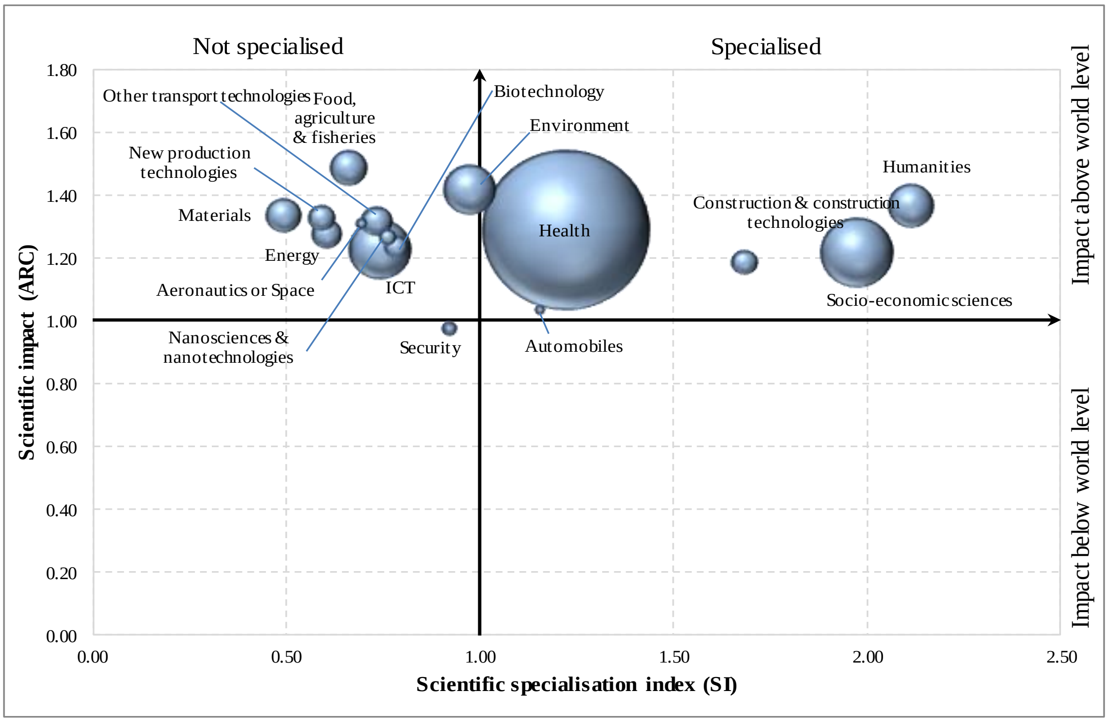
The United Kingdom appears to be specialised in science but not in technologies in the field of automobiles. This situation is likely due to a decline of technology that was once strong. In addition, the field of S&T for automobiles appears to be quite static, without spectacular growth rates in S&T over the last decade and with a rather linear quality of science over the same period: just above the world average and second to last compared to all other research fields in the United Kingdom. According to the theoretical model presented at the beginning of this chapter, a certain decline in industry might produce a similar decline in the quality of science in the longer term if policies are not promoted for the resuscitation of the automobile industry.

In order to revitalise the sector, the UK government decided to support a shift to ultra-low carbon vehicles, in the context of the current overall orientation of the United Kingdom towards the emerging low-carbon economy. This may be an example of economic transformation driven by high-quality science. However, as this S&T base is currently limited and of relative lower scientific quality in the United Kingdom compared to related sectors, such as science for other transport technologies or energy, the country's strategy will benefit from close integration in intra–European global value chains (GVCs) in the sector.

Figure II.5.4 shows that the UK's scientific production is of a very high quality when measured by the high impact of its scientific publications. The high quality of science coupled with a technological specialisation that covers more areas than the science specialisation may reveal that the technological performance of the country is based both on excellent quality science at national level and on science sourced from abroad.

Figure II.5.4: Scientific specialisation and quality in the United Kingdom

Positional analysis of United Kingdom publications in Scopus by FP7 (specialisation versus impact), 2000-2010



Source: DG Research and Innovation - Economic Analysis Unit

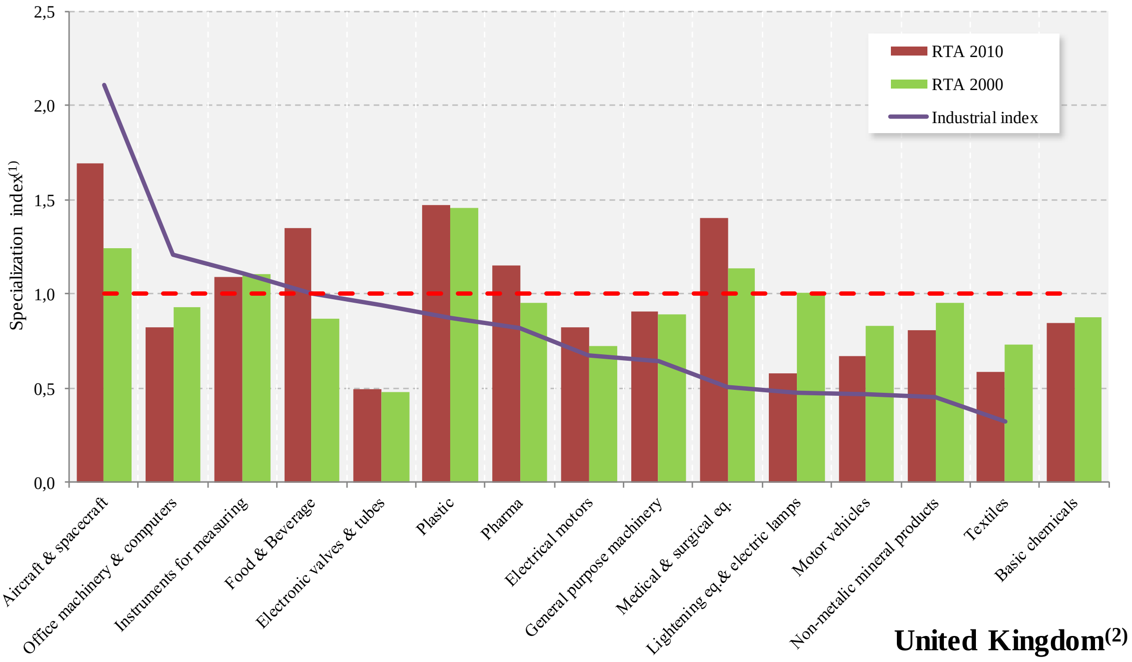
Data: Science Metrix - Canada, based on Scopus

Notes: Scientific specialisation include 2000-2010 data; the impact is calculated for publications of 2000-2006, citation window 2007-2009

Several key industries in the United Kingdom are backed up by a strong S&T base, but there is room for further matching

Figure II.5.5 is based on a classification by NACE categories, closer to the industrial dynamics than the previous classification model, based on FP7's main thematic areas. It provides a complementary picture on the matching between technology and industrial specialisation. It shows that the technological specialisation for many sectors (e.g. aircraft and spacecraft, instruments for measuring, medical and surgical equipment, pharmaceuticals, plastics, and food and beverage) is broader than the actual industrial specialisation. For each sector, national industry has a large technology base to build upon. Compared to Figure II.5.4, some, but not all, of these sectors can also count on scientific specialisation and high scientific quality. This is particularly clear for industry segments in the field of health. At the same time, industrial specialisation in other important manufacturing sectors, such as office machinery and computers or electronic valves and tubes, do not count on any corresponding technological specialisation in the country. These are also sectors where Europe in general is less specialised in technologies in comparison to other regions of the world, especially the United States and some developed Asian countries.

Figure II.5.5: Technological and industrial specialisation in the United Kingdom, 2010

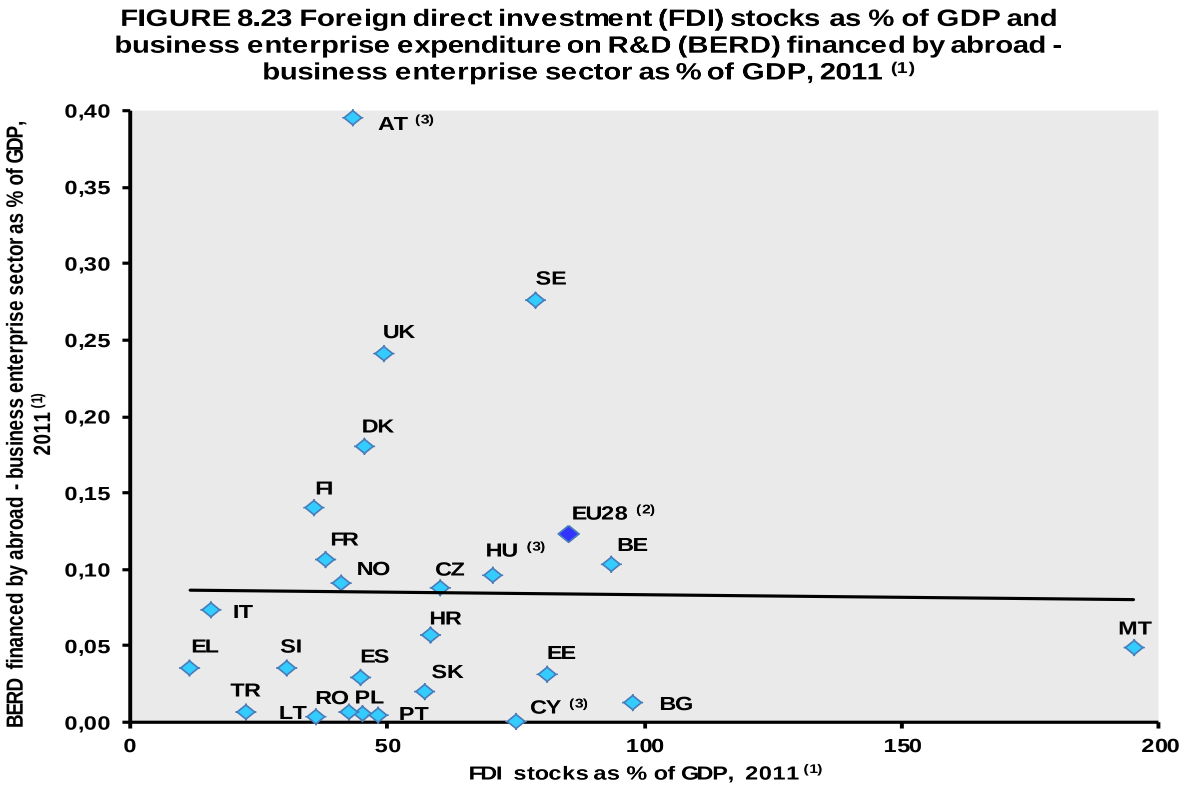


Source: DG Research and Innovation - Economic Analysis unit
Data: Univ. Bocconi - Italy, based on WIPO-PCT applications; OECD, Eurostat, IMF (based on Sector Study);
Notes: (1) The economic specialisation (industrial specialisation) is based on LQ (Balasa index) of value added, using EU27 as reference (EU27=1).
For the NACE sectors with fewer than one patent applications in 2000 and/or 2010, the RTA is not taken into account.
(2) For the NACE sector Basic chemicals (except pharmaceuticals) industrial specialisation data are not available.

The Czech Republic is a good example of a country benefiting from knowledge-intensive FDI, but where the science base does not match the technology profile

Figure II.5.6 shows the amount of FDI stocks as a percentage of GDP in different European countries and at the same time the knowledge intensity of the inward FDI. Among eastern European countries, the Czech Republic and Hungary have FDI stocks with private R&D intensity that is closer to the EU average. In other words, the FDI in these two countries has an important R&D component.

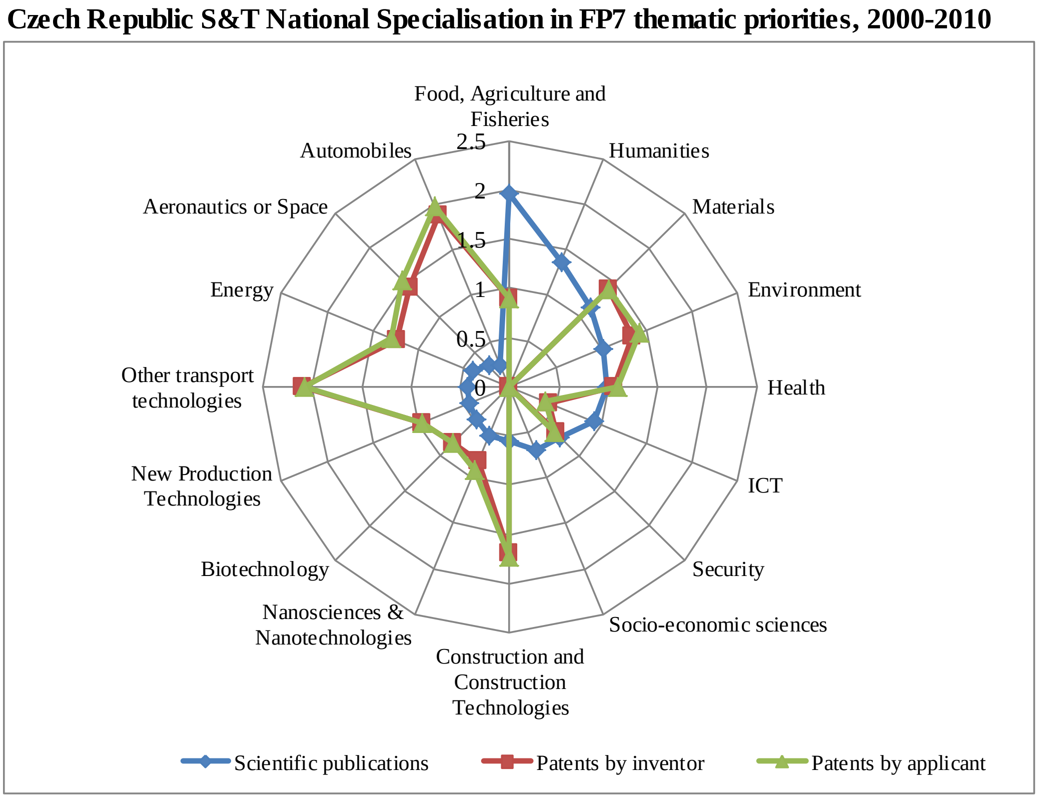
Figure II.5.6. Foreign direct investment and business enterprise investment in R&D



Source: DG Research and Innovation - Economic Analysis Unit   Innovation Union Competitiveness Report 2013
Data: Eurostat
Notes: (1) BE, BG, AT, SE, EU28: 2009; CZ, EE, SK: 2010;
EL: BERD financed by abroad - business enterprise sector as % of GDP refers to 2007; Foreign direct investment stocks as % of GDP refer to 2008.
(2) EU28: (i) EU28 does not include DE, IE, LV and NL. (ii) Special Purpose Entitles (SPEs) are included.
(3) CY, HU, AT: Special Purpose Entities (SPEs) are not included.
(4) DE, IE, LV, LU, NL, IS, CH, US, JP: These countries are not included due to unavailability of data.

Taking the Czech Republic as an example, Figure II.5.7 compares the country's scientific and technological specialisation. It shows that the technological base is specialised in more sectors than the science base. Technology production is strongly specialised in automobiles, other transport technologies and construction technologies, but also in aeronautics and energy, without any corresponding scientific specialisation. Sectors with the best match between S&T specialisations are materials, environment and health. These sectors can also count on stronger scientific quality (see Figure II.5.8). Conversely, in the food and agriculture sector, the Czech Republic has strongly specialised scientific production without any corresponding technological specialisation (although Figure II.5.9. shows that there is a certain level of industrial specialisation in the food and beverage sector).

Figure II.5.7: Scientific and technological specialisation profile of the Czech Republic



Source: DG Research and Innovation - Economic Analysis Unit

Data: Science Metrix - Canada, Univ. Bocconi - Italy

Notes: Values over 1 show specialisation, under 1 lack of specialisation

Patents in "Aeronautics or Space" refers only to "Aeronautics" data.

For the thematic priorities with less than 5 patent applications over 2000-2010, the RTA is not taken into account.

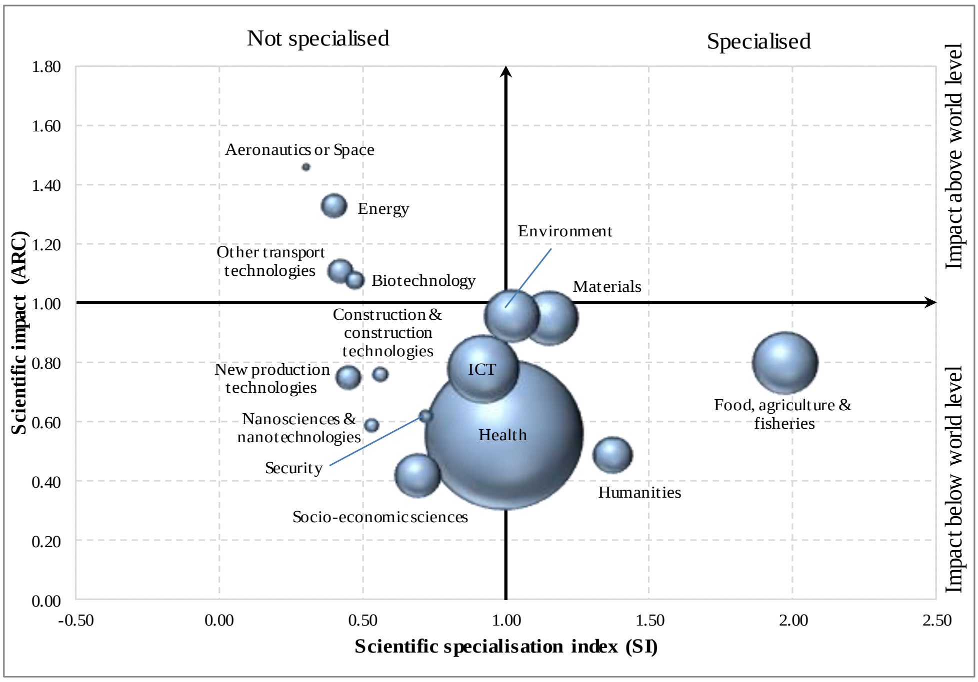
The scientific specialisation pattern in the Czech Republic is not fully consistent with its technological and industrial profile

The country displays relevant scientific strength in several sectors where scientific quality is combined with technological and industrial specialisation, while scientific production and quality is much more limited in several other sectors relevant to its industry.

Figure II.5.8 shows that technological performance as visible in Figure II.5.7 is not leveraged by the quality of domestic science, highlighting a clear need for improvement. The Czech Republic has established scientific strength in the fields of materials and environment, where scientific production and quality are correlated with a certain technological specialisation. In these sectors, the scientific profile is coupled with the country's technological and industrial profile. The same holds true for the fields of other transport technologies and energy. On the other hand, industrial specialisation in office machinery and computers, as well as in motor vehicles (see Figure II.5.9) is not backed up by domestic scientific specialisation or quality.

Figure II.5.8: Scientific specialisation and quality in the Czech Republic

Positional analysis of Czech Republic publications in Scopus by FP7 (specialisation versus impact), 2000-2010



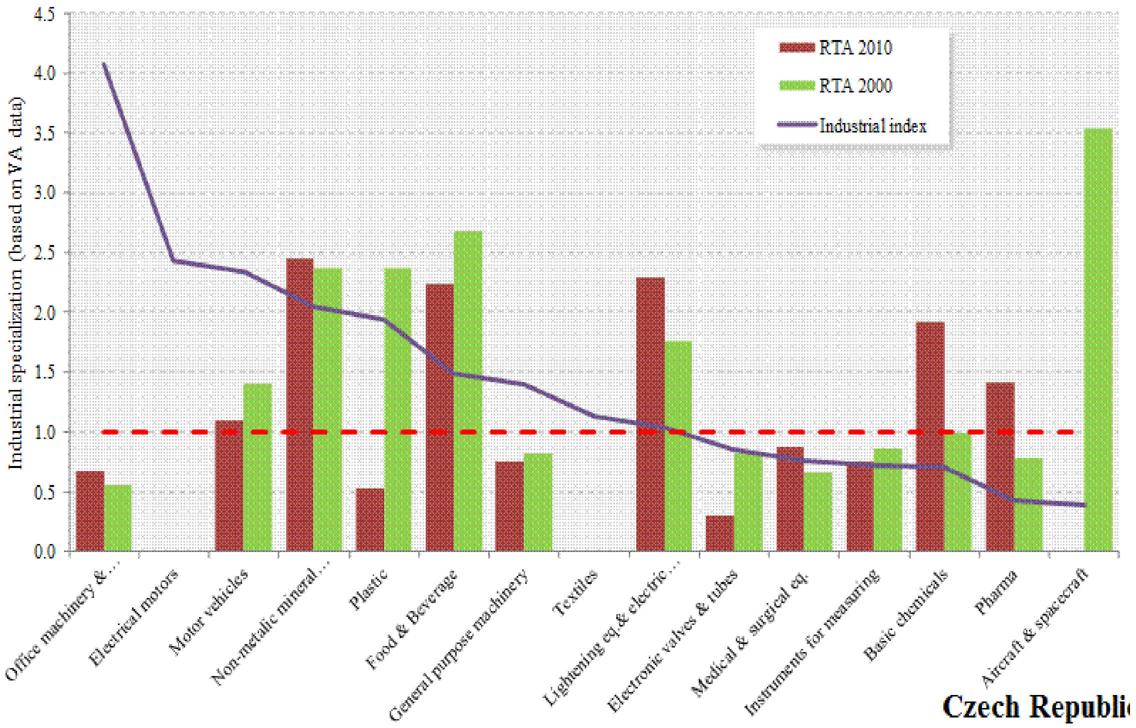
Source: DG Research and Innovation - Economic Analysis Unit

Data: Science Metrix - Canada, based on Scopus

Notes: Scientific specialisation include 2000-2010 data; the impact is calculated for publications of 2000-2006, citation window 2007-2009

In terms of matching technology supply to industry needs, the Czech Republic presents a stronger mismatch than the United Kingdom. The Czech Republic boasts industrial specialisation in particular in office machinery and computers, electrical motors, motor vehicles, non-metalic products and plastics. However, the level of technology specialisation in these industries is not very high, with the exception of technologies for office machinery and computing, motor vehicles and general purpose machinery industry (also showing strong growth over the 2000–2010 period). On the other hand, strong technology specialisations in pharmaceuticals, basic chemicals, medical and surgical equipment, and lighting equipment and electricity are not matched with similar industrial specialisation. This confirms the conclusions from the previous matching analysis based on FP classification: that the Czech Republic has major potential to improve its science, technology and industry matching, which would enhance the economic impact of research activities and funding.

Figure II.5.9: Technological and industrial specialisation in the Czech Republic



Source: DG Research and Innovation - Economic Analysis unit

Data: Univ. Bocconi - Italy, based on WIPO-PCT applications; OECD, Eurostat, IMF (based on Sector Study);

Notes: (1) The economic specialisation (industrial specialisation) is based on LQ (Balasa index) of value added, using EU27 as reference (EU27=1).

For the NACE sectors with fewer than one patent applications in 2000 and/or 2010, the RTA is not taken into account.

5.3. Matching science with technology and industry specialisation at European level

The analysis in Sub-section 5.2 showed that industrial specialisation is not always matched with scientific and technological specialisation at national level, which opens up collaboration opportunities at European level. Industrial specialisation can benefit from a related knowledge specialisation, or excellence, in another country. In this sense, there are opportunities for the European industry for better knowledge spillover across European countries. At the same time, scientific and technological specialisation in a country can give rise to industrial transformation in related industries, given high scientific quality coupled with the right framework conditions for business creation.

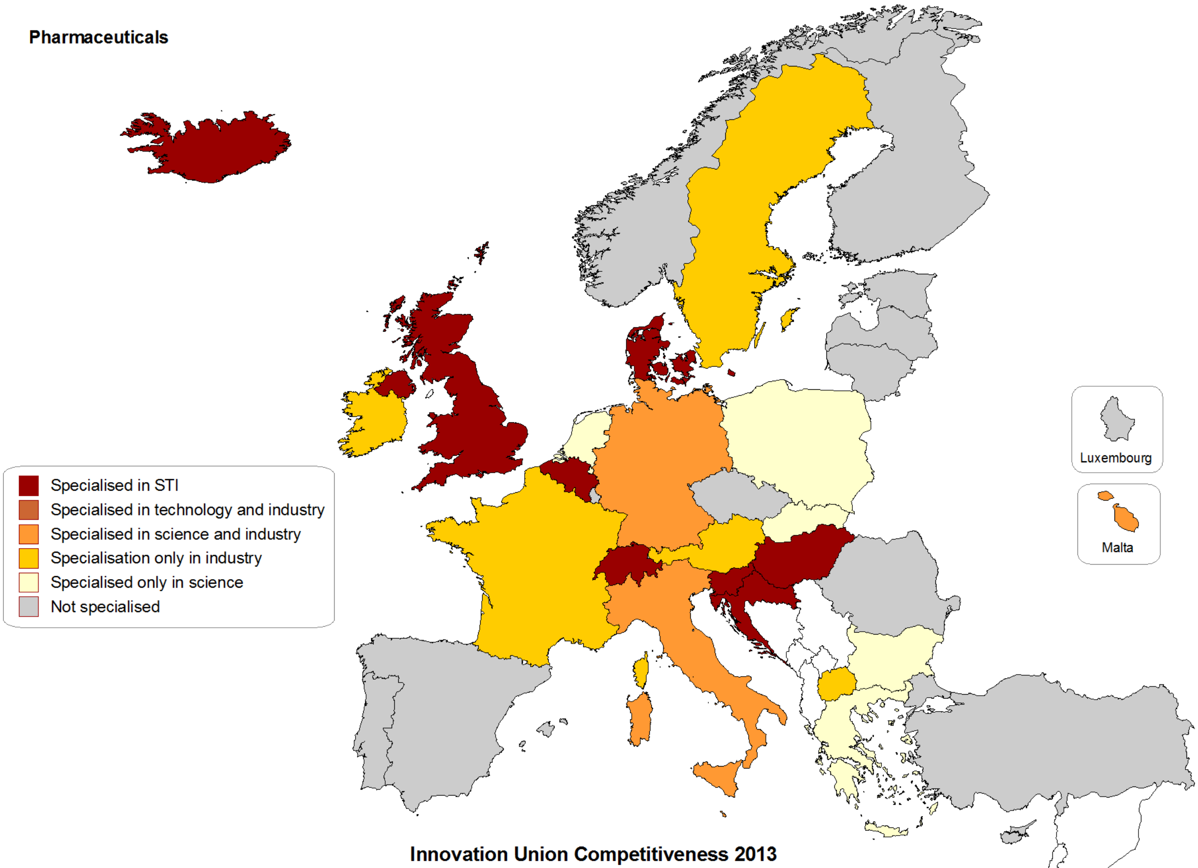
The maps in Figures II.5.10 to II.5.17 illustrate the situation for a number of industrial sectors. They have been created using specialisation indexes in science, technology and industrial value added moulded into a common classification system using NACE. The matching points add new insights but they have to be considered as indicative, given the methodological classification challenges and the complex relationship between science and technology and their use in various industries ([114]).

[114] See Methodological notes for a more detailed explication of the classification systems and their limitations.

Health-related industries have the potential to gain from strategies that form links with the specialisation profile of other European countries

The maps II.5.10 and II.5.11 illustrate this match in two industry sectors related to scientific and technological findings in health and biotechnology. For the medical and surgical equipment industry, there are good conditions for knowledge development in Ireland, Sweden, Denmark, the Netherlands, Germany and Austria. Industry in these countries is reinforced by either scientific or technological specialisation. In the pharmaceutical industry, there is a stronger match between knowledge production and industry, in particular in Belgium, Denmark, Hungary, Slovenia, Croatia, Iceland, Switzerland and the United Kingdom. Conversely, there are margins for a better match between specialisation strategies in several European countries, including the case of science supporting the medical equipment industry in Finland or S&T supporting the pharmaceutical industry in Ireland, Austria or even France.

Figure II.5.10. Specialisation profiles in European countries in pharmaceutical industries



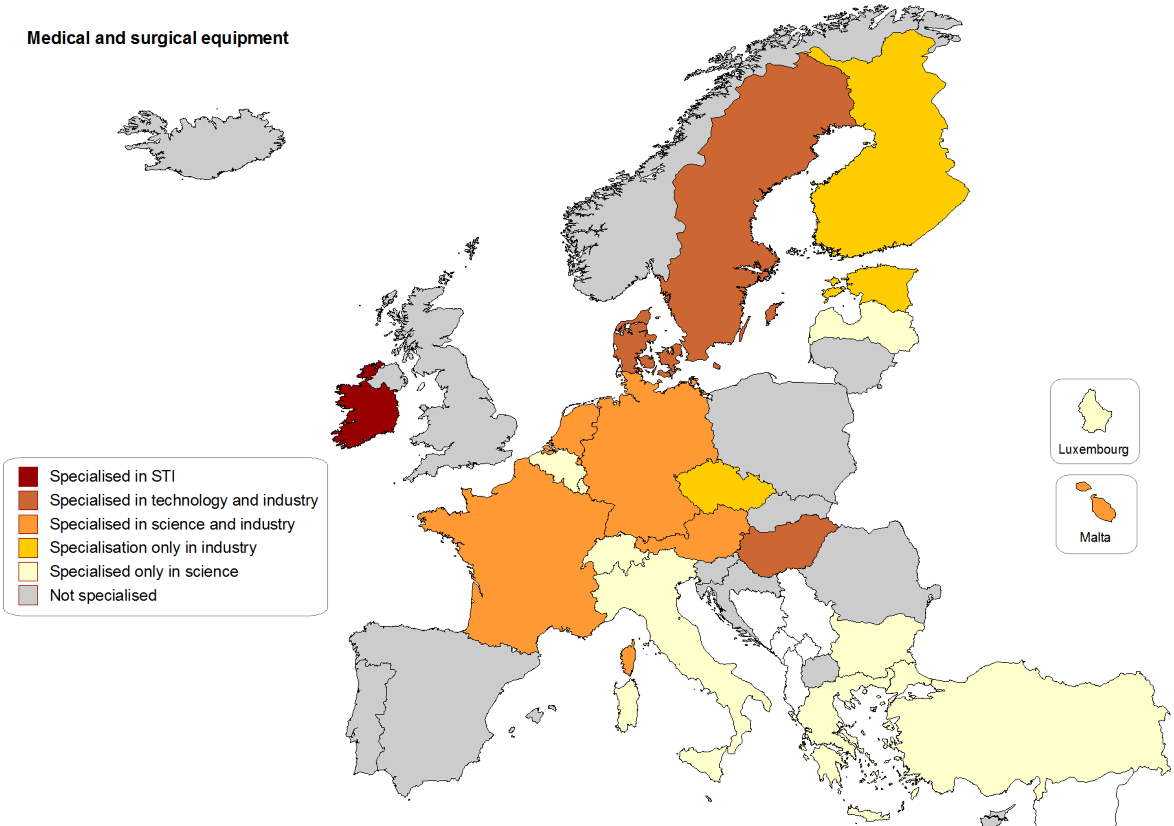
Source: DG Research and Innovation - Economic Analysis unit
Data: Science Matrix (Canada), based on Scopus data; University Bocconi (Italy), based on WIPO-PCT applications; Eurostat, OEDC, IMF
Notes: A country is considered specialised in science or technology if the scientific index (SI) or the revealed technological advantage (RTA) has a value greater or equal to 0.98.
The economic specialisation (industrial index) is based on LQ (Balasa index) of value added, using EU27 as reference (EU27=1).
A country is considered specialised from economic perspective if the industrial index has a value greater or equal to 0.75.

In the Netherlands, the science base in health research is among the highest in terms of quality in Europe, together with Iceland, Switzerland, Denmark and Finland (see analysis in

Chapter II.2). The pharmaceutical industries in Belgium, Denmark, Switzerland and the United Kingdom also benefit from excellent research in biotechnology.

The maps also highlight a clear economic interest in knowledge dissemination across European countries, in particular in the medical and surgical equipment industry. Scientific specialisation in health in Belgium and Switzerland, coupled with high quality, means it is in demand in other European countries such as Germany, Austria and the Netherlands. There is also cooperation potential between Latvia and Finland, and between the larger scientific producers in health research, such as France and Italy. Finally, there are scientific opportunities for catching-up countries such as Greece, Bulgaria or Turkey to link up with related industry in other European countries. There are similar European cooperation opportunities for the pharmaceutical industry. Scientific specialisation in Poland, Slovakia, Bulgaria and Greece would benefit from closer cooperation with other European countries specialised in this industry. The four mentionned countries offer potential partners for the outsourcing and the cross-national value chains of the European pharmaceutical industry.

Figure II.5.11. Specialisation profiles in European countries in medical and surgical equipment industries



Innovation Union Competitiveness 2013

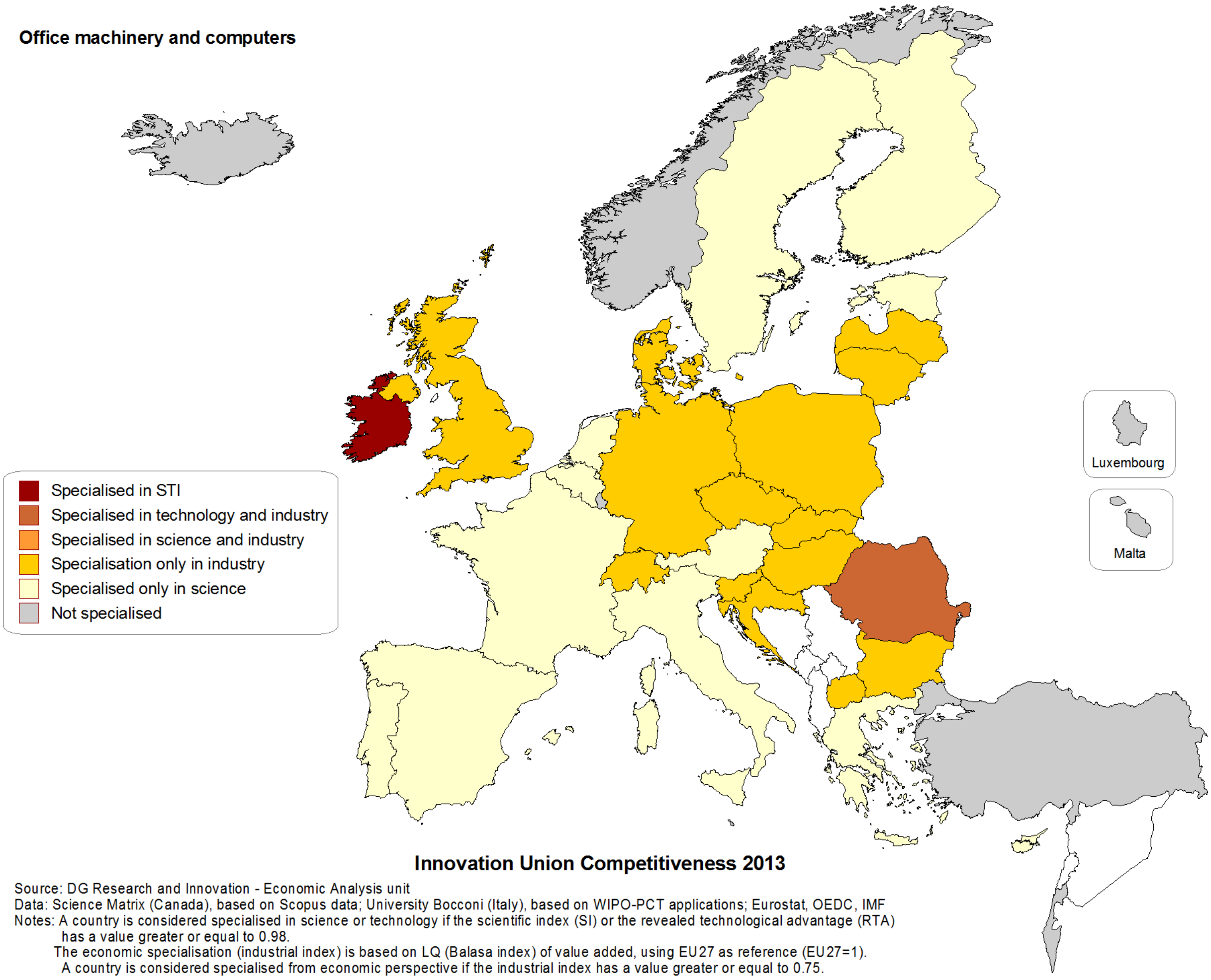
Source: DG Research and Innovation - Economic Analysis unit
Data: Science Matrix (Canada), based on Scopus data; University Bocconi (Italy), based on WIPO-PCT applications; Eurostat, OEDC, IMF
Notes: A country is considered specialised in science or technology if the scientific index (SI) or the revealed technological advantage (RTA) has a value greater or equal to 0.98.
The economic specialisation (industrial index) is based on LQ (Balasa index) of value added, using EU27 as reference (EU27=1).
A country is considered specialised from economic perspective if the industrial index has a value greater or equal to 0.75.

Alternative scenarios to address a mismatch can be either a reconsideration of the specialisation strategies or a more comprehensive effort of firm renewal. The case of the UK is striking for its transformative capacity in the field of health, being the largest scientific producer in health research in Europe, producing excellent quality, without any industrial or technological specialisation in related industries with large absorptive capacity. Spain is similar, with considerable scientific production of good quality in health and biotechnology, but without any related industrial specialisation in these areas. Their opportunities for knowledge diffusion in these sectors are subject to favourable framework conditions for firm creation.

ICT-related industries offer opportunities for radical service innovation using the complementary specialisation profiles of European countries

Overall, Europe is relatively de-specialised in these sectors, with Asia dominating at world level, both in ICT-related manufacturing and electronic components, as well as in services for computers, this time together with the United States. This situation is quite well reflected by the maps in Figures II.5.12 to II.5.13, with most of the EU countries specialised either in industry or in science, but not in technologies. Regarding ICT-related manufacturing, the exceptions are Ireland, which has a triple specialisation in science, technology and industry, and Romania, specialised in ICT — both in technology and industry.

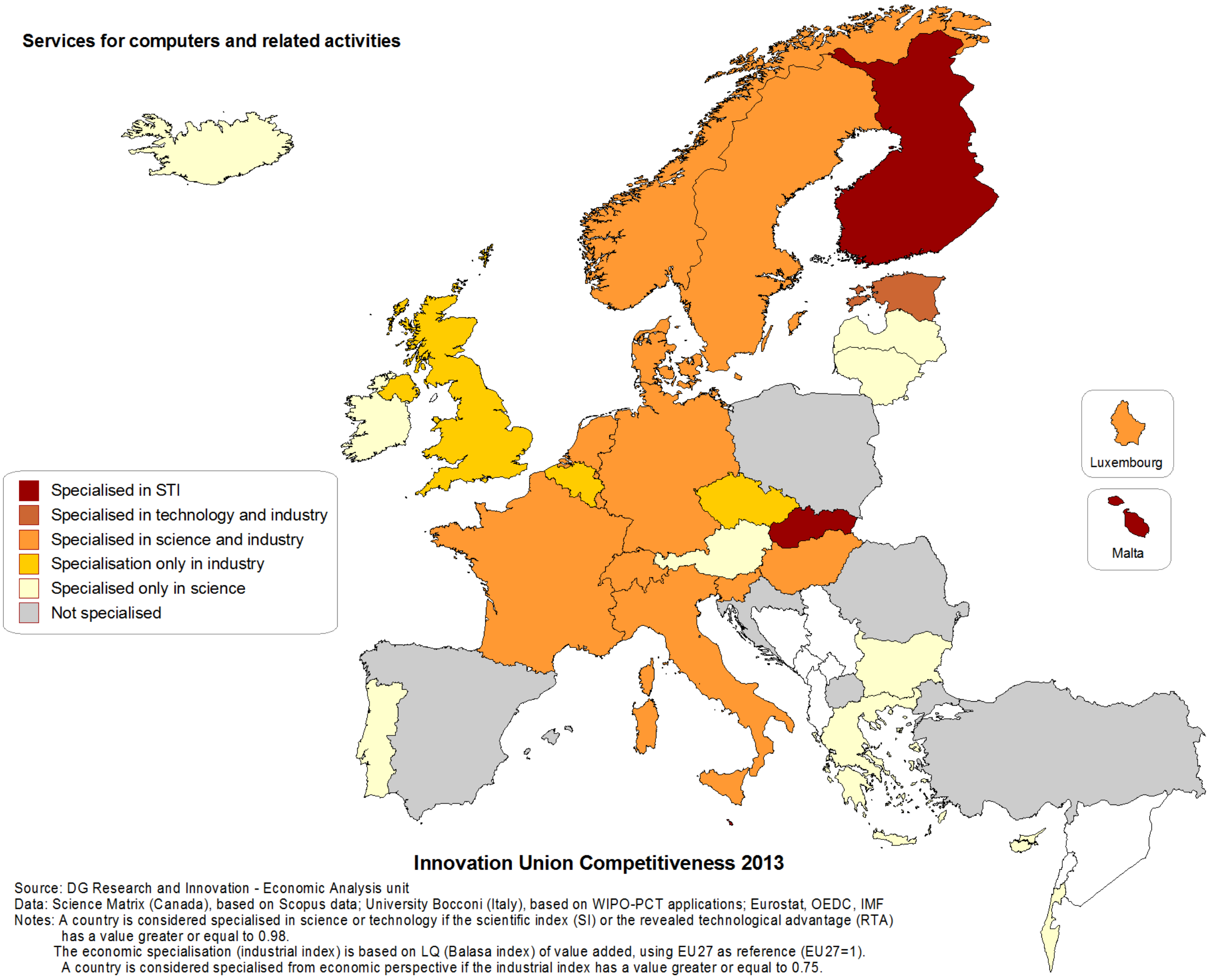
Figure II.5.12. Specialisation profiles in European countries in office machinery and computers



The ICT-related service sector for computers is one of the fastest growing, and among the most knowledge intensive of the service sectors.[115] Overall, the map in Figure II.5.13 illustrates a positive and strong match between industrial and scientific specialisation, opening up radical innovation potential. Finland is in a particularly strong position in this sense, also counting on related technology specialisation. Switzerland, Italy and the Netherlands reinforce their scientific specialisation with very high scientific quality in ICT.

[115] See also Chapter III.5, analysing innovation in services.

Figure II.5.13. Specialisation profiles in European countries in services for computers

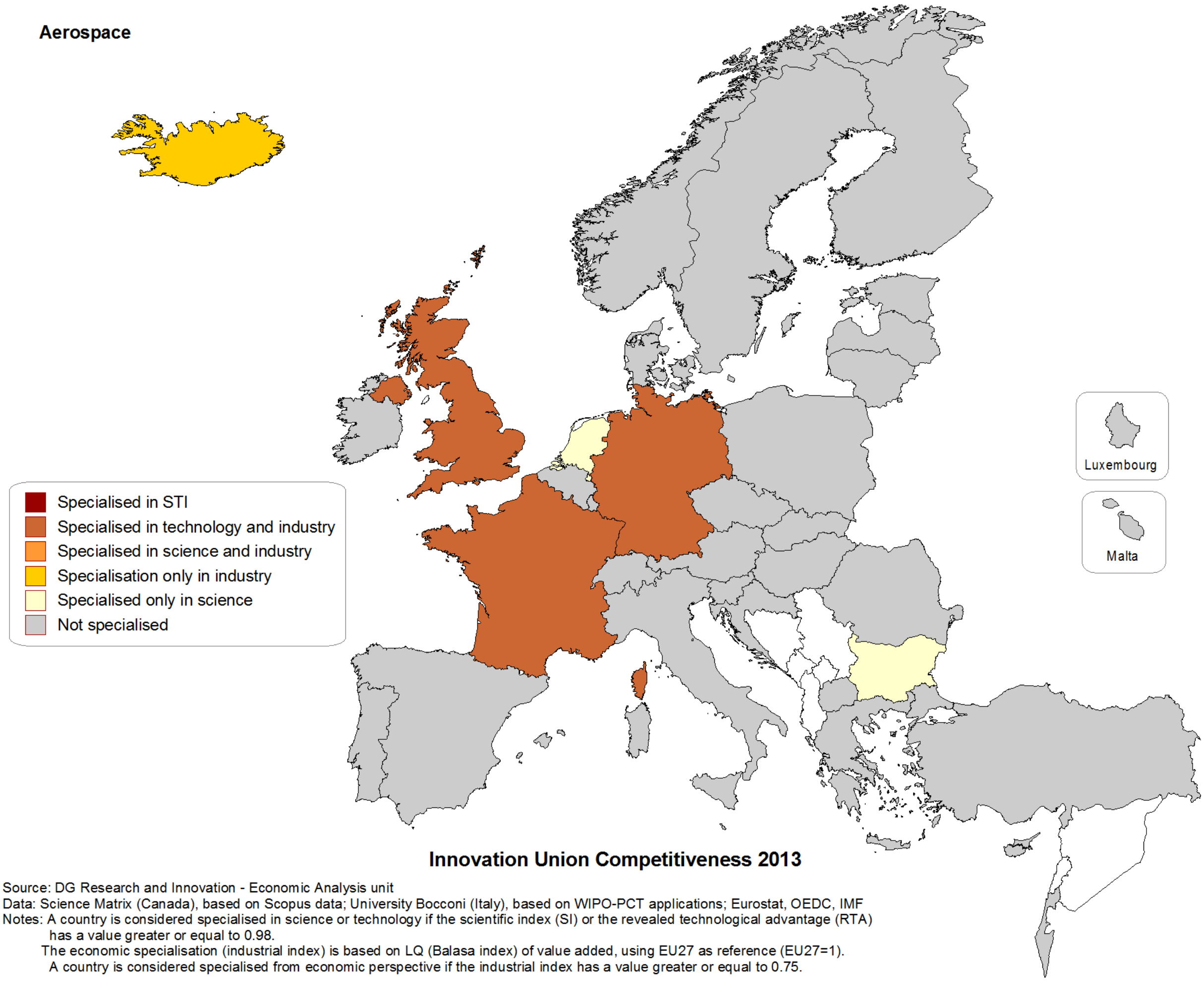


Opportunities for further scientific specialisation and knowledge spillover are apparent for Spain, Belgium and the Czech Republic. The UK is unusual in that its lack of scientific specialisation is compensated by a very large scientific production activity in ICT in absolute terms, reinforced by excellent quality.

Intra-European collaboration in S&T in the aerospace and motor vehicles industries may reinforce Europe's industrial strongholds

Aerospace and motor vehicles are among Europe's overall technology strengths. However, as shown in the map in Figure II.5.14, in aerospace there are only three large countries that are specialised both in technology and industry in this domain: Germany, France and the United Kingdom, with the rest of Europe showing a lack of specialisation. Interestingly enough, almost no European country is specialised exclusively in science for these industries, with the exceptions of the Netherlands and Bulgaria. The reason might be the specificity of the sector, rather patenting than publishing in order to protect intellectual property for competition-related reasons. It is however worth mentioning that despite the lack of scientific specialisation, the publications that exist in many European countries are of a very good quality. This is the case for the three countries indicated above, but also for Austria, Belgium, Finland, Italy, Hungary, Poland, the Czech Republic, Slovakia and Greece, creating the potential for knowledge flows to European countries that have industries capable of absorbing the knowledge created.

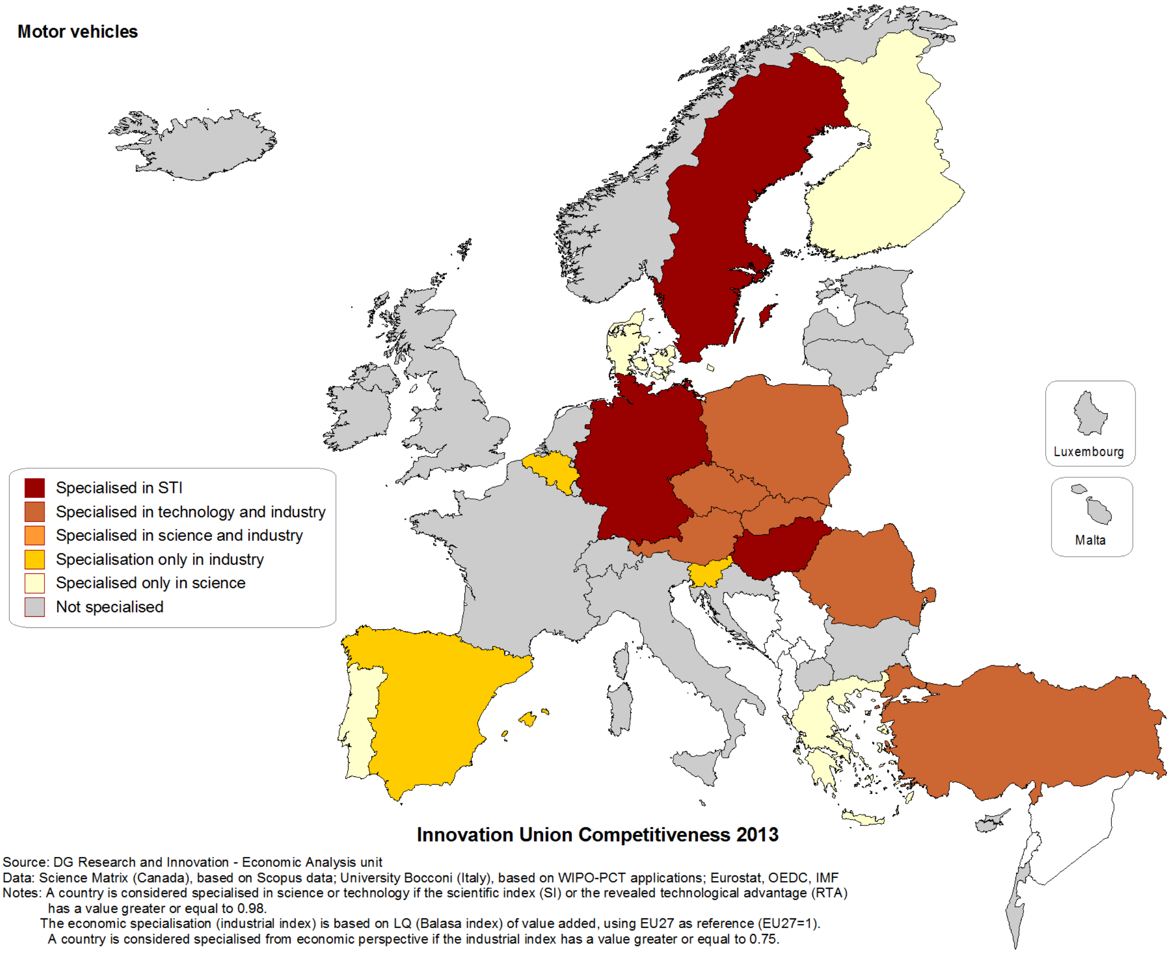
Figure II.5.14. Specialisation profiles in European countries in aerospace industries



Source: DG Research and Innovation - Economic Analysis unit
Data: Science Matrix (Canada), based on Scopus data; University Bocconi (Italy), based on WIPO-PCT applications; Eurostat, OEDC, IMF
Notes: A country is considered specialised in science or technology if the scientific index (SI) or the revealed technological advantage (RTA) has a value greater or equal to 0.98.
The economic specialisation (industrial index) is based on LQ (Balasa index) of value added, using EU27 as reference (EU27=1).
A country is considered specialised from economic perspective if the industrial index has a value greater or equal to 0.75.

The specialisation of European countries in the motor vehicles industry (see figure II.5.15) is broader than in the case of aerospace. Sweden, France and Hungary are triple specialised in science, technology and industry, and a good number of countries are specialised in science and industry: Poland, the Czech Republic, Slovakia, Austria, Romania and Turkey. Intra–European technology flows are quite widespread in Europe for this sector, through FDI, such as from France to Romania in the case of Renault.

Figure II.5.15. Specialisation profiles in European countries in motor vehicles

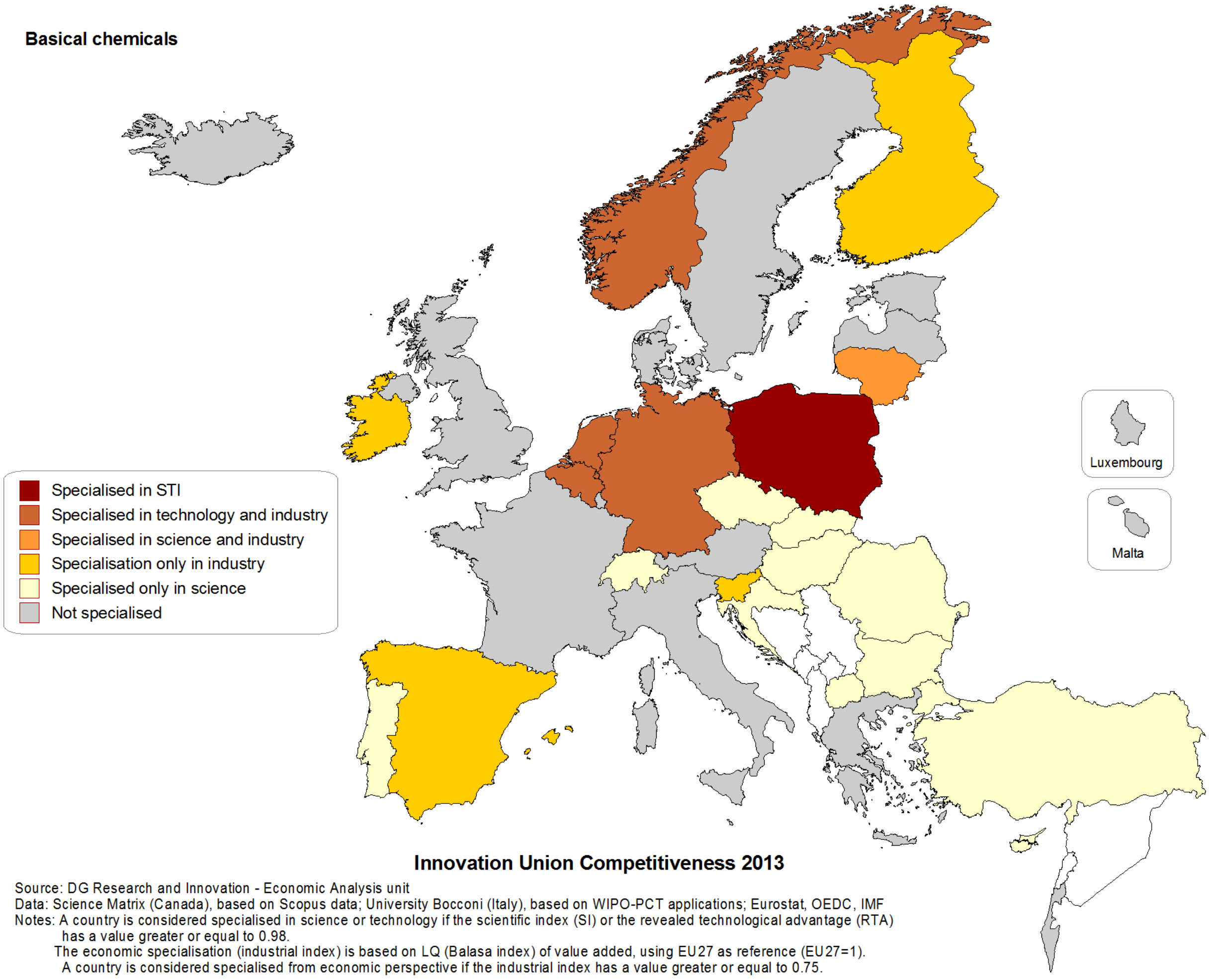


The transformation potential in this industry is substantial in the context of the transition towards a low-carbon economy. This is well reflected by the increasing development of electric cars as well as by the current focus on developing the next generation of ultra-low-carbon vehicles (e.g. the United Kingdom).

European industries for basic chemicals and plastic products present a good match but also opportunities for knowledge circulation across European countries

In a global environment, Europe is strongest in medium-tech sectors, among them the chemical industry (medium-high-tech) and plastic products (medium-low-tech). Several European countries are specialised in one or several sub-sectors of chemical industry. A knowledge-based chemical industry has a long presence in Europe, having originated in the second industrial revolution. Therefore, over time a good match has emerged, linking industrial specialisations to related knowledge specialisation in S&T.

Figure II.5.16. Specialisation profiles in European countries in the basic chemicals industry

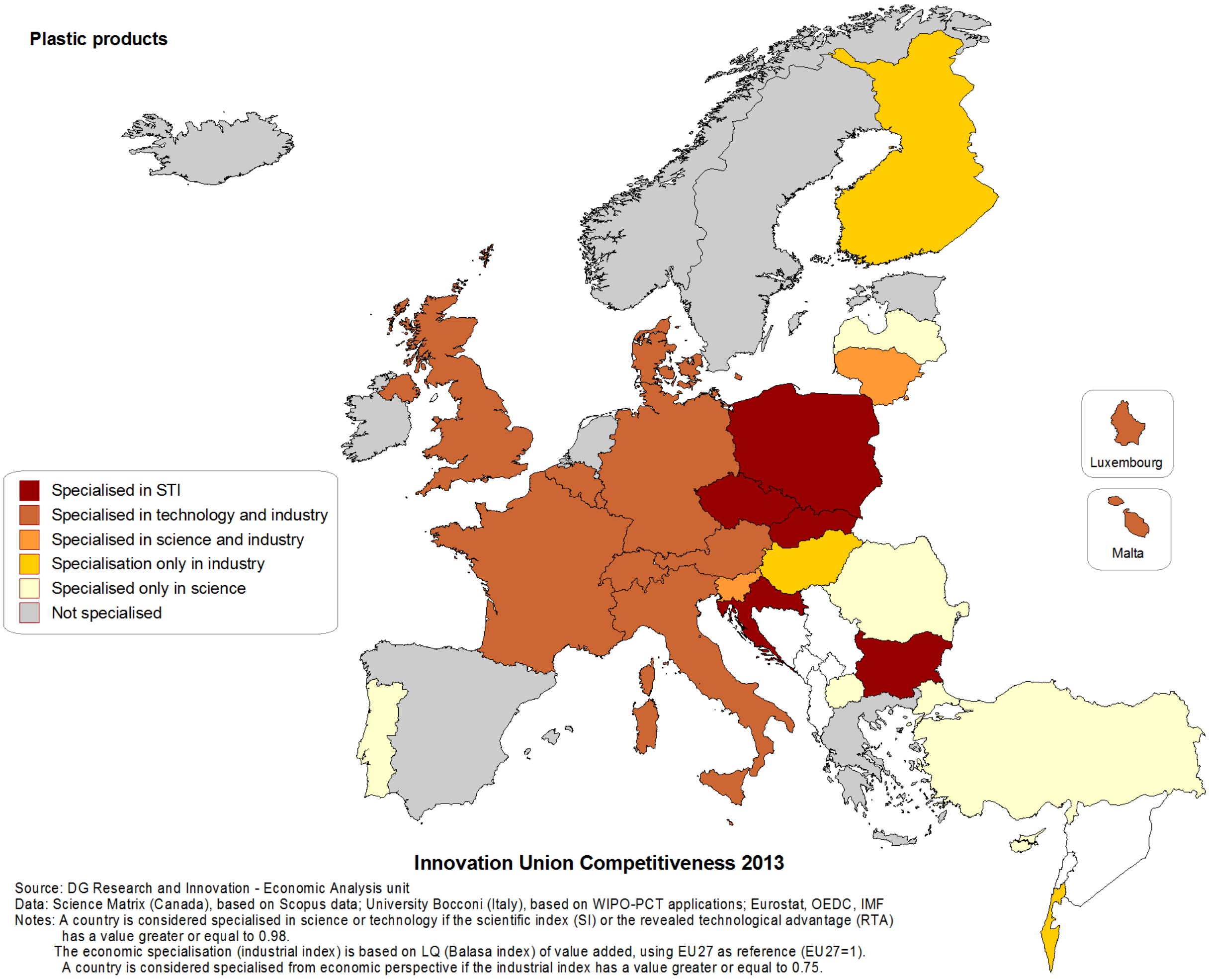


The strongest match in the field of basic chemicals (figure II.5.16) is found in Poland, followed by Germany, the Netherlands, Belgium and Norway in terms of technology and industry. It is noteworthy that science in the field of basic chemicals shows strong specialisation in Eastern Europe, in countries such as the Czech Republic, Slovakia, Hungary, Romania, Bulgaria, Turkey and Croatia. The current challenge for these countries is to enhance their scientific quality, including in related and emerging fields such as science for nanotechnologies, materials and environmental technologies. On the other hand, Spain, Ireland, Finland and Slovenia all have the potential to reinforce their scientific and technological specialisation in fields relevant for the knowledge needs of the basic chemicals industry. This would facilitate an upgrade and increased international competitiveness of this industry.

In the field of plastic products, the strongest matching is found in Poland, the Czech Republic, Slovakia, Croatia and Bulgaria, with an overall higher specialisation in science towards the east and a greater specialisation in technology spread across Europe.

There are also opportunities for economic impact of knowledge flows across Europe. For example, Portugal shows a scientific specialisation in science related to both industrial segments of basic chemicals and plastic products, while it has no corresponding industrial specialisation. This absorptive capacity is found in other larger European countries like Italy and Germany. However, this would imply support to science–industry links across countries. Similar knowledge flows can be enhanced between neighbouring countries, such as between Latvia and Lithuania, or between Hungary and Austria.

Figure II.5.17. Specialisation profiles in European countries in the plastic product industry



For more transformative knowledge sources related to the chemicals industry, such as nanotechnologies, materials and environmental technologies, there is also scope for value added from European knowledge circulation. Scientific excellence in these fields is partly found in countries lacking industrial specialisation in chemistry, such as Sweden and the United Kingdom. Given the high performing innovation system in these two countries, there is potential for industrial renewal and creation of firms, but this process would benefit from an early and strong international outreach linked with the specialisation profiles and larger firms in other European countries.

III. Transform:

Innovation for growth and jobs

Structural change for a more knowledge-intensive European economy

Highlights

Structural change is essential for productivity growth and competitiveness

There is a correlation between research and development (R&D) intensity and total factor productivity growth. There is also a correlation between R&D intensity and technology success in global competition. A structural change towards a more knowledge-intensive economy in Europe is therefore crucial for maintaining medium-term competitiveness and for preserving high-quality jobs and innovation in Europe. Currently, the European Union (EU) economy is less knowledge intensive than those of the United States and Japan, whereas the Chinese economy is progressing rapidly towards higher knowledge intensity.

There are indications that EU Member States, in particular eastern and southern European countries, are making progress to upgrade the knowledge-intensity of their economies

The overview of this chapter indicates that almost all European countries may have managed to transform their economic structures to some extent over the last decade. This transformation trend is visible in the business sector. Some very knowledge-intensive countries in Europe have been successful in pursuing this upgrading, but other knowledge-intensive Member States have tended to lose momentum.

The economic transformation is particularly noticeable in eastern and southern European countries, indicating a possible catching-up process in terms of the knowledge-intensity of their economies. Simultaneously, eastern European countries are shifting towards a greater weighting for services in their economies.

Some Member States need to upgrade their industries while others need to stimulate new knowledge-intensive sectors

European countries are faced with different options for transforming their economies. Some have the leeway to upgrade with more knowledge and R&D in existing industries without having to significantly modify the sectoral composition of their economies. Others may progress in both directions, enhancing the framework conditions for corporate growth strategies based on R&D investments while supporting fast-growing firms in emerging and knowledge-intensive sectors, thus transforming the sectoral composition of the economy. Yet other countries are characterised by a very high service base in their economies, calling for a policy mix of knowledge upgrading combined with service innovation.

Introduction

The concept of structural change refers to the long-term dynamics of the economy, through which the types and nature of existing production, consumption and trade transform through the integration of higher levels of knowledge.[116] Previous chapters of the Innovation Union Competitiveness (IUC) report have presented Europe's increasing efforts to accumulate knowledge in a broad sense, in human resources, science and technology for innovation. Investments are growing; efficiency is enhanced by reforms at national and European levels, backed up by framework conditions for a better dissemination of this knowledge throughout the economy.

However, this report has also shown how other world economies are making similar efforts, competing at ever higher segments of the value chain. The world knowledge economy is changing. Competition is harshening from an increasing number of players in an interconnected global economy. European countries with a high level of knowledge embedded in their economies, backed up by a competitive manufacturing sector, have suffered less during the economic crisis and recovered faster. But these countries are also challenged by the globalisation of research and innovation (R&I). If European countries are to maintain sustainable economies based on high living standards and wages, we need to be able to compete on non-cost factors pursuing a real structural change towards a more knowledge-intensive economy. This requires not only accumulation of knowledge and effective dissemination mechanisms but also relevant industry structures and business strategies demanding and using this knowledge. A competitive European economy with high-quality jobs can only be based on innovative products and services.

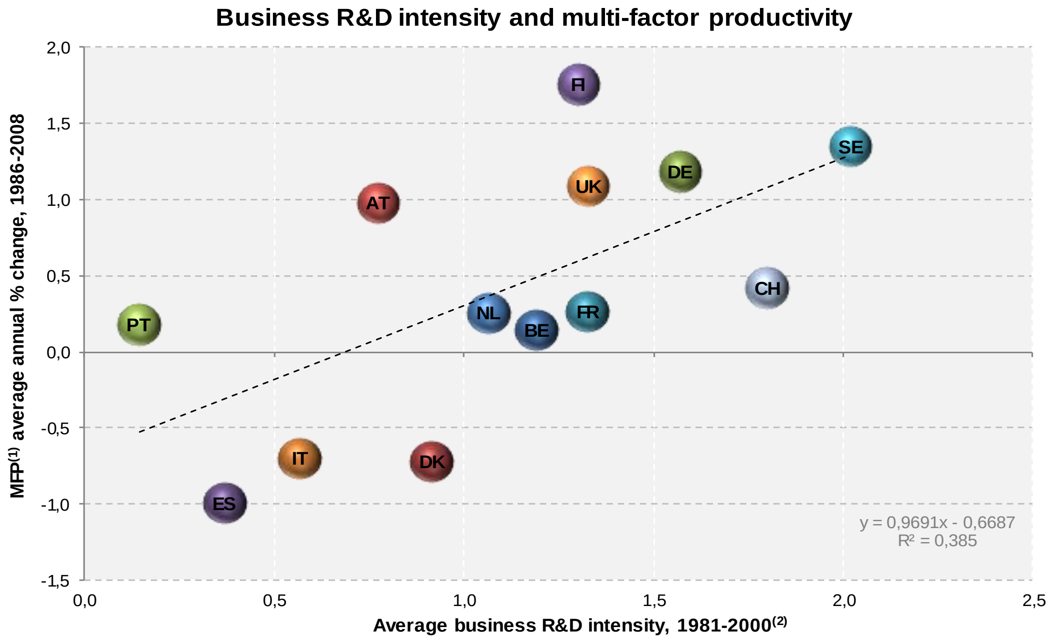
An economy with enterprises investing significantly in R&D is a more competitive economy

Business enterprise investments in R&D are associated with a higher level of productivity. Investing in R&D is part of a sustainable growth strategy to compete in the higher end of the value chains. Figure III.1 shows that countries where business R&D intensity was high over the period 1981–2000 show higher growth rates of multi-factor productivity in the period after the innovation process. Most probably, this is not a strict causality link but a comprehensive picture of the relevant factors influencing the competitiveness of modern economy. Structural change towards a more competitive economy requires a structural change in the economy towards more firms operating in knowledge-intensive product and service markets. It is an

[116] The term *knowledge-intensity* is here measured by different indicators: business R&D intensity, the KIA indicator and a new composite indicator on structural change, which includes as well trade balance data and specialisation profile of the industry. Thereby, the concept measurement provides a proxy for both the capacity of an economy to produce new knowledge-based goods and to absorb existin of new technologies produced elsewhere.

economic structure with a higher level of multi-factor productivity, competing not only with factor costs but also with knowledge in the form of R&I capabilities.

Figure III.1: Business R&D intensity and multi-factor productivity growth



Source: DG Research and Innovation - Economic Analysis unit

Data: (1) Multi-factor productivity (OECD): Dan Andrews & Chiara Criscuolo, 2013. "Knowledge-Based Capital, Innovation and Resource Allocation", OECD Economics Department Workinh Paper 1046, OECD Publishing

(2) Business R&D intensity (Eurostat): DE: 1991-2000; IT: 1990-2000; AT: 1981,1984-1985,1989,1993,1998; PT: 1995-2000; SE: 1981,1983,1985,1987,1989,1991,1993,1995,1997,1999; UK: 1981,1983,1985-2000; CH: 1981,1983,1986,1989,1992,1996,2000

This third and last part of the Innovation Union Competitiveness report therefore presents an overview of the current state of the art and dynamics of structural change in Europe. Thereafter, in subsequent chapters, it analyses more in-depth two main avenues for progress: a Schumpeterian firm renewal through fast-growing innovative enterprises, and a structural upgrading of existing manufacturing and service industries through knowledge-based innovation. Framework conditions such as innovation-driven clusters and positioning in global value chains (GVCs) are essential in this context, but the basic drivers are entrepreneurial choices and framework conditions enhancing business strategies that actively use knowledge and innovation for their long-term growth.

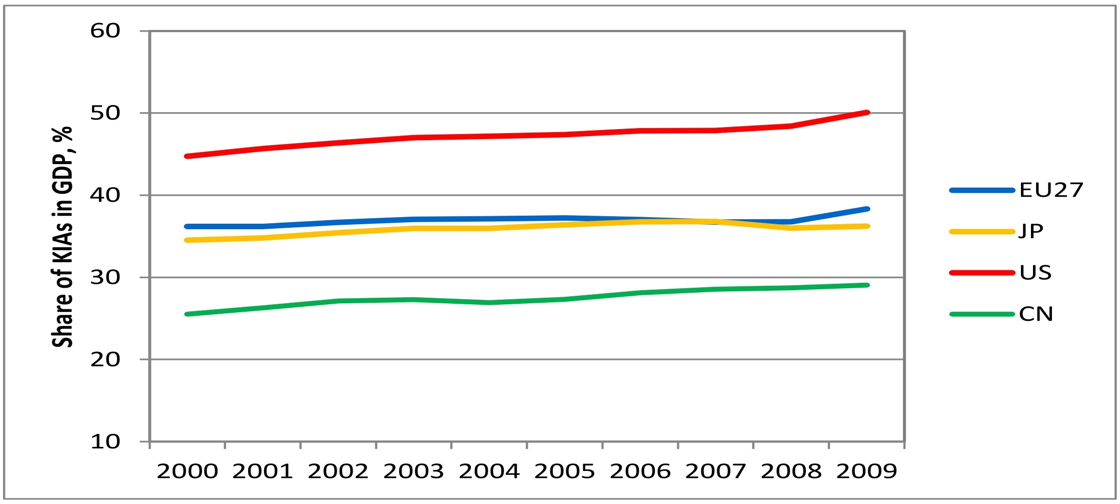
1. Measuring Europe's structural change from the perspective of different indicators

Knowledge-intensive activities (KIAs) rely on the performance of scientific and technological R&D and the exploitation of its outcomes, which requires a highly skilled labour force and capital investments. If performed successfully, they result in increased domestic and foreign competitiveness for knowledge-based goods, which is often associated with high-tech specialisation and a greater economic openness. Strong performance in all these aspects creates a mutually reinforcing dynamic that is a sustained source of growth. Monitoring structural change towards a knowledge-based economy will therefore require consideration of multiple aspects.

The EU has a less knowledge-intensive economy than the United States

The embedding of skilled and highly educated labour into the economic structure is relevant to the knowledge economy. A shift towards a greater incorporation of knowledge in the economy can be measured by the share of employment of persons having completed International Standard Classification of Education (ISCED) 5 or ISCED 6. This indicator is a proxy for firm’s and market demand for knowledge and avoids bias regarding manufacturing versus services, or technology-oriented versus non-technological innovation. It is also a useful tool to benchmark the potential of a region or country for future innovation. The weakness of this indicator is that it does not correct for over-qualifications within the workforce, which could be more important in countries hit by the economic crisis, university graduates tend to experience a high unemployment rate. Figure III.2 and Figure III.3 illustrate the EU's performance on this indicator in terms of value added. The same data can also be constructed in terms of employment ([117]). The figures show that the EU has made some progress in the past decade in increasing its share of KIAs, but not only is this share lower by more than 10 percentage points than that of the United States, it is also increasing more slowly. In other words, Europe's knowledge-intensity gap with the United States continues to grow according to this indicator, while China's knowledge intensity is expanding rapidly.

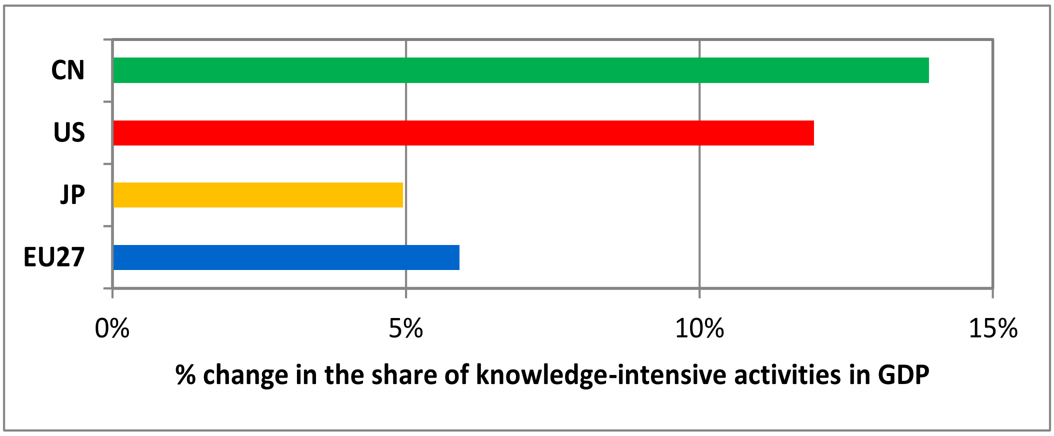
Figure III.2 Value added in knowledge-intensive activities as a % of GDP, 2000-2009



Source: DG Research and Innovation — Economic Analysis Unit; DG JRC — Ispra
Data: Computations of value added in KIA sectors by the Vienna Institute for International Economic Studies (WIIW) based on national accounts data from Eurostat, OECD, EUKLEMS, WIOD and national statistical offices.
Note: KIA sectoral definitions according to NACE Rev.2 were back-casted. Data for China excludes service sectors.

[117] Knowledge-intensive activities are defined as economic sectors in which more than 33 % of the employed labour force has completed academic-oriented tertiary education (i.e. at ISCED 5 and 6 levels). They cover all sectors in the economy, including manufacturing and services sectors, and can be defined at two- and three-digit levels of the statistical classification of economic activities.

Figure III.3 Change in the share of knowledge-intensive activities in GDP, 2000-09



Source: DG Research and Innovation – Economic Analysis Unit; DG JRC-Ispra
Data: Computations of value added in KIA sectors by the Vienna Institute for International Economic Studies (WIIW) based on national accounts data from Eurostat, OECD, EUKLEMS, WIOD and national statistical offices.
Note: KIA sectoral definitions according to NACE Rev.2 were back-casted. Data for China excludes service sectors.

Data on KIAs can also be presented in terms of share of employment. This is done in Figure III.4, showing that Europe is becoming more knowledge intensive as KIAs continue to increase (from 34.1 % in 2008 to 35.5 % in 2011). The EU is, however, still less knowledge intensive than the US and Japan, as this indicator also shows. It is important to note that this construction of KIAs in employment shows, contrary to Figure III.3, that the EU's gap with the United States is not growing. The problem is to understand the effect of the crisis, which may have led to an over-qualification of the work force in certain European countries.

Almost all European countries appears to have experienced a change towards a more knowledge-intensive economic structure, including within business[118]

Apart from Cyprus, the Netherlands, Iceland and Turkey, all European countries have registered growth in KIAs during the period 2008–2011. When considering the private sector in particular, Finland and Belgium have also experienced a slight decrease in knowledge intensity. Among the highly knowledge-intensive countries, Denmark has achieved the highest average annual growth rate over the period 2008–2011. France has also achieved high growth in its business industries. The growth in KIA employment is particularly strong in the eastern European countries and the countries severely affected by the economic crisis, such as Ireland, Spain, Portugal and Greece. Average annual growth rates range between 2.2 % for Greece and 4.7 % for Ireland, with Portugal and Spain registering an average growth of 2.8 % and 3.9 %, respectively. These findings must be handled with care and compared to other indicators on structural change, as unemployment in these countries more severely touches

[118] A complete assessment of structural economic transformation must consider also growth in absolute values of highly-skilled manufacturing and services. The positive evolution visible in the indicators presented in this chapter should be interpreted with care as they may also be due to a relative decrease of medium- and lower-skilled industries in the wake of the crisis.

non-skilled workers and also leads to labour market pressures forcing over-qualification. Nevertheless, these trends of catching-up in terms of knowledge intensity are also confirmed by other complementary indicators on structural change, as seen subsequently.

Figure III.4: Structural change measured by Knowledge-Intensive Activities

Table III.3.1 Employment in Knowledge Intensive Activities (KIA) as % of total employment, 2008-2011

	Total					Business industries				
	2008	2009	2010	2011	Average annual growth (%) 2008-2011 (1)	2008	2009	2010	2011	Average annual growth (%) 2008-2011 (1)
Belgium	41,2	41,4	41,9	41,5	0,2	14,9	14,5	14,6	14,8	-0,2
Bulgaria	25,4	25,9	26,2	26,1	0,9	8,2	8,6	8,6	8,4	0,8
Czech Republic	28,1	29,2	30,3	30,6	2,9	11,2	11,3	11,8	12,3	3,2
Denmark	36,3	38,6	39,5	39,2	2,6	14,8	15,3	15,8	15,6	1,8
Germany	36,5	37,5	37,2	37,4	0,8	14,9	15,5	15,3	15,1	0,4
Estonia	28,5	31,8	32,4	32,0	3,9	9,4	10,2	9,8	10,7	4,4
Ireland	37,5	40,9	42,8	43,1	4,7	18,1	19,2	19,5	19,8	3,0
Greece	31,5	31,6	32,3	33,6	2,2	10,8	10,8	10,9	11,3	1,5
Spain	28,6	30,3	31,4	32,1	3,9	11,8	11,8	11,5	11,8	0,0
France	38,7	39,2	39,1	39,6	0,8	13,4	13,7	13,8	14,4	2,4
Croatia	26,4	27,4	28,6	28,9	3,1	9,5	9,3	9,9	10,3	2,7
Italy	33,0	33,0	33,0	33,1	0,1	13,6	13,5	13,7	13,4	-0,5
Cyprus	35,1	33,8	34,2	34,9	-0,2	14,9	14,2	14,4	15,0	0,2
Latvia	28,6	30,1	31,0	30,1	1,7	8,2	9,2	9,6	9,1	3,5
Lithuania	29,1	31,2	32,7	32,2	3,4	7,5	8,1	8,7	9,0	6,3
Luxembourg	54,7	56,5	56,3	56,2	0,9	23,6	24,8	25,7	24,8	1,7
Hungary	33,1	33,5	34,4	34,5	1,4	12,8	12,3	12,8	13,1	0,8
Malta	38,5	38,9	39,2	40,8	2,0	15,7	16,0	15,8	16,4	1,5
Netherlands	37,3	37,0	37,0	36,8	-0,4	16,6	15,5	15,2	14,9	-3,5
Austria	34,1	35,4	35,7	34,8	0,7	13,8	14,2	14,4	14,0	0,5
Poland	26,9	28,0	28,7	28,6	2,1	8,2	8,9	9,1	9,3	4,3
Portugal	27,1	27,9	28,0	29,4	2,8	8,8	8,8	8,6	9,1	1,1
Romania	19,2	19,8	19,9	20,5	2,2	5,6	5,8	6,0	6,5	5,1
Slovenia	30,6	31,9	32,9	33,6	3,2	12,2	12,9	13,4	13,7	3,9
Slovakia	28,0	29,1	30,3	30,6	3,0	10,0	10,1	10,1	10,5	1,6
Finland	36,3	36,9	36,2	36,6	0,3	15,5	15,2	15,2	15,3	-0,4
Sweden	41,6	42,3	42,9	43,0	1,1	16,6	16,8	17,1	17,4	1,6
United Kingdom	41,1	42,9	42,5	42,7	1,3	16,8	17,5	17,0	17,6	1,6
EU27	34,1	35,1	35,3	35,5	1,4	13,2	13,5	13,5	13,6	1,0
Iceland	42,8	43,6	43,5	41,9	-0,7	18,1	18,6	18,1	18,5	0,7
Norway	37,4	38,7	38,2	39,4	1,8	13,8	14,8	14,2	15,1	3,0
Switzerland	40,2	41,9	40,4	40,6	0,3	19,5	19,9	19,8	20,0	0,8
Macedonia (2)	:	:	:	25,9	:	:	:	:	7,2	:
Turkey	:	18,4	18,3	18,1	-0,8	:	4,8	4,8	4,7	-1,0
United States	:	39,3	39,4	39,3	0,0	:	16,7	16,6	16,8	0,3
Japan	36,4	37,0	37,5	:	1,5	17,7	17,5	17,5	:	-0,6

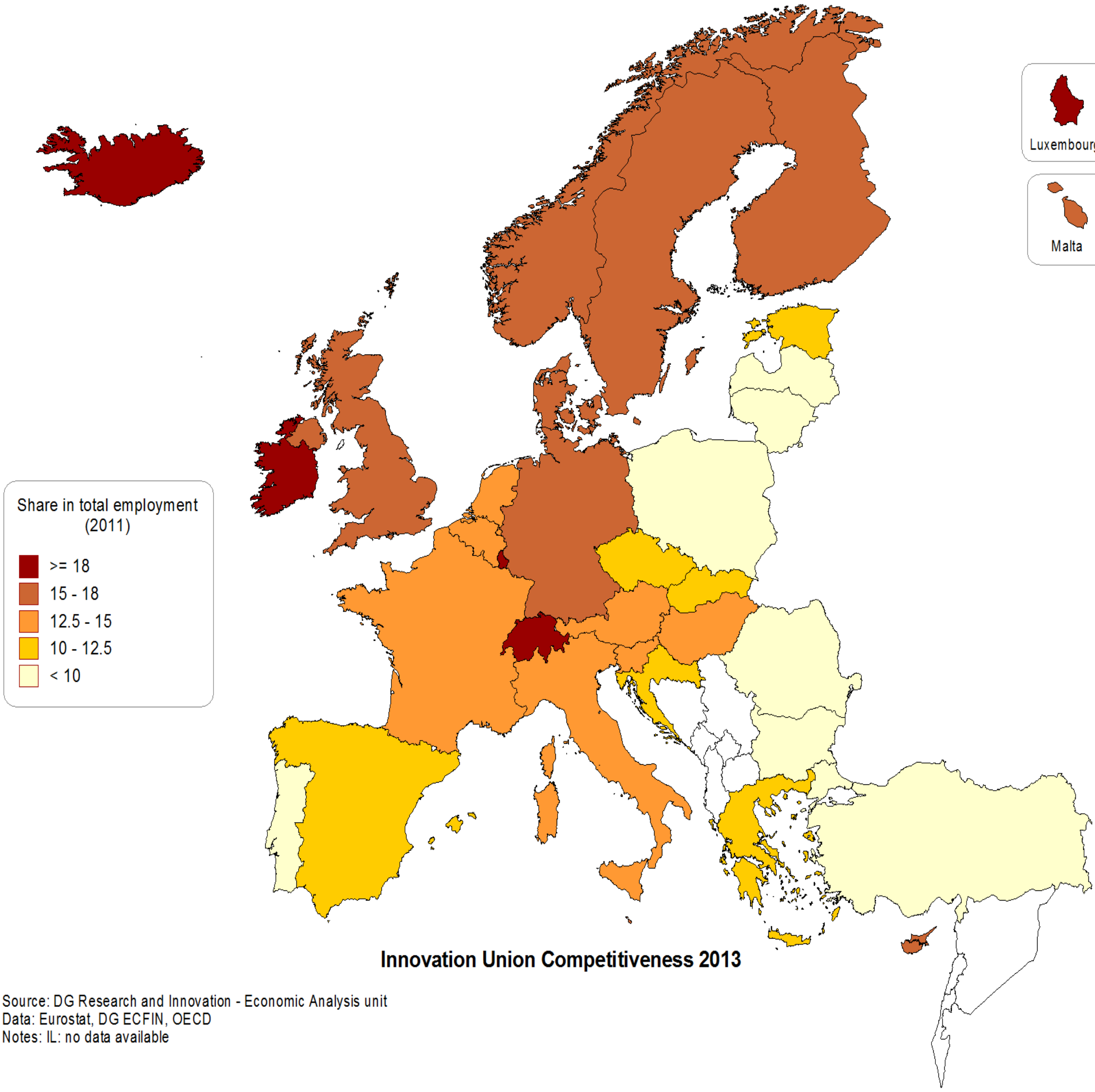
Source: DG Research and Innovation
Data: Eurostat, DG ECFIN, OECD
Notes: (1) JP: 2008-2010; TR, US: 2009-2011.
(2) The former Yugoslav Republic of Macedonia.

Given that structural change primarily refers to the economy, it is appropriate to look in particular at structure and change within the business industries (also illustrated in Figure III.5 and Figure III.6). Switzerland has the most knowledge-intensive business structure according to this indicator, followed by Iceland and Ireland. The United Kingdom and Sweden score high as well. Ireland has also strongly increased knowledge intensity for its business industries over the period 2008–2011 ([119]). Norway, France and Denmark are the knowledge-intensive economies that have achieved the highest growth in their business sector knowledge intensity. On the other hand, the Netherlands has lost part of the knowledge intensity of its

[119] These findings vary slightly depending on which indicators are used, as visible when comparing to the composite indicator on structural change presented later in this chapter.

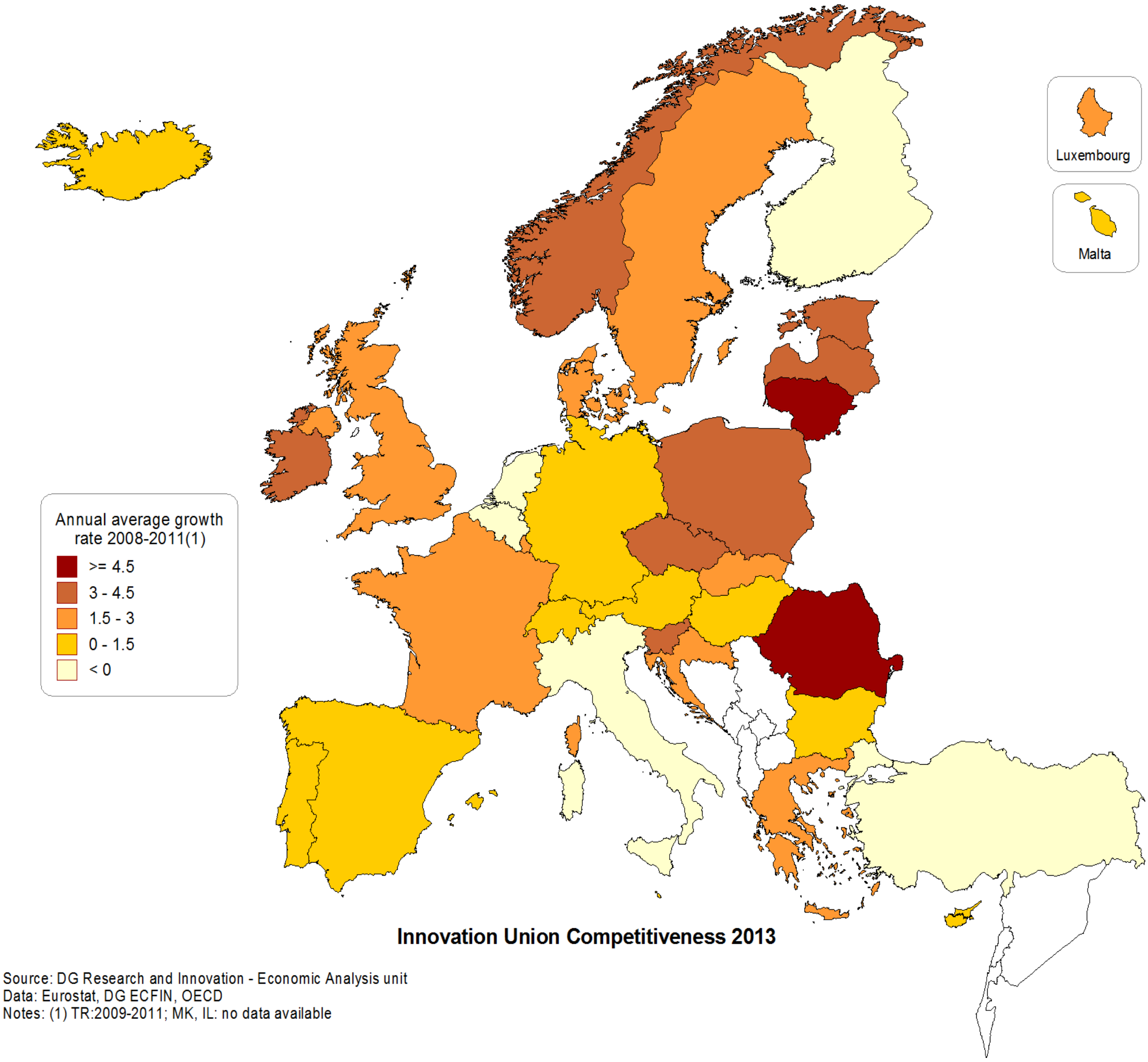
economy over the crisis period. There is positive catching-up in the business industries of most eastern European countries, in particular in Romania and Lithuania.

Figure III.5: Employment in Knowledge Intensive Activities — Business Industries as% of total employment, 2011



Source: DG Research and Innovation - Economic Analysis unit
Data: Eurostat, DG ECFIN, OECD
Notes: IL: no data available

Figure III.6: Employment in Knowledge Intensive Activities — Business industries as% of total employment, annual average growth 2008-2011



There are slightly more men than women employed in knowledge-intensive business industries

Figure III.7 presents a gender breakdown of the same indicator. It allows assessment of how the knowledge-intensive workforce is structured in terms of gender composition.

Figure III.7: Gender breakdown of employment in knowledge-intensive business industries

Employment in Knowledge Intensive Activities - Business Industries (KIABI), 2011
Total, Aggregate 1 (1) and Aggregate 2 (2) - thousands (age group 15-64)

	Total KIABI			KIABI - Aggregate 1 (1)			KIABI - Aggregate 2 (2)		
	Total	Males	Females	Total	Males	Females	Total	Males	Females
Belgium	664	378	286	593	334	259	433	252	181
Bulgaria	255	116	139	229	102	127	174	81	93
Czech Republic	594	315	279	503	268	235	384	218	166
Denmark	412	237	175	363	210	153	280	168	112
Germany	5865	3250	2614	5233	2867	2366	3959	2256	1702
Estonia	63	30	33	53	25	28	42	22	21
Ireland	356	204	152	301	169	131	209	128	80
Greece	456	255	201	433	242	192	319	183	137
Spain	2121	1199	923	1991	1119	872	1556	879	676
France	3674	1982	1692	3387	1812	1575	2515	1424	1091
Croatia	148	76	72	132	64	68	98	54	44
Italy	3028	1771	1257	2774	1595	1180	2127	1234	893
Cyprus	58	26	33	57	25	32	37	17	20
Latvia	75	32	43	73	31	42	56	26	30
Ltihuania	109	46	63	102	43	60	85	38	46
Luxembourg	55	34	21	55	34	21	27	17	10
Hungary	493	252	241	369	189	180	277	155	121
Malta	27	16	11	23	14	9	17	11	6
Netherlands	1228	762	466	1168	720	448	944	589	355
Austria	569	314	255	522	284	238	373	202	171
Poland	1476	704	772	1312	611	700	925	481	444
Portugal	415	226	189	387	211	176	283	153	130
Romania	567	285	283	480	230	250	336	179	157
Slovenia	126	65	61	110	55	54	80	44	37
Slovakia	245	118	127	204	99	105	151	82	69
Finland	372	209	162	333	184	149	283	164	119
Sweden	775	463	312	743	443	300	649	398	251
United Kingdom	4909	2928	1981	4529	2643	1886	3330	2013	1317
EU28	29134	16292	12842	26461	14624	11837	19947	11468	8479
Iceland	29	15	14	29	15	14	21	12	9
Norway	371	230	141	336	203	133	288	176	112
Switzerland	841	519	322	730	448	282	485	300	186
Turkey	1098	726	372	1004	652	352	724	495	229
Macedonia (3)	46	27	19	41	23	18	30	19	12

Source: DG Research and Innovation
Data: Eurostat
Notes: (1) Aggregate 1: KIABI excluding the following NACE Rev.2 sectors: mining support service activies (09), manufacture of coke and refined petroleum products (19), manufacture of basic pharmaceutical products and pharmaceutical preparations (21), manufacture of computer, electronic and optical products (26).
(2) Aggregate 2: KIABI excluding the following NACE Rev.2 sectors: mining support service activies (09), manufacture of coke and refined petroleum products (19), manufacture of basic pharmaceutical products and pharmaceutical preparations (21), manufacture of computer, electronic and optical products (26), products (26), financial service activities, except insurance and pension funding (64), insurance, reinsurance and penson funding, except compulsory social security (65), activities auxiliary to financial services and insurance activities (66).
(3) The former Yugoslav Republic of Macedonia.

In 2011, men were responsible for 55.8 % of knowledge-intensive activities within business industries (KIABIs) in the EU. While the balance between mean and women is similar in most Member States, there are some exceptions, as in the cases of Bulgaria, Estonia, Cyprus, Latvia, Lithuania, Poland and Slovakia, where women represent a higher share of KIABI than the men. Among the larger Member States, gender balance in KIABI employment varies: Germany follows the EU average, with similar percentages, but the United Kingdom and Italy register more unbalanced situations, with 59.6 % and 58.5 % of men employed in KIABIs, respectively. Outside the EU, the imbalance is higher in Turkey, with men representing more than 66 % of employment in KIABIs, while for Switzerland and Norway this share is 61.7 % and 61.9 %, respectively.

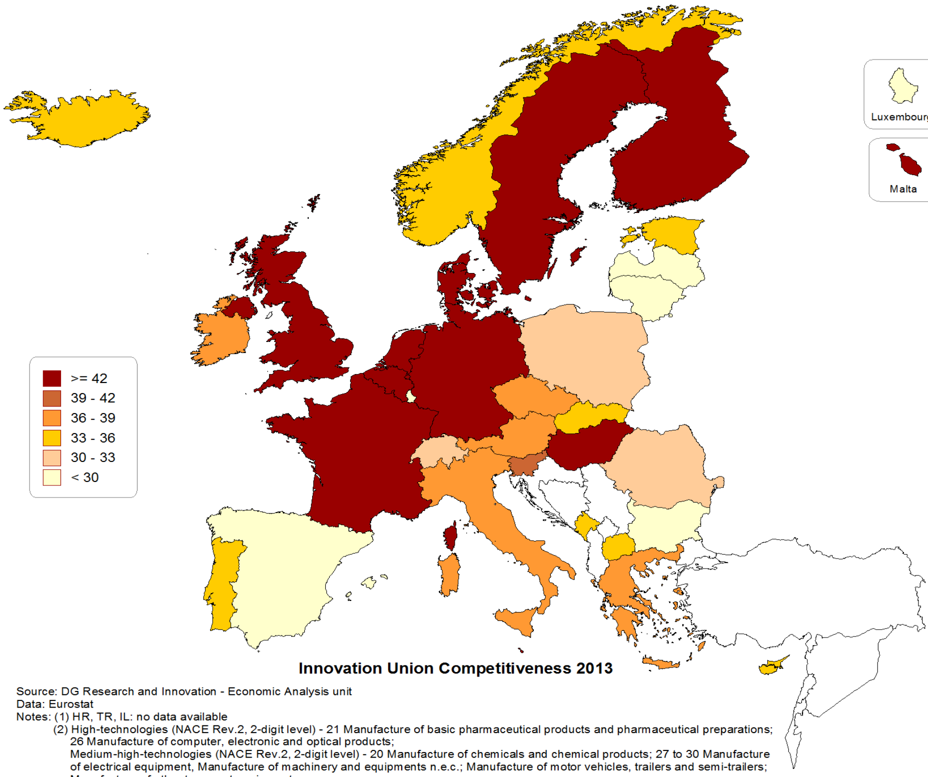
The structural change in Southern and Eastern Europe and the capacity of some knowledge-intensive economies to further upgrade are confirmed by technology-based indicators

A complementary indicator on the knowledge intensity of the economy is the Organisation for Economic Co-operation and Development (OECD) classification of high-tech, medium-high–tech and knowledge-intensive services (KISs). Like the KIA indicator, this indicator includes both manufacturing and services sectors, but with a slightly higher weight on manufacturing. However, the main difference is that this latter indicator gives higher importance to technology production capacity, while the KIAs indicator also includes knowledge capacity embedded in capital acquisition ([120]). The maps in Figure III.8 and Figure III.9 illustrate this indicator constructed on the base of value added, not employment as the previous presentations of the KIAs indicator. This allows a complementary and more solid interpretation of the knowledge intensity and structural change in the countries struck hardest by the economic downturn; the possible bias of higher unemployment rates should not affect this indicator.

In this context, Figure III.8 also highlights a structural change in Spain, Romania, Cyprus and Slovakia. There is also a relatively marked structural change in Lithuania, Estonia, Slovenia, Greece and Ireland. The strong performance of Denmark is also visible in this map, confirming the trend towards a knowledge-intensive economy that has managed to keep structural change in motion over first last three years of the economic downturn.

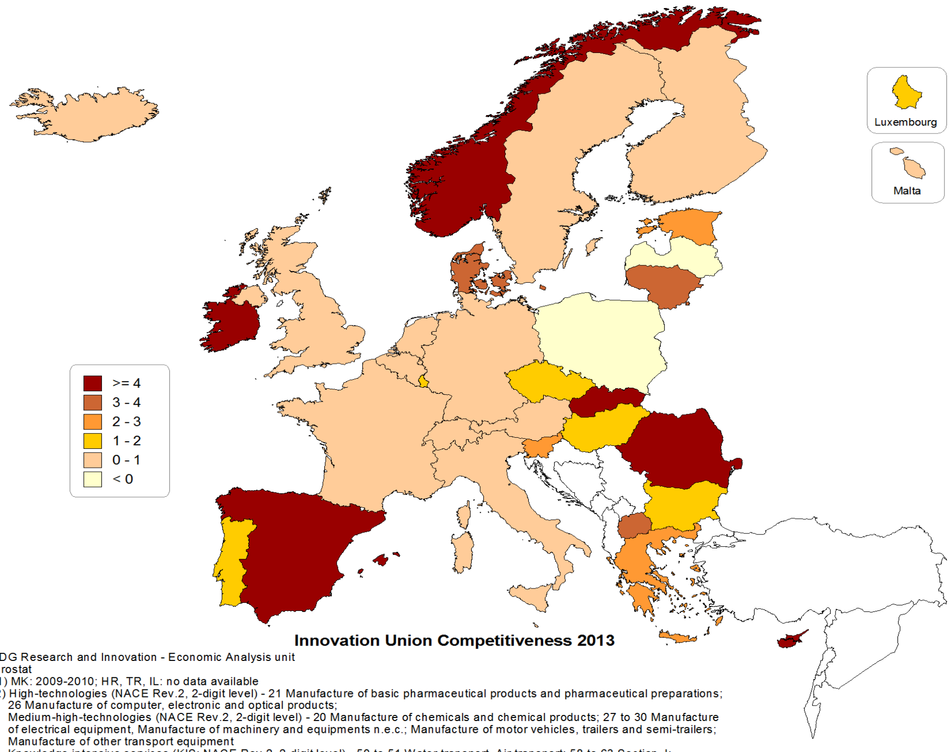
[120] European Research Area indicators and monitoring expert group report to the European Commission, 2009 (http://ec.europa.eu/research/era/pdf/era_indicators&monitoring.pdf).

Figure III.8: Value Added in high-tech and medium-high–tech manufacturing and knowledge intensive sectors (KIS) as % of total VA, 2011



Source: DG Research and Innovation - Economic Analysis unit
Data: Eurostat
Notes: (1) HR, TR, IL: no data available
(2) High-technologies (NACE Rev.2, 2-digit level) - 21 Manufacture of basic pharmaceutical products and pharmaceutical preparations; 26 Manufacture of computer, electronic and optical products;
Medium-high-technologies (NACE Rev.2, 2-digit level) - 20 Manufacture of chemicals and chemical products; 27 to 30 Manufacture of electrical equipment, Manufacture of machinery and equipments n.e.c.; Manufacture of motor vehicles, trailers and semi-trailers; Manufacture of other transport equipment
Knowledge intensive services (KIS; NACE Rev.2, 2-digit level) - 50 to 51 Water transport, Air transport; 58 to 63 Section J; 69 to 75 Section M; 78 Employment activities; 80 Security and investigation activities; 84 to 93 Sections O, P, Q and R

Figure III.9: Value added in high-tech and medium-high–tech manufacturing and knowledge intensive sectors (KIS) as % of total VA, annual average growth 2008-2011



Source: DG Research and Innovation - Economic Analysis unit
Data: Eurostat
Notes: (1) MK: 2009-2010; HR, TR, IL: no data available
(2) High-technologies (NACE Rev.2, 2-digit level) - 21 Manufacture of basic pharmaceutical products and pharmaceutical preparations; 26 Manufacture of computer, electronic and optical products;
Medium-high-technologies (NACE Rev.2, 2-digit level) - 20 Manufacture of chemicals and chemical products; 27 to 30 Manufacture of electrical equipment, Manufacture of machinery and equipments n.e.c.; Manufacture of motor vehicles, trailers and semi-trailers; Manufacture of other transport equipment
Knowledge intensive services (KIS; NACE Rev.2, 2-digit level) - 50 to 51 Water transport, Air transport; 58 to 63 Section J; 69 to 75 Section M; 78 Employment activities; 80 Security and investigation activities; 84 to 93 Sections O, P, Q and R

Some countries have margins to increase their R&D intensity within the existing industry structure; others are confronted with the need for a simultaneous structural transformation

In terms of mobilising R&D for a more sustainable knowledge economy, European countries face different situations and policy options. Some countries have margins to increase their R&D intensity within the existing economic sector structure ([121]), while others need to simultaneously push through complementary policy measures to change the very sector composition of their economies, favouring industry segments in which demand for research and skilled labour is high. Yet other countries have chosen to move further towards a service-based economy, combined with very open economies. The competitiveness of these economies is less prominent in terms of R&D intensity and more visible through other knowledge-intensive innovation indicators ([122]). However, given the determined upgrading of R&D investments in all Asian and other emerging economies, even advanced service-based economies probably need to be backed up with R&D centres and industrial R&D investments if they are to be sustainable and competitive in the long term.

In this respect, Figure III.10 presents, on the horizontal axis, the presence of economic sectors generally considered as providing a higher value added for the economy; that is, high-tech and medium-high–tech manufacturing and KISs. On its vertical axis, Figure III.10 gives complementary information on the business enterprise research and development (BERD) intensity of the economy, defined as business expenditures on R&D as percentage of gross domestic product (GDP). The most knowledge-intensive economies in this respect are some of the Nordic countries: Finland, Sweden and Denmark as well as Switzerland, large countries Germany and France, then Austria and Belgium, and also central and eastern European countries, such as Slovenia and Estonia.

Figure III.10 can be used to analyse two avenues to a more R&D-intensive economy ([123]). In broad terms, countries on the left-hand side need to increase their share of high-tech, medium-high–tech manufacturing and KIS sectors in the structure of the economy. This can be done both by promoting policies aiming to intensify the knowledge transfer from science to economy in sectors where the science and technology (S&T) capabilities are strong at national level, but also by attracting foreign direct investment (FDI) for higher value-added activities. The second option is particularly important for countries that do not have strong S&T capabilities at home. At the same time, countries in the lower part of the graphic would need to put in place measures triggering an increase in private R&D investment. The countries in the lower right corner may be there because of the high representation of services in their

[121] Chapter III.3 presents data on this challenge in some industry sectors, showing that within the same industry segment firms in different countries can have different levels of research and development intensity, partly reflecting different business strategies and corporate cultures.

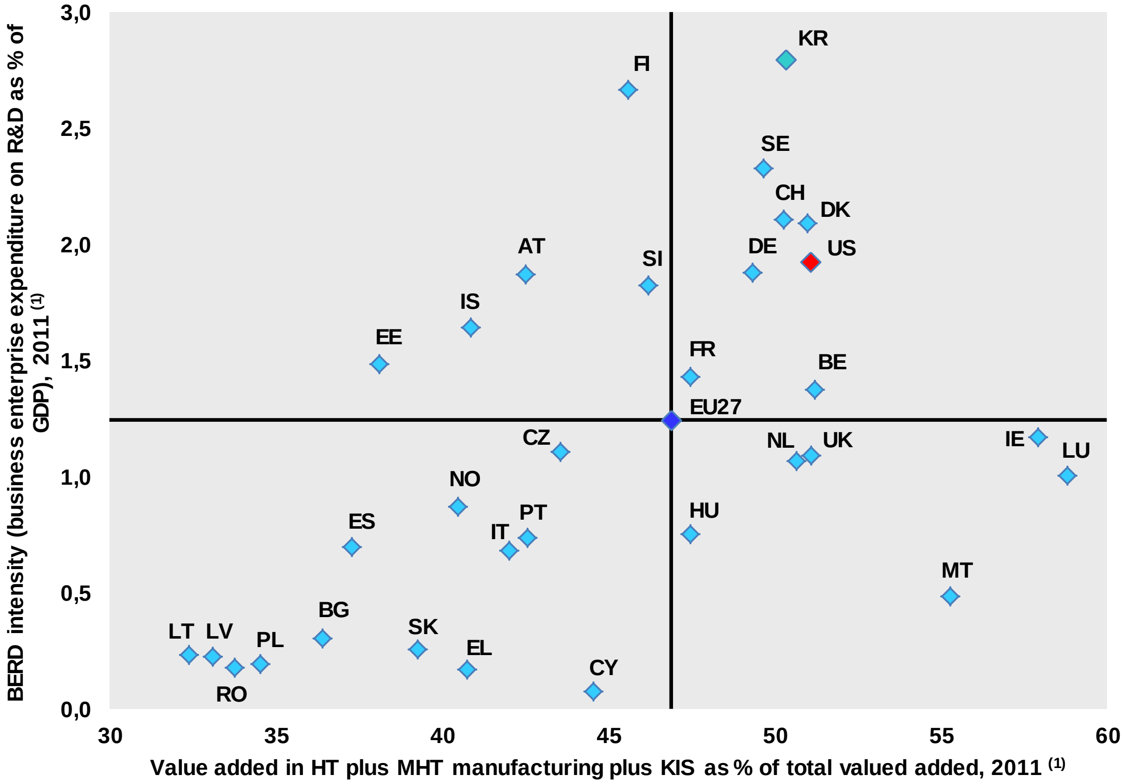
[122] Chapter III.5 presents an analysis on innovation in services, based on a recent study by the OECD, co-funded by the Directorate-General for Research and Innovation (DG RTD). Indicators on competitiveness of business services are also presented in the analysis of global value chain income, as presented in Chapter III.4.

[123] Further analysis of business enterprise investments in research and development is found in Chapter I.3.

economy (see Figure III.15). The countries in the lower left corner could benefit from changing both the structural sector composition of their economies and stimulating higher R&D intensity within firms, thus providing better framework conditions and enhancing their firms' abilities to invest in R&D as part of their growth strategies.

Figure III.10: R&D intensity and the economy's sector structure

FIGURE 8.24 Value added in high-tech (HT) and medium-high-tech (MHT) manufacturing and in knowledge-intensive services (KIS) as % of total value added and BERD intensity, 2011 (1)

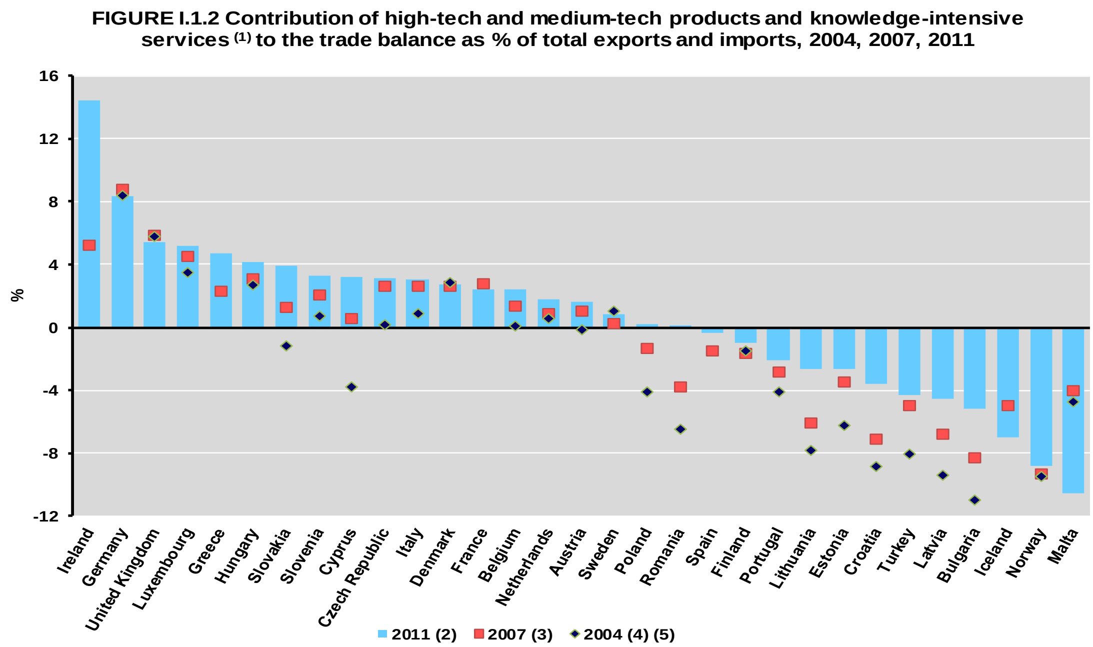


Source: DG Research and Innovation - Economic Analysis Unit   Innovation Union Competitiveness Report 2013
Data: Eurostat, OECD
Notes: (1) CH: 2008; IS: 2009; DE, IT, LV, LT, LU, PL, PT, SE, EU27, NO, US, KR: 2010.
EL: Value added in HT plus MHT manufacturing plus KIS as % of total value added refers to 2008; BERD intensity refers to 2007.
(2) IE, ES, CH, KR: Water transport, air transport, employment activities,security and investigation activities are not included.
(3) LU: Water transport, air transport, and employment activities are not included.
(4) MT: Air transport is not included.
(5) SE: Scientific research and development is not included.
(6) IS: Water transport is not included.
(7) NO: Coke and refined petroleum products is included.
(8) US: Employment activities, and security and investigation activities are not included
(9) Elements of estimation were involved in the compilation of the data.

The contribution of knowledge-intensive goods and services to the trade balance is growing in both knowledge-intensive and catching-up countries

Another approach to measuring the knowledge intensity of an economy involves trade data. A larger contribution of knowledge-intensive goods and services to the trade balance is an indicator that measures the extent to which a country is competitive in high value-added goods and services, and the extent to which the trade balance is specialised in these goods and services. Trade in components and intermediates are growing. A full picture of the competitiveness at the higher end of the value chains therefore requires data on the GVC income of the country ([124]). Figure III.11 highlights Ireland, Germany and the United Kingdom as countries with competitive and specialised trade in value-added goods and services. Over the period 2007–2011, a structural change in the trade balance is visible in several central and eastern European countries, in particular Hungary, Slovakia and Cyprus. A reduction in the negative trade balance in knowledge-intensive goods and services is also visible in Bulgaria, Latvia, Croatia, Lithuania, and in southern Europe in Spain, Greece and Portugal.

Figure III.11: Contribution of knowledge-intensive goods and services to the trade balance



Source: DG Research and Innovation

Innovation Union Competitiveness Report 2013

Data: Eurostat, COMTRADE

Notes: (1) DK, EE, IE, EL, ES, HR, LV, MT, AT, PT, SI, FI, IS, NO, TR: Data were not available for all knowledge intensive sectors for all years.
(2) NO: 2009; EL, CY, MT: 2010.
(3) EL: 2006; SI: 2008; IS: 2009.
(4) DK, HU, PT, RO, SK, FI, TR: 2005.
(5) 2004: Data are not available for IE, EL, ES, FR, IS.

[124] See Chapter III.4.

2. Measuring structural change through a composite indicator

Structural change is complex, but can be measured through a composite indicator taking into consideration several economic dimensions simultaneously. A complex methodology of measuring such change has been developed using a composite indicator ([125]). This approach is justified given the multidimensional and complex nature of economic structural change. An expert group to the European Commission on 'Measurement of Innovation' ([126]) identified three types of indicators related to structural change: enablers, compositional variables and Schumpeterian variables. Enablers refer to the framework conditions in a country that could support or hinder novelty and variety creation by firms (i.e. business environment, attitudes to S&T or the availability of venture capital). Compositional structural change indicators measure changes in the actual sectoral composition of the economy in terms of R&D, skills, output, exports, technologies and FDI. Schumpeterian structural change indicators refer to the micro level, to the dynamics of innovation and entrepreneurship at the level of firms, technologies and markets. The group also concluded that the compositional dimension was most quantifiable and data were most 'mature', especially at the country level, as Schumpeterian dynamics often involved technology- and industry-specific qualitative changes.

Based on the shortlist of indicators identified by this expert group to measure the compositional aspects of structural change, the size of the knowledge economy can be measured across five dimensions. These express the different characteristics of a knowledge-based economy:

- Increased research intensity, as well as emergence and growth of R&D, as a specialised sector of the economy (R&D indicators);
- Increased demand for highly qualified human resources in the economy (skills indicators);
- Increased economic value creation in sectors relying on highly qualified human resources (sectoral specialisation indicators);
- Increased specialisation of countries in the development of high technologies and in exporting medium- and high-tech products (international specialisation indicators);
- Increased openness of economies in terms of foreign investments (internationalisation indicators).

Each of the five dimensions is measured by one or two indicators ([127]) at three points in time to better capture change: 2000, 2005 and 2011 (or most recent year available). Data have been collected for all EU Member States, Associated countries and key international benchmark

[125] Vertesy, D., Albrecht, D., and Tarantola, S., 2012, 'Composite Indicators measuring structural change, to monitor the progress towards a more knowledge-intensive economy in Europe', European Commission.
[126] Malerba, F., Salter, M., and Saltelli, A., 2011, 'Expert Group on the Measurement of Innovation: Indicators for Structural change', Brussels.
[127] See Methodological annex for a full list of the indicators used.

countries, such as the United States, Japan, China, Israel, Brazil, India, Russia and South Korea.

The five dimensions were computed using the arithmetic average of the normalised indicators ([128]) within each dimension ([129]). Principal component analysis confirmed that the five dimensions express multiple perspectives of the same phenomena, and could therefore be aggregated into a single composite indicator on the knowledge-based economy. When indicator scores were missing for a country, the respective averages were imputed, thus the dimensions and composite scores are based on the average of the available indicators.

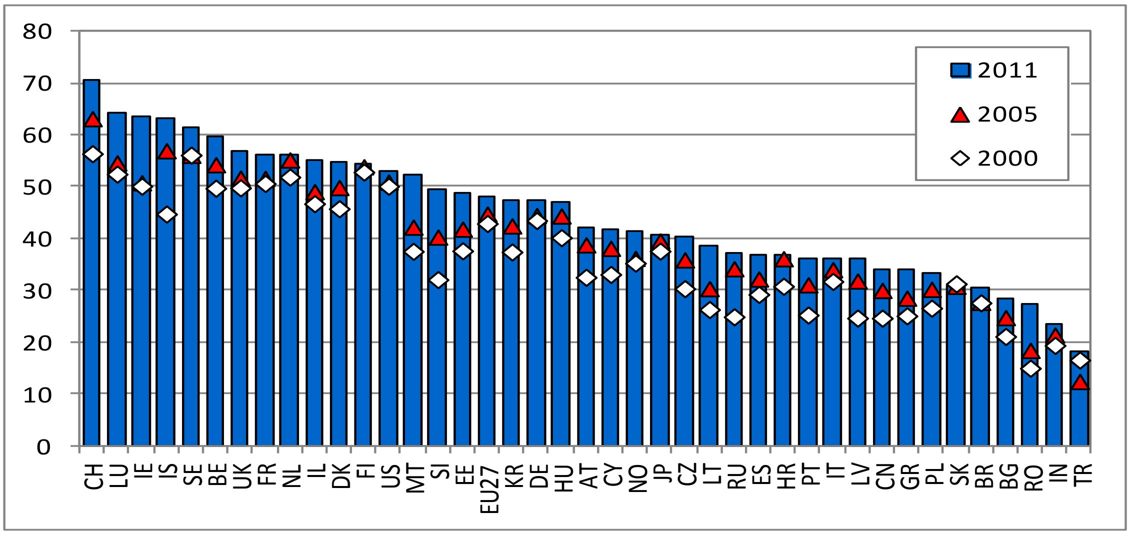
Switzerland, Luxembourg, Ireland, Iceland, Sweden and Belgium have the most knowledge-intensive their economies. Since 2000, almost all European countries have advanced towards this model.

The resulting scores are presented in Figure III.12 for three points in time. The figure shows a snapshot of the size of the knowledge economy in the countries studied, reflecting the outcome of past structural change. At the same time, past scores are also shown to put performances into perspective. Note that given the measurement and aggregation procedure, the performance scores should not be read as the size of knowledge economy, but rather as a ranking of countries. Furthermore, the large differences in the size of countries significantly influence their specialisation and internationalisation scores, which is why it is easier for smaller countries to make it to the top of the ranking.

[128] Indicators were normalised using the min–max method (between 10 and 100 in order to allow geometric aggregation), considering all three time points simultaneously to be able to meaningfully measure change over time. It should be noted that both FDI indicators were treated for the presence of outliers by winsorisation.

[129] In the case of the R&D and international specialisation dimensions, the correlation between the indicators was positive and significant, but relatively weak (0.36 and 0.33, respectively). In this way, countries performing stronger in one of the indicators in these dimensions may compensate their weaker performance in the other indicator of the dimension.

Figure III.12: Composite scores on the size of the knowledge-intensive economy, 2000-2011

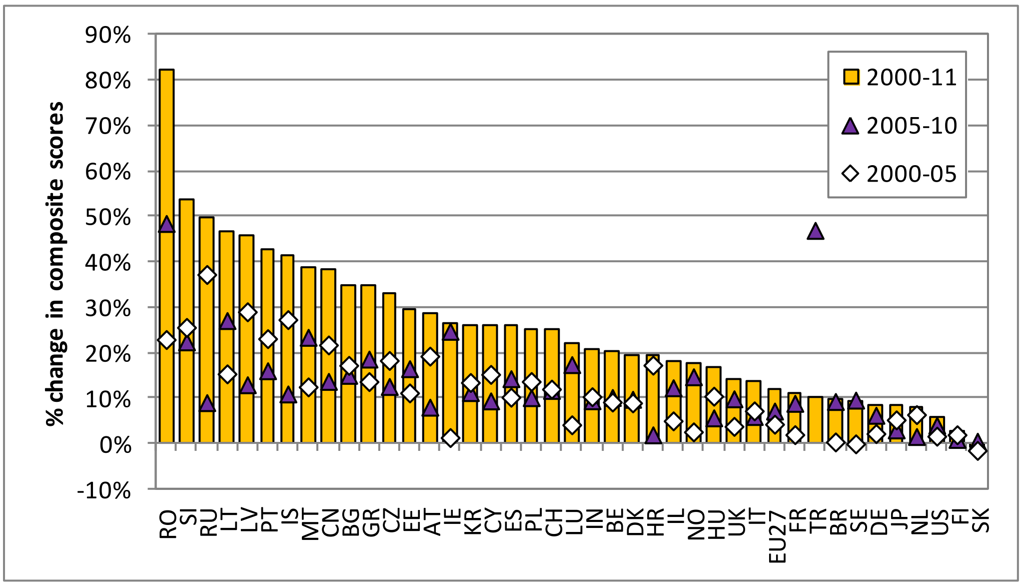


Source: DG Research and Innovation – Economic Analysis Unit; DG JRC Ispra
Data: JRC calculations

Structural change is more pronounced in eastern and southern European countries, confirming they are catching up in terms of knowledge upgrading of the economy

For a more direct illustration of structural change, Figure III.13 ranks countries based on the changes in composite scores over 5-year and 11-year periods. Looking at the graphs in Figures III.12 and III.13 together, it is clear that countries where the knowledge share of the economy increased the most were often the ones with the lowest scores.

Figure III.13: Structural change measured as change in composite scores on the knowledge economy, 2000-2011



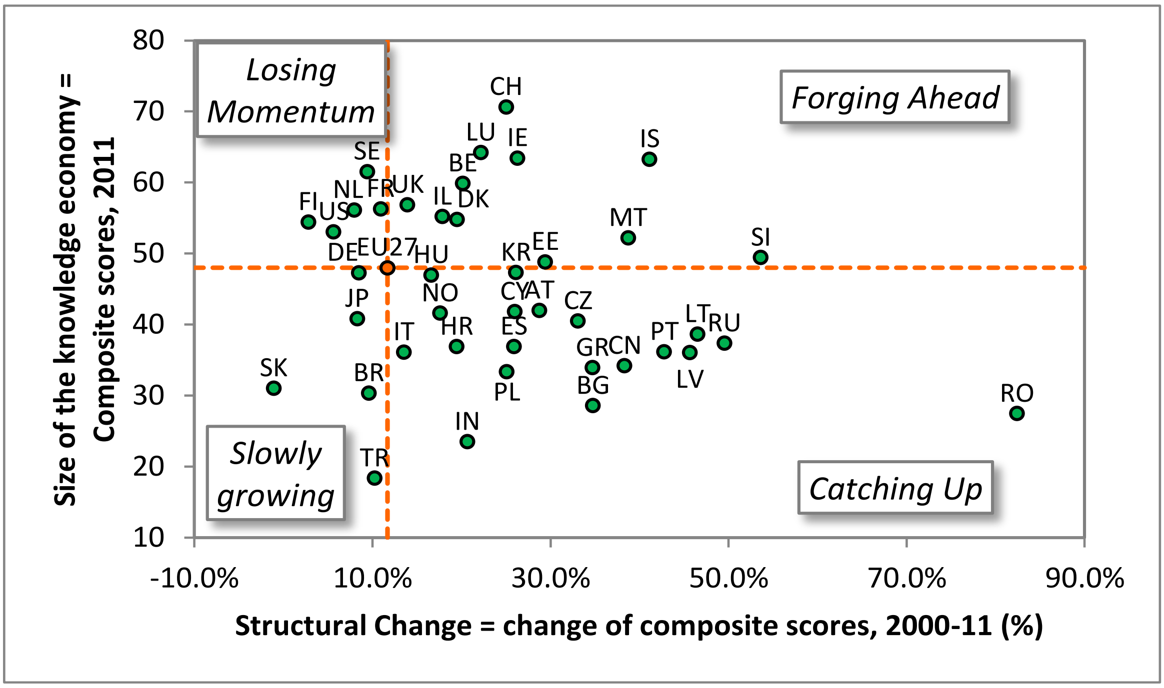
Source: DG Research and Innovation – Economic Analysis Unit; DG JRC Ispra

Data: JRC calculations

Plotting the indicators showing the size of the knowledge economy (composite scores of 2011) against structural change over the past decade (or the growth of the composite scores, 2000–2011) confirms that most of the least knowledge-intensive economies are catching up. Figure III.14 illustrates that EU Member States with relatively smaller-sized knowledge economies, such as Romania, Bulgaria, Latvia, Lithuania, but also the Mediterranean countries, have achieved greater growth than the EU in total. Among the countries that outperformed the EU in both dimensions, we find many of the smaller Member States. The country facing the most challenges in terms of catching-up is Slovakia, where the size of the knowledge economy has even been shrinking over the past decade — although the 1.5 % decline between 2000 and 2005 was reversed after 2005, and the country has achieved a modest growth of 0.5 % over the past 6 years. It is also important to note that many knowledge-intensive economies in Europe (as well as the United States) tend to lose momentum, an evolution that calls for close monitoring in the years to come.

Figure III.14: Four Quadrants Charts on Structural Dynamics

(Size of the knowledge economy, 2011 against its growth, 2000-2011)

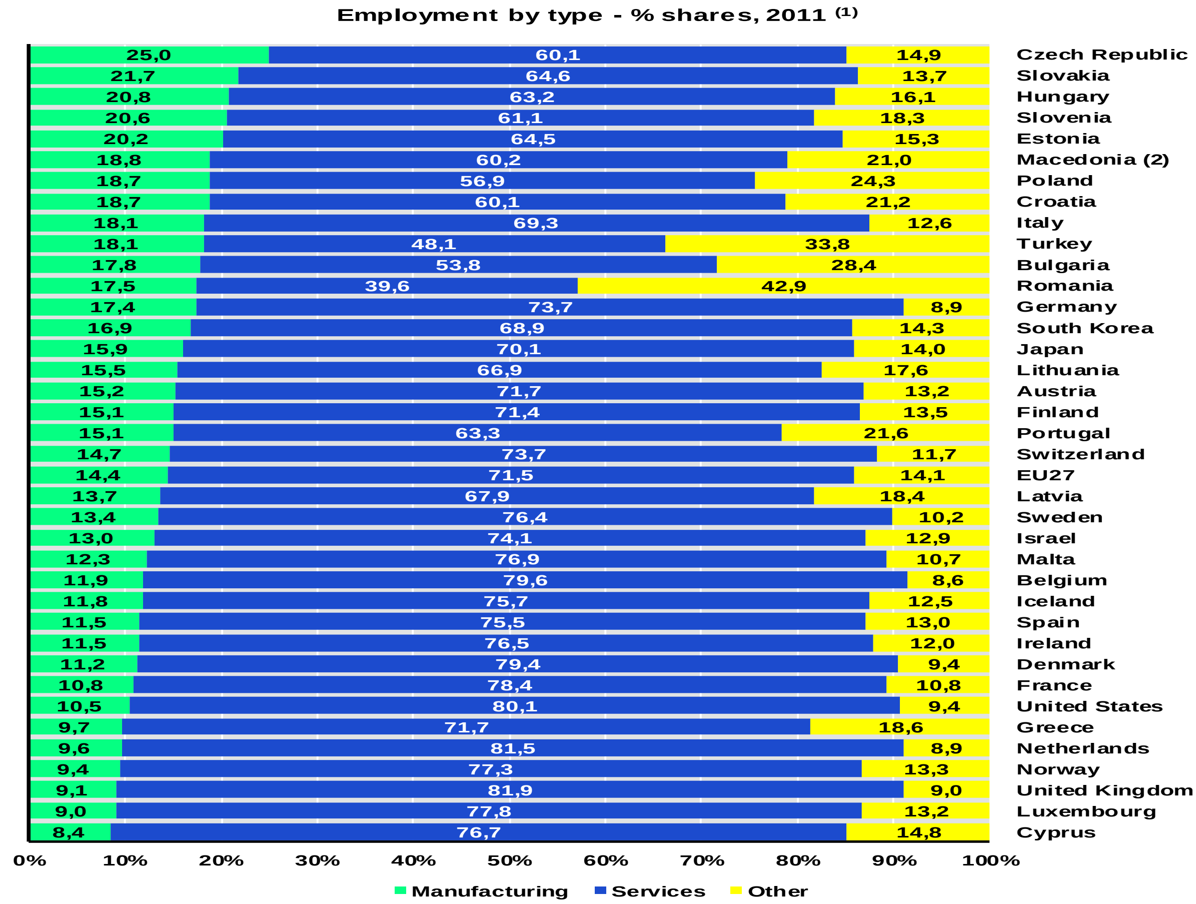


Source: DG Research and Innovation – Economic Analysis Unit; DG JRC-Ispra calculations
Note: comparison made with regards to EU weighted average.

3. Considering a move to a service-based economy

Structural change towards a more knowledge-intensive economy cannot be fully understood without looking at the simultaneous change in most European countries from an industry-based economy to a service-based economy. Given that several indicators of knowledge intensity (i.e. R&D intensity, technology intensity or trade data) are all higher in manufacturing than services, the evolution towards a service economy has an impact on how the knowledge intensity of an economy (and its competitiveness) is interpreted. It is therefore important to relate the knowledge intensity to the weight of services within the economy.

Figure III.15: Employment by type of economic sector — % shares, 2011



Source: DG Research and Innovation
Data: Eurostat, DG ECFIN, OECD
Notes: (1) HR: 2007; IL: 2008; UK: 2009; BG, PT, RO, EU27, MK, JP: 2010.
(2) The former Yugoslav Republic of Macedonia.

Employment in services is growing, and decreasing in manufacturing. However, the EU has been able to maintain a larger share of manufacturing employment than the US

The overall evolution of the EU in terms of manufacturing employment differs from that of the United States and Japan ([130]). The EU's move towards a service economy is visible when comparing the changes in the shares of the EU's employment in manufacturing (20.1 %) and

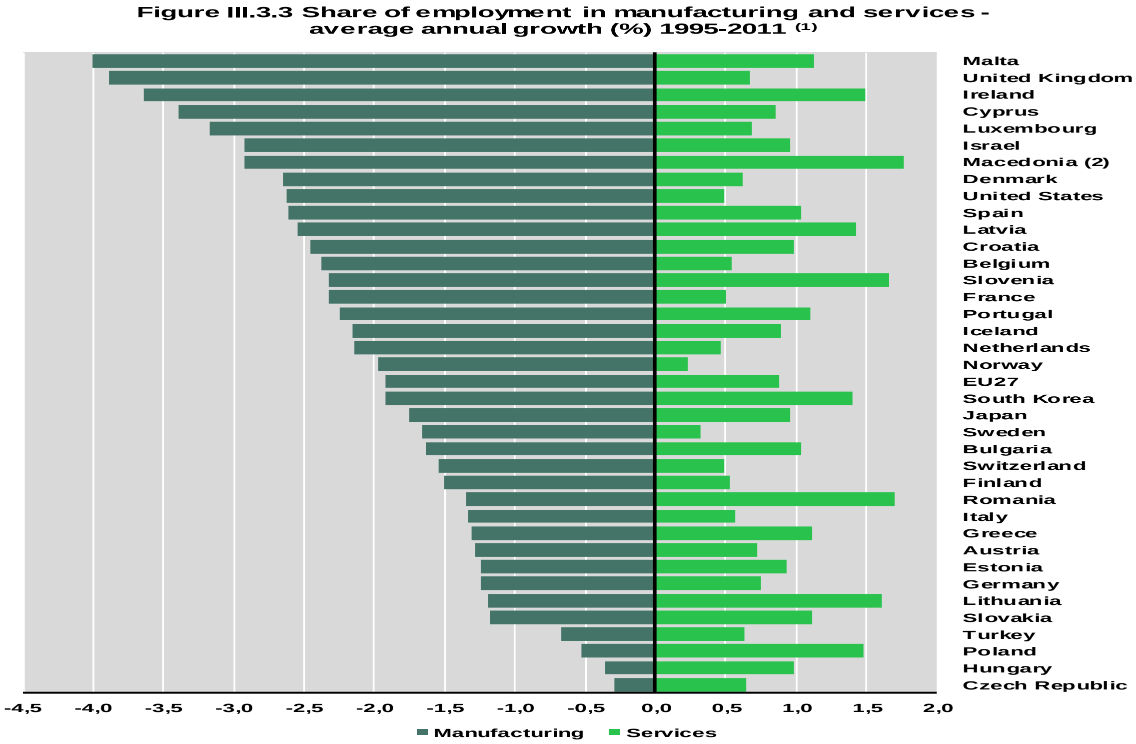
[130] This analysis is not directly presented in any figure, but the data come from Eurostat.

services (62.9 %) in 1995 to those in 2011 (14.4 % and 71.5 %, respectively). Very similar evolution is shown by the economic structure of Japan over the period 1995–2010 (2010 being the last year available), with the employment share of the manufacturing sector dropping from 20.8 % to 15.9 %, while the share of employment in the services sector increased from 60.7 % to 70.1 %. The evolution of employment in the US followed the same trend until 2009, when manufacturing began to slightly increase its share in overall employment, albeit from a lower level than the EU.

Catching-up countries in Europe in terms of knowledge intensity are simultaneously moving towards more service-oriented economies

Complementing the analysis of employment shares, Figure III.16 presents the average annual growth rates of employment in manufacturing and in services, between 1995 and 2011. All employment growth rates for manufacturing are negative, and those for services are positive. The figure indicates that the highest employment growth rates for services are taking place in catching-up countries. Employment in manufacturing has decreased the least in the Czech Republic, Hungary and Poland, and the most in Malta, the United Kingdom and Ireland.

Figure III.16: Average annual growth of employment in manufacturing and services



Source: DG Research and Innovation
Data: Eurostat, DG ECFIN, OECD
Notes: (1) IL: 1995-2008; UK: 1995-2009; BG, PT, EU27, JP: 1995-2010; HR: 1996-2007; MK: 1997-2010; IE: 1998-2011; TR: 2004-2011.
(3) The former Yugoslav Republic of Macedonia.

The following chapters provide a deeper understanding of some of the mechanisms driving a knowledge-based structural change for a more sustainable economic growth.

1. High-growth innovative enterprises

Highlights

The European Union is making progress towards an Innovation Union in spite of the economic downturn

Innovation output is crucial for productivity growth and competitiveness. The new European innovation indicator reveals that the European Union is making progress towards an Innovation Union even in the current period of economic downturn. Top innovation performers in the EU are Member States characterised by open and highly knowledge-intensive manufacturing or services sectors often coupled with strong firm dynamics in transformative technologies. Top innovation performers have a larger share of the employment in high-growth innovative enterprises (HGIEs), highlighting the key importance of this type of firm for the innovation output of an economy.

The main market for the majority of the high-growth innovative enterprises is the national market but they also tend to focus on emerging knowledge-intensive growth sectors at international level, with this level being the main market for one quarter of the high-growth innovative enterprises.

The chapter presents a first overview of the characteristics of high-growth innovative enterprises (HGIEs) based on a survey of 580 firms in four EU Member States and four non-EU Member States. According to the survey, the population of medium-sized and large enterprises is much higher than in the rest of the economy. This indicates that a critical size is helpful for accelerating growth. This shows again that policies to encourage growth should not only be focused on the early stages of firm development. Very few are spin-offs from public research. For most of these HGIEs, the national market is the main market, although they are also positioning themselves internationally. HGIEs are most frequently active in computer programming, management consulting, and architectural and engineering activities. The most cited factors for high growth in these firms are a skilled workforce and an active growth target.

Skilled labour, research and development capacities, intellectual property rights framework and entrepreneurship are highly relevant for HGIEs

Asked about specific framework conditions for further innovation and growth, the majority of HGIEs see the need for public policy to improve framework conditions governing skills development, in-house research and development (R&D) and intellectual property (IP) protection. The share of respondents having received public support is much higher in the EU than in non-EU countries. The need for policy adjustments seems to be less pressing in Germany, the United Kingdom, Switzerland, the United States and Japan, than in France, Poland and South Korea. Other recommendations from the survey concerning policies to promote HGIEs are: a) focus policies on the specific needs of the country and industry concerned; b) enhance continued education for employees; and c) target high-growth consulting and coaching for entrepreneurs.

1.1. Innovation output performance in Europe — a new innovation indicator

Measuring the impact of innovation policies is vital for the development and monitoring of evidence-based policymaking. Innovation is the cornerstone of any strategy aimed at transforming an economy facing increased global competition. In order to monitor the performance and progress of each Member State and of the EU as a whole more effectively in this area of strategic importance, the European Commission has developed a new indicator for measuring innovation output.

The new innovation indicator shows that the EU is making progress towards an Innovation Union in spite of the economic downturn

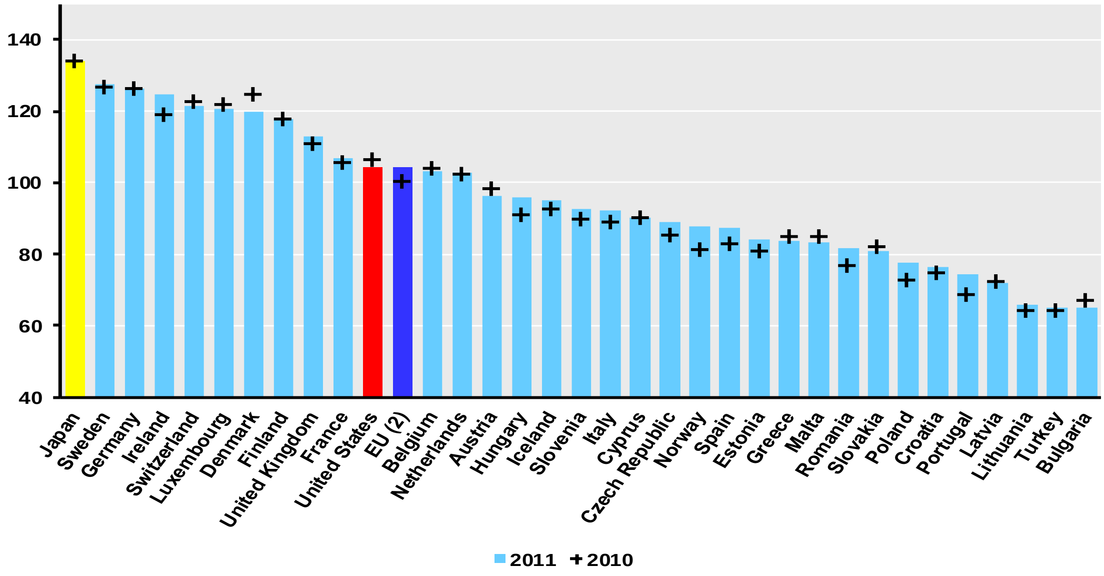
Innovation output is wide-ranging and differs from sector to sector. Measuring it entails quantifying the extent to which ideas for new goods and services stemming from innovative sectors carry economic value added and are capable of reaching the market. The new indicator is therefore based on four components: technological innovation as measured by patents, employment in knowledge-intensive activities (KIAs), the competitiveness of knowledge-intensive goods and services, and employment in fast-growing firms within innovative sectors. The indicator has been developed using international quality standards and state-of-the-art statistical analyses. Four principles are applied when identifying components and underlying data: policy relevance; data quality; international availability and cross-country comparability of underlying data; and robustness of results. [131] Results for the new innovation indicator show strong performance differences between Member States, and thus potential for peer learning, but they also show that the EU as a whole is progressing, despite the crisis. The EU appears to have increased its performance in 2011 compared to 2010.[132] Progress in this period was strongest in knowledge-intensive service (KIS) exports. Most Member States have likewise increased performance. However, given that longer time series are not yet available, it is too early to observe any trends.

Data are currently only available for some key non-European partners (Unites States and Japan) and for some Associated Countries (Switzerland, Iceland, Norway and Turkey). Japan is outperforming all EU countries and is the number one performer in the new innovation indicator. Japan performs well in all sub-indicators. It performs particularly well in the contribution of medium- and high-tech products to the trade balance and Patent Cooperation Treaty (PCT) patent applications. The United States performance is similar to that of the EU. It performs well in employment in KIAs as percentage of total employment and near the EU average for the other components.

[131] However, further refinements are needed to bring the indicator to its full potential.(EC Communication COM (2013) 624 final, “Measuring innovation output in Europe: towards a new indicator”, 2013

[132] Although the indicator refers to 2010 and 2011, a mix of different reference years has been used for its underlying components.

Figure III.1.1 The composite indicator measuring innovation output [(1)]



Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Eurostat, OECD, UNESCO
Notes: (1) EU average set to 100 in 2010. In 2011, the components reflect the situation in 2009 (PCT), 2010 (DYN) or 2011 (KIA, COMP). In 2010, they are based on 2008 (PCT), 2009 (DYN) or 2010 (KIA, COMP) data.
(2) EU does not include Croatia.

Figure III.1.2 Innovation output - performance by Member State [(1)]
(EU2010 = 100 [(2)])

	2010	2011
Sweden	126,4	127,5
Germany	125,9	126,1
Ireland	118,7	124,8
Luxembourg	121,6	120,7
Denmark	124,7	119,7
Finland	117,5	117,9
United Kungdom	110,8	112,8
France	105,5	106,7
Belgium	103,8	103,1
Netherlands	102,4	102,8
Austria	98,0	96,4
Hungary	90,9	96,0
Slovenia	89,5	92,8
Italy	89,0	92,3
Cyprus	90,1	90,3
Czech Republic	85,2	89,0
Spain	82,8	87,4
Estonia	80,5	84,3
Greece	84,7	83,9
Malta	84,5	83,5
Romania	76,8	81,5
Slovakia	81,9	81,0
Poland	72,7	77,6
Croatia	74,7	76,6
Portugal	68,6	74,3
Latvia	72,0	72,1
Lithuania	63,9	65,9
Bulgaria	66,7	64,9

Innovation Union Competitiveness report 2013
Source: DG Research and Innovation - Economic Analysis Unit
Data: Eurostat, OECD, UNESCO
Notes: (1) EU average set to 100 in 2010. In 2011, the components reflect the situation in 2009 (PCT), 2010 (DYN) or 2011 (KIA, COMP). In 2010, they are based on 2008 (PCT), 2009 (DYN) or 2010 (KIA, COMP) data.
(2) EU does not include Croatia.

Top EU performers on innovation output are characterised by open and highly knowledge-intensive manufacturing or services, coupled with firm dynamics in transformative technologies

Sweden is the top EU performer for the European innovation indicator. It shows strong performance in all components. Performance slightly improved in 2011 in comparison to 2010. Sweden performs particularly well as regards patents, where it is the second best performer in the EU. This is mostly the result of strong patenting in the information and communication technologies (ICT) sector. The Swedish company Ericsson is among the most prolific of EU companies filing for patents. Sweden also has a relatively high level of patenting in biotechnology and medical technology. Despite a strong technology orientation within the Swedish economy, the high share of wood and paper exports impacts negatively on its contribution of medium/high-tech goods to the trade balance, which is only average. Sweden performs extremely well (best performer in the EU) as regards employment in fast-growing innovative firms as a percentage of total employment in fast-growing firms. This is a result of the high share of computer programming, scientific R&D, and architectural and engineering companies (all with high innovation scores) among fast-growing enterprises.

Germany's performance is notably high on patents and on the share of medium/high-tech goods exports in trade balance, where it is the best EU performer. The good performance in patents is explained by the above average share of industries with a high patent intensity in Germany (ICT, automobile industry, medical equipment, energy technology). Companies like Siemens, Bosch and BASF are among the top patent producers in Europe. The existence of large and export-oriented automobile, other transport equipment and machinery industries also explains the high score as regards the contribution of medium/high-tech exports to trade balance. When it comes to the export share of KISs, Germany’s strong performance is explained by the fact that it is an important hub for knowledge-intensive transport services, such as passenger and freight transport by air, an important software exporter, and a major exporter of research, professional and technical services. Germany also performs well as regards employment in fast-growing innovative firms as a percentage of total employment in fast-growing firms. This is a result of the high share of activities with high innovativeness scores, such as computer programming and information service activities, among fast-growing firms.

Ireland is one of the top performers for the European innovation indicator. It ranks third in the EU after Sweden and Germany. This is a result of good or very good performance for all of the indicator’s components with the exception of patent applications. Ireland performs particularly well as regards employment in KIAs, the export share of KISs, and employment in high-growth enterprises in innovative sectors as a share of employment in all high-growth firms. The relatively low performance in patents is linked to limited research capacity, the economic structure and the division of work within international (American) companies, which have European headquarters in Ireland (contributing to value added but less to patenting). Ireland performs above the EU average in the contribution of medium/high-tech goods to the trade balance, mainly as a result of its exports of medicinal and pharmaceutical products. The strong performance in KIAs and the outstanding performance in the export share of KISs is explained by the economic structure of the country, with financial services and computing services being relatively important in the Irish economy.[133] Ireland is the largest software exporter in the world, after India (computer services exports of EUR 32 billion in 2011). Ireland performs well as regards employment in fast-growing innovative firms as a percentage of total employment in such firms. This is a result of a high share of computer programming companies among them.

Luxembourg is a top performer for the European innovation indicator. Performance is especially strong in employment in KISs and in KIS exports. As regards patents and the contribution of medium/high-tech manufacturing exports, Luxembourg's performance is however, below average and stagnating. The relatively low performance in patents is linked to the economic structure of Luxembourg, which has a relatively small capital goods sector, limited research capacity and lack of large manufacturing companies, which are typically very active in patenting. The large international companies headquartered in Luxembourg conduct large parts of their research and patenting outside the country. Luxembourg has by far the best scores among all Member States as regards share of knowledge intensive services in services export as well as employment in KIAs (nearly twice the EU average). This is due to very strong specialisation in the financial services sector, which has been Luxembourg's main growth engine since the early 1980s and which has a very high innovation coefficient. The fees earned by asset managers alone constitute around half the total (goods + services) of Luxembourgish exports. Apart from the strong financial sector, others, such as insurance, communication (Voice over Internet Providers), satellite operators, and air freight transport services contribute to the high share of KISs exports (the highest in the EU). Luxembourg has only a small technology-intensive manufacturing sector (manufacturing represents only 6.5 % of total value added, the lowest share of all EU Member States). The contribution of medium/high-tech goods to the trade balance is hence low.

Innovation output is closely associated with fast-growing innovative enterprises

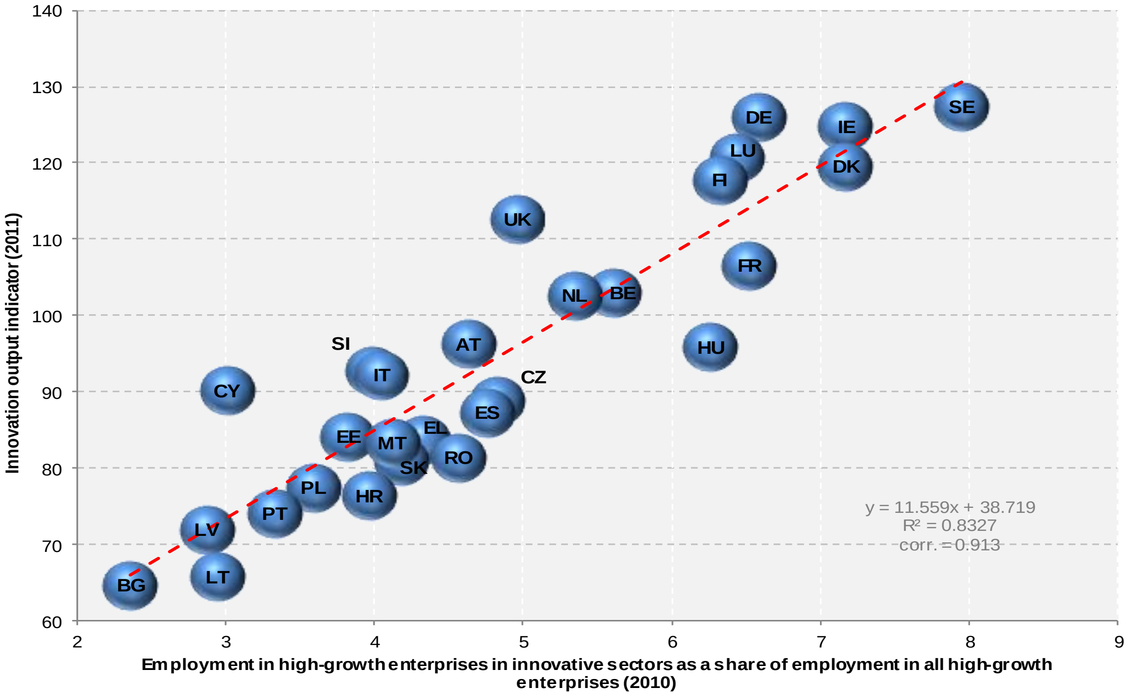
As indicated above, the new European innovation indicator is constructed around four pillars: technological innovation as measured by patents, employment in KIAs, the competitiveness of knowledge-intensive goods and services, and employment in fast-growing firms of innovative sectors.[134] While the second and third pillars are more structural, the first and fourth are also underlying drivers in a Schumpeterian transformative mode. Given that the top performers for the European innovation indicator combine manufacturing and services or evolve towards a predominant service economy, the fourth pillar is particularly relevant since it covers firm growth dynamics in innovative sectors, which can be both manufacturing and

[133] The OECD 2013 economic survey of Ireland suggests that Ireland's innovation capacity should be assessed with care. The high value of indicators measuring knowledge-intensive industries or indicators measuring export share of knowledge-intensive services (mainly computer software) may be related to multinationals located in Ireland.

[134] Further refinement of the indicator will be made to bring it to its full potential. See Commission Staff Working Document, "Developing an indicator of innovation output, SWD (2013) 325 final, 13.09.2013

service sectors. Figure III.1.3 illustrates the close correlation between fast-growing innovative enterprises and overall innovation output (which in turn is closely correlated with total factor productivity growth, as seen in Chapter III.1).

Figure III.1.3: Innovation performance and dynamics of fast-growing innovative firms

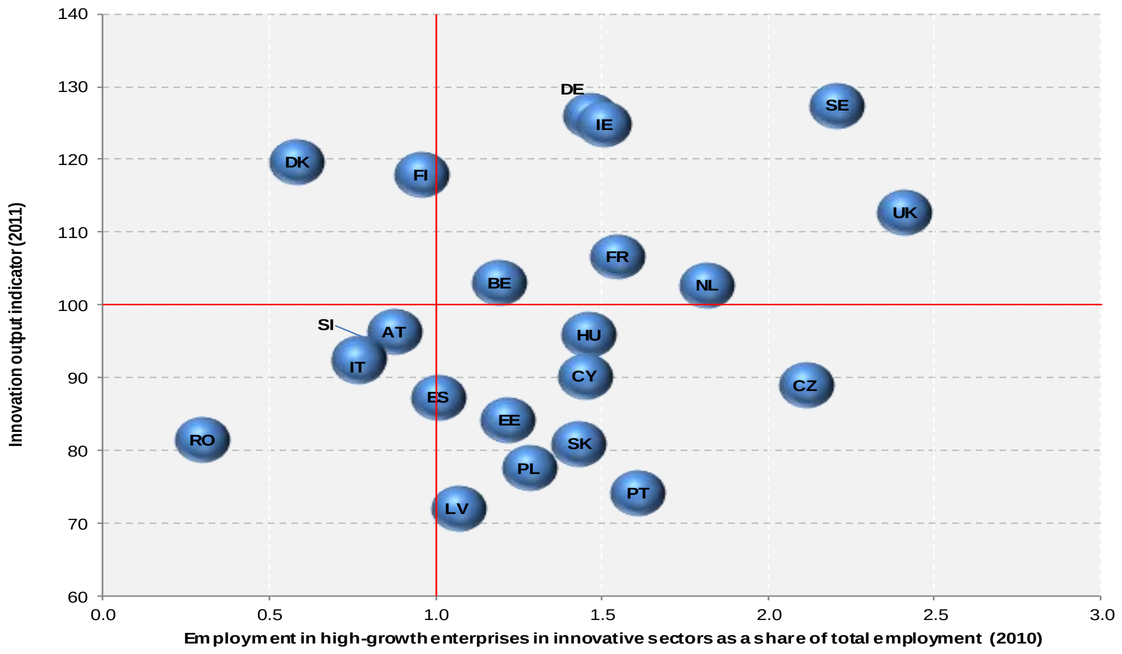


Source: DG Research and Innovation - Economic Analysis unit

Data: Eurostat

Figure III.1.4 focuses on the employment structure in innovation-driven economies. It shows that the top innovation performers have a larger share of their total employment in HGIEs. Despite their relatively small share in the economy, these firms have vigorous spillover effects spurring innovation and fostering transformation into a knowledge-based and more sustainable economy. Some countries, like Denmark and Finland, may have margins of manoeuvre to further stimulate employment share in these fast-growing innovative enterprises and thus step up from very good to top innovation performers.

Figure III.1.4: Employment structure and innovation performance



Source: DG Research and Innovation - Economic Analysis unit
Data: Eurostat

1.2. General characteristics of high-growth innovative enterprises

Which then are these high-growth innovative enterprises? Some general features can be identified, although there is still a lack of knowledge about the precise characteristics of HGIEs, the framework conditions under which they thrive, and the policies that could support their emergence and growth.

This section presents the findings of a survey and study focused on HGIEs and HGIE support policies, initiated by the European Commission's Directorate-General for Research and Innovation (DG RTD) and coordinated by Empirica ([135]). The study will be referred to as the "HGIE study". The survey encompasses a sample of 580 HGIEs in eight countries: Germany (100), France (99), the United Kingdom (84), Poland (49), Switzerland (39), the United States (150), South Korea (44) and Japan (15).

In this study, HGIEs are defined as firms belonging to 36 three-digit NACE sectors identified by the European Commission as being particularly innovative[136], whose number of employees has grown at least one third over a period of three years during the past five years.[137] So, in

[135] Policies in support of high-growth innovative enterprises, a study coordinated by Empirica Gesellschaft für Kommunikations- und Technologieforschung mbH, 2013.

[136] *i.e.* NACE Rev. 2 sectors 201, 202, 211, 212, 262, 263, 264, 265, 266, 267, 291, 303, 304, 465, 582, 601, 602, 612, 613, 619, 620, 639, 641, 643, 651, 652, 663, 701, 702, 711, 721, 722, 741, 742, 743, 749.

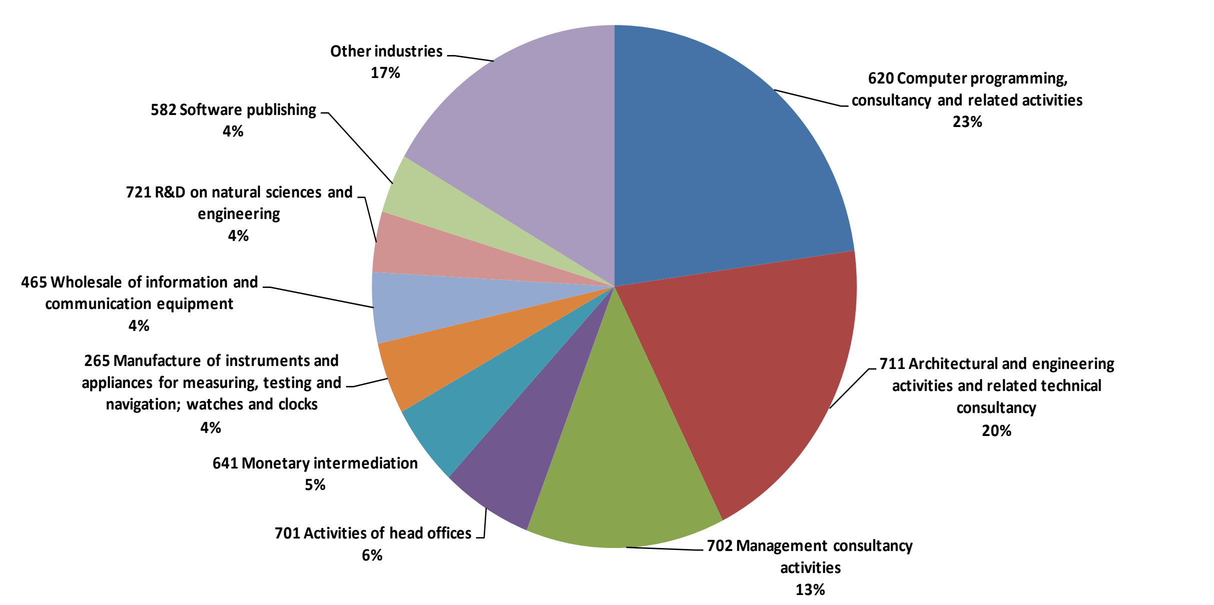
[137] For Poland, the target was revised to 22% in the past two years in order to be able to find a reasonably high number of enterprises qualifying for the survey. Only originally growing enterprises were considered; enterprises

this study, HGIEs are identified as high growth firms from innovative sectors. Their activity does not necessarily need to be technology-related (e.g. it may also be related to marketing or organisational innovation). This definition is fully consistent with the definition of HGIES used in the new innovation indicator launched by the European Commission[138] and welcomed by the European Council.[139] This section will present the characteristics of the HGIEs surveyed for this study.

Three industries are predominant among high-growth innovative enterprises

Three industries dominate the population ([140]) of HGIEs: 1) computer programming (NACE 620), 2) management consulting (NACE 702), and 3) architectural and engineering activities (NACE 711). More than half (56 %) of all HGIEs stem from these three industries. Figure III.1.5 shows the nine largest industries where HGIEs are found (all others are subsumed under 'Other industries').

Figure III.1.5: HGIEs by sector in % of all HGIEs



Source: DG Research and Innovation; HGIE study — Innovation Union Competitiveness report 2013
Data: Empirica survey HGIE, 2013
Note : "All HGIEs" refers to the all the HGIEs in the universe of enterprises in the address data from Dun & Bradstreet.

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which had grown due to mergers and acquisition were not included. The size threshold for enterprises to be included was ten employees at the beginning of the growth period. In the survey, no cases could be collected in 4 of the 36 three-digit NACE sectors identified as being particularly innovative (NACE Rev.2 sectors 619, 663, 743 and 749). The size threshold for enterprises to be includes is ten employees at the beginning of the growth period. The enterprises must not, during the past five years, have acquired other companies or have merged with another company.

[138] COM (2013) 20.

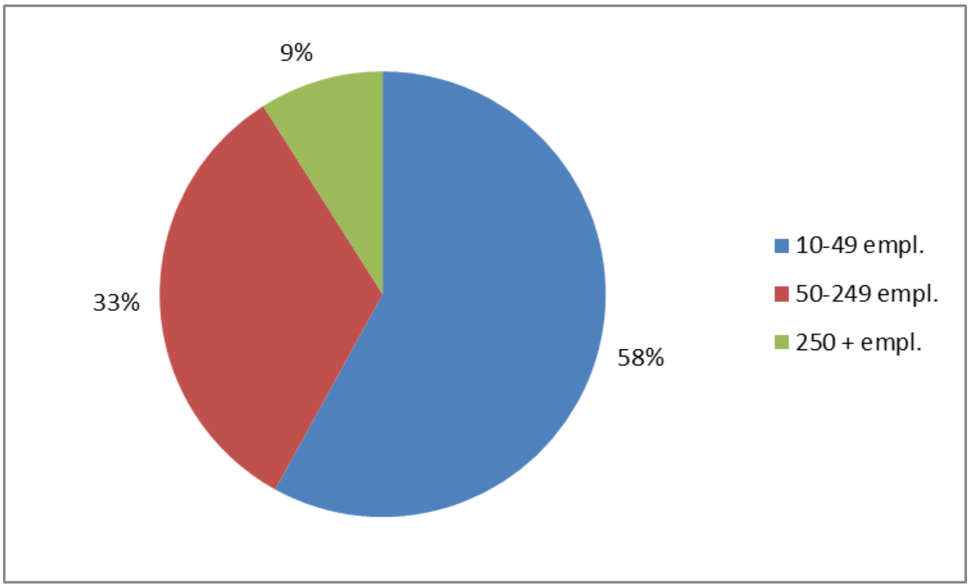
[139] European Council of 24-25 October 2013.

[140] This refers to the universe of enterprises in the address data from the Dun & Bradstreet company; i.e. all HGIEs of this universe, from which the sample for the interviews of the study was drawn.

Medium sized and large enterprises are over-represented among HGIEs

As shown on Figure III.1.6, the majority (58 %) of HGIEs surveyed are small, having between 10 and 49 employees. There is a considerable share (33 %) of medium-sized HGIEs (50 – 250 employees). It is however noticeable that the share of medium-sized HGIEs is larger than the share of medium-sized enterprises in the data universe of Dun & Bradstreet, which has been used for the study; for small enterprises it is the other way round. The share of large enterprises (9 %) among HGIEs is also much higher than in the overall economy, namely 0.2 % of the number of enterprises in Europe in non-financial sector. This may indicate that for many enterprises a minimal size is required to take off for high growth.

Figure III.1.6: HGIEs by size class in % of respondents



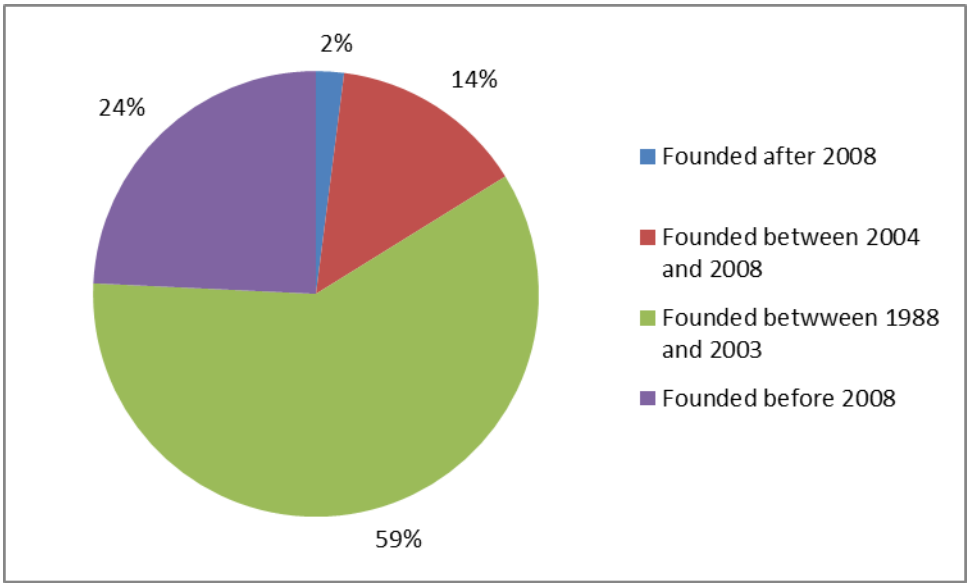
Source: DG Research and Innovation; HGIE study Innovation Union Competitiveness report 2013
Data: Empirica survey HGIE, 2013

High growth is generally not a start-up phenomenon

As shown in Figure III.1.7, the majority of HGIEs in the sample are older than 10 years: 59 % were founded between 1988 and 2003, 24 % before 1988, 14 % between 2004 and 2008, and only 2 % after 2008 (which effectively means founded in 2009 so that the companies qualify for three years of consecutive growth up until 2012). High growth is apparently generally not a start-up phenomenon but may take place once the initial struggles involved in establishing a firm in the market have been overcome.

Such a characteristic has also been found for high-impact firms in the United States. Acs et al. (2008), using data from all US establishments and businesses, found that high-impact firms have a mean age of 25 years.

Figure III.1.7: HGIEs by year of foundation in % respondents

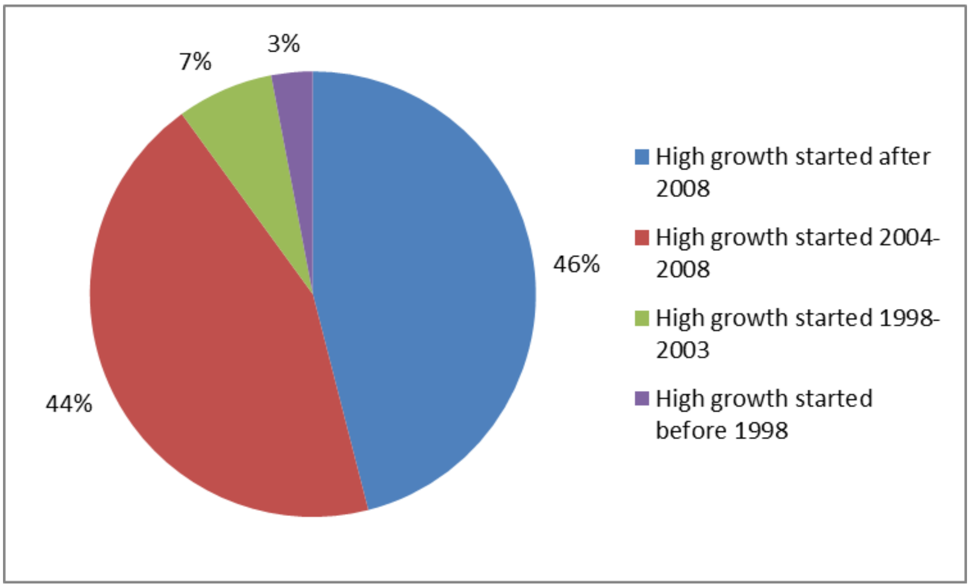


Source: DG Research and Innovation; HGIE study Innovation Union Competitiveness report 2013
Data: Empirica survey HGIE, 2013

The growth of the vast majority of HGIEs started within the past 10 years

As shown in Figure III.1.8, 46 % of HGIEs said their high growth started recently, between 2009 and 2012. Almost the same share (44%) stated that their high growth started between 2004 and 2008. The shares of HGIEs saying their high growth started in the period 1998–2003 (7 %) or before 1998 (3 %) were considerably smaller. Thus, high growth for the vast majority of HGIEs started in the past 10 years. The characteristics of HGIEs whose high growth started before 2004 are as follows: their largest share is among medium-sized enterprises (50–249 employees); the share in EU sample countries is larger than in sample countries outside the EU; highest shares in all HGIEs were found in France (18 %) and Germany (12 %); and their share is considerably larger in the services sector (12 %) than in manufacturing (5 %).

Figure III.1.8: HGIEs by period when fast growth started in % of respondents



Source: DG Research and Innovation; HGEI study Innovation Union Competitiveness report 2013
Data: Empirica survey HGIE, 2013

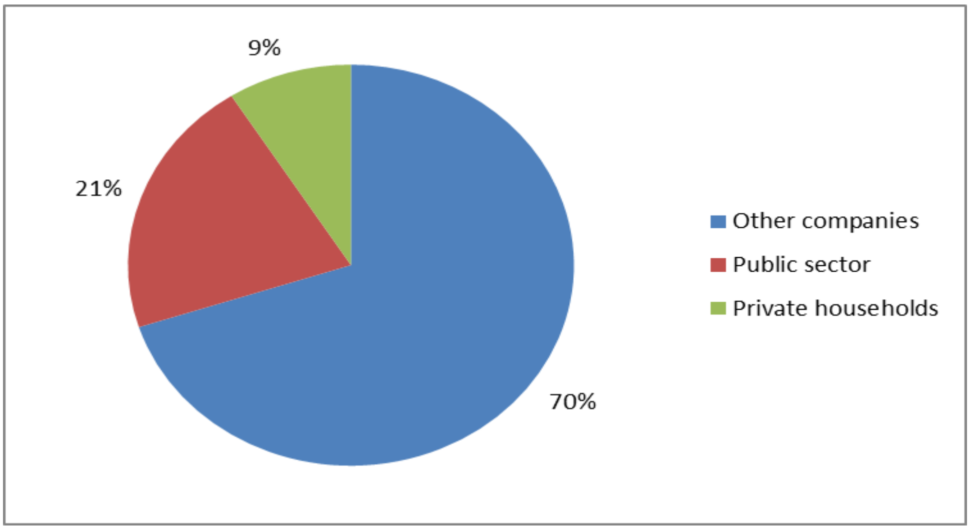
Few HGIEs are spin-offs from public research

The interviewees were asked: 'When your company was founded, was it based on research findings from another organisation?' Some 14 % of the enterprises surveyed said 'yes'. They were further asked whether this other organisation was a university, a public research organisation other than a university, or another company. The answers revealed that 25 % originated from a university, 17 % from a public research organisation and 71 % from another company. These shares amount to more than 100 %, indicating that a certain share of the HGIEs spun out from different organisation types, for example as an outcome of joint research. As a whole, therefore around 5 % of all HGIEs were spin-offs originating from universities or PROs. This demonstrates the distinction needed between on the one hand policies in favour of technology transfer and on the other hand policies in favour of HGIEs. The latter cannot be seen as a sole extension of the former policies.

Other companies in business-to-business dynamics are the dominant customers of HGIEs

The interviewees were asked what percentage of their total product or service sales was sold to certain customer groups. The results reveal that other companies in business-to-business relations are the dominant customers of the HGIEs in the sample. The average percentage of total sales to other companies was 70 %, while the average percentage for households was only 9 % and for the public sector 21 %.

Figure III.1.9: HGIEs' average % of sales of goods sold for all respondents

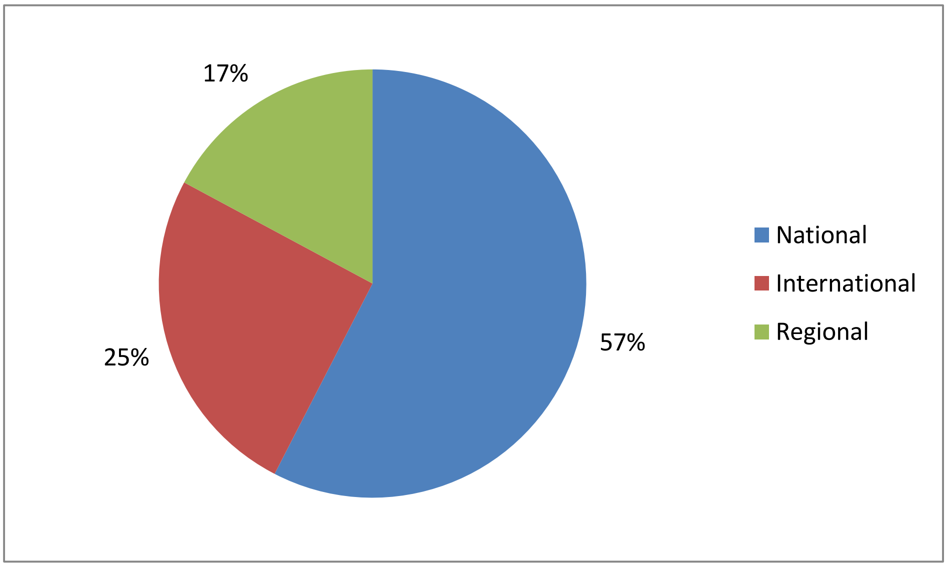


Source: DG Research and Innovation; HGIE study Innovation Union Competitiveness report 2013
Data: Empirica survey HGIE, 2013

For the majority of HGIEs, the national market is the main market

The interviewees were asked what their company's most significant sales market is: the regional market, the national market or international markets. As shown in Figure III.1.10, it seems that for the majority (57 %) of HGIEs, the national market is the main market. Furthermore, 25 % stated that their main market is international, and only 17 % said that their main market is regional. Even among firms with more than 249 employees, the share of firms predominantly selling to international markets is only 33 %. These figures show the potential of national lead markets and advanced customers, but they also suggest that many HGIEs may have the potential to grow further into international markets.

Figure III.1.10: Most significant sales market of HGIEs in % of respondents



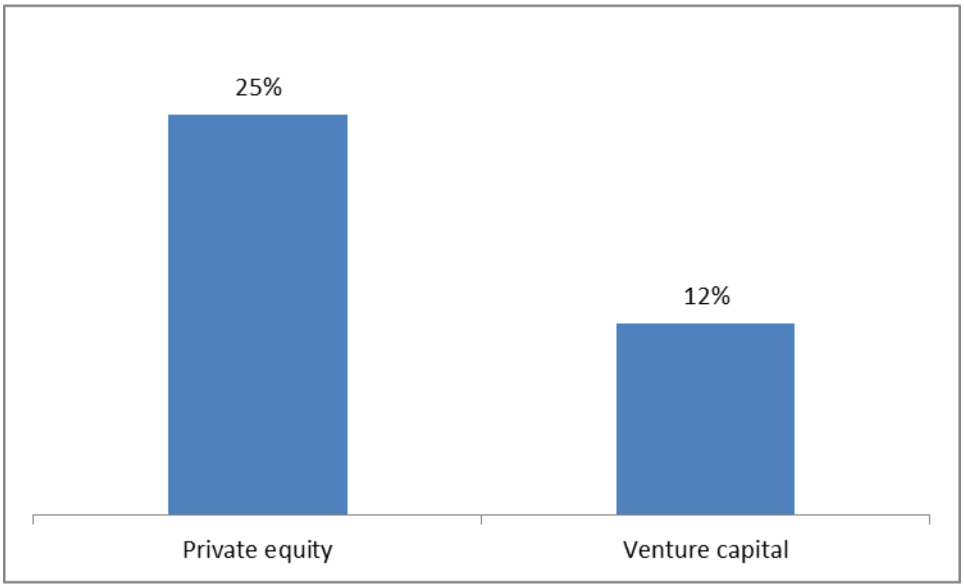
Source: DG Research and Innovation; HGIE study Innovation Union Competitiveness report 2013
Data: Empirica survey HGIE, 2013

The share of HGIEs with venture capital or private equity investments may be higher than average

The companies were also asked whether their assets include private equity (PE) or venture capital (VC) ([141]). This question was meant to find out how important these types of external finance are for high growth. As shown in Figure III.1.11, 25 % of the companies had private equity investments (PE), and 12 % venture capital (VC). PE and VC investments are similar across sizes, and across manufacturing and service sectors. While such assets affect only a minority of HGIEs, the shares of VC and private equity may be higher than in the universe of firms, i.e. including less innovative industries.

Figure III.1.11: HGIEs' financial assets including venture capital and/or private equity in % of respondents

[141] 'Private equity is a form of equity investment into private companies that are not quoted on a stock exchange. Private equity (…) seeks to deliver operational improvements in its companies (…). Venture capital is a type of private equity focused on start-up companies' (http://evca.eu/what-is-private-equity).



Source: DG Research and Innovation; HGIE study   Innovation Union Competitiveness report 2013
Data: Empirica survey HGIE, 2013

Most HGIEs are not part of an international group

Finally, the HGIEs operate with a certain level of autonomy. Some 15 % of interviewees said that their company is part of an international enterprise group. In firms with more than 250 employees, the share was 33 %.

1.3. Characteristics of high-growth innovative enterprises by country

In Germany, there is no innovative sector with an outstandingly large share of HGIEs. More than half of German HGIEs stem from the three industries: 1) computer programming, consultancy and related activities, 2) architectural and engineering activities, and 3) manufacture of instruments and appliances. In these three industries, most enterprises and HGIEs are small, but in computer programming as well as in architectural and engineering activities, medium size is often favourable for high growth. Furthermore, in these three industries, most enterprises, as well as HGIEs, are between 10 and 25 years old, revealing that HGIEs are over-represented in this age group.

In France, the percentage of HGIEs among all firms was found to be very high. Most firms (in absolute terms) are located in the industries of 1) architectural and engineering activities, 2) computer programming, consultancy and related activities, and 3) management consultancy activities. Relative to the number of firms within each sector, however, HGIEs are particularly present in various manufacturing industries. The most common HGIE type, based on industries, is somewhat bigger than other firms in the same sectors. There is no such difference for the age of HGIEs.

In the United Kingdom, HGIEs are relatively concentrated, with 66 % being located in 1) architectural and engineering activities, 2) computer programming, consultancy and related activities, and 3) management consultancy activities. Compared to all other UK firms, the share of HGIEs is distributed relatively equally over the various sectors, with the most in manufacture of basic chemicals. On average, UK HGIEs are larger and older than regular UK firms. A large part of HGIEs (41 % versus 12 % on average) state that their establishment was based on research findings from another organisation.

In Poland, no innovative sector has an outstandingly large share of HGIEs; the shares of industries with a reasonably high number are all below 10 %. Almost half of HGIEs are located in industry of 1) monetary intermediation, 2) wholesale of information and communication equipment, and 3) management consultancy activities. In these three industries, most enterprises and HGIEs are small, but the share of medium-sized HGIEs (50–249 employees) is 16–20 percentage points higher than the share of medium-sized enterprises overall. In monetary intermediation, the majority of HGIEs is older than 25.

In Switzerland, the percentage of HGIEs among all firms is rather low. HGIEs are mainly found in the industries of 1) computer programming, consultancy and related activities, 2) architectural and engineering activities, and 3) software publishing. The sector with the highest share of HGIEs is the manufacture of motor vehicles. The majority of Swiss respondents have fewer than 50 employees.

In the United States, compared to the absolute number of firms, the percentage of HGIEs is rather low. HGIEs are mainly found in the industries of 1) computer programming, consultancy and related activities, 2) architectural and engineering activities, and 3) management consultancy activities. The sector with the highest share of HGIEs is the manufacture of basic pharmaceutical products. US HGIEs are significantly larger than regular US firms. Yet, at the same time, they are also significantly younger. For most of them (51 %) high growth started after 2008.

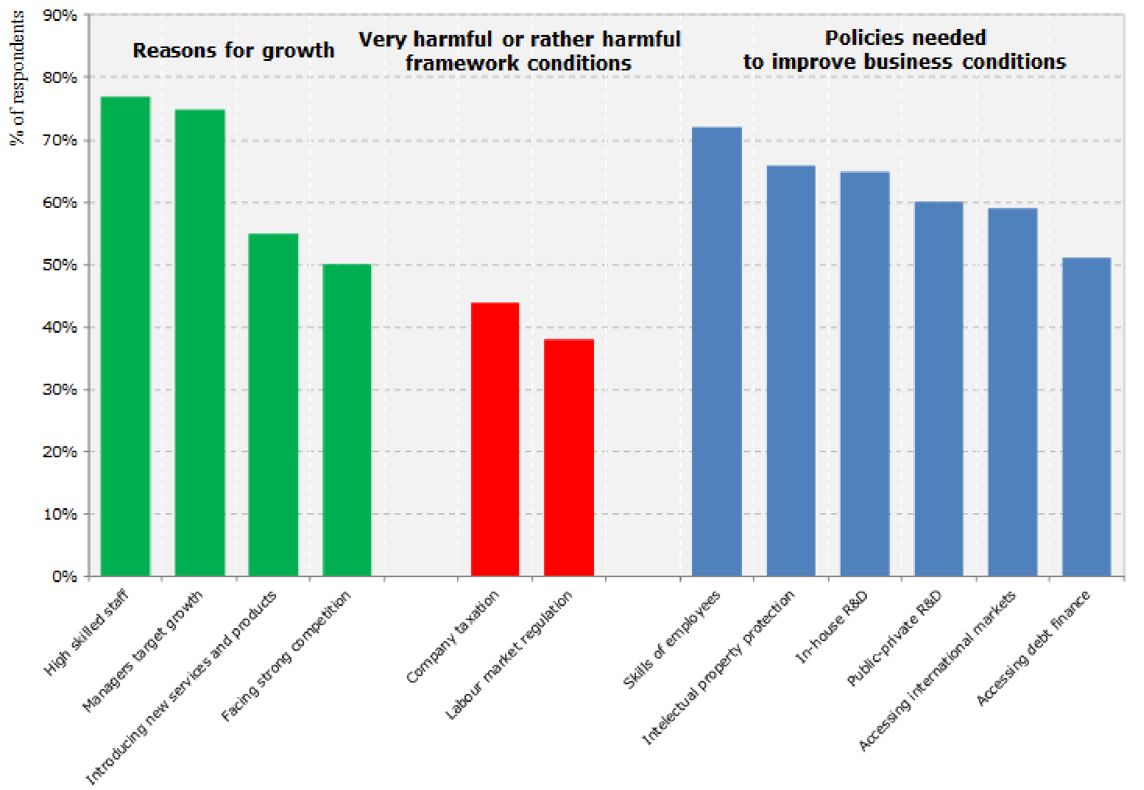
In South Korea, a small share of 2% of firms was found to be HGIEs. Together with the US this was the smallest share in the sample countries A relatively large share of Korean HGIEs (i.e. as a share of all Korean HGIEs) is in the industries of manufacture of communication equipment as well as manufacture of instruments and appliances, reflecting the country's overall large shares of enterprises in these NACE categories. Medium-sized HGIEs were found to be over-represented compared to the share of all HGIEs in the data universe. Korean HGIEs mainly sell to other companies, and the share of HGIEs having received state support is slightly smaller than in the other sample countries.

For Japan, specific conditions for analyses apply. Assessments of characteristics of Japanese HGIEs are very limited, due particularly to the small size of the Japanese sample. The percentage of Japanese HGIEs saying they received state support was right the average of all sample countries. The share of HGIEs stating that their high growth started after 2008 was considerably larger than in the other countries, which is however due to the fact that a quarter of the Japanese HGIEs in the sample was founded after 2008.

1.4. Growth factors and barriers as perceived by HGIEs

The survey on HGIEs conducted for the HGIE study also addressed the factors and barriers influencing HGIE growth. Figure III.1.12 presents a synthetic overview of the main factors and perceived barriers for growth and of the state support policies deemed useful, according to the respondents.

Figure III.1.12: Main reasons and barriers for growth and main public policy needs for HGIEs in % of respondents



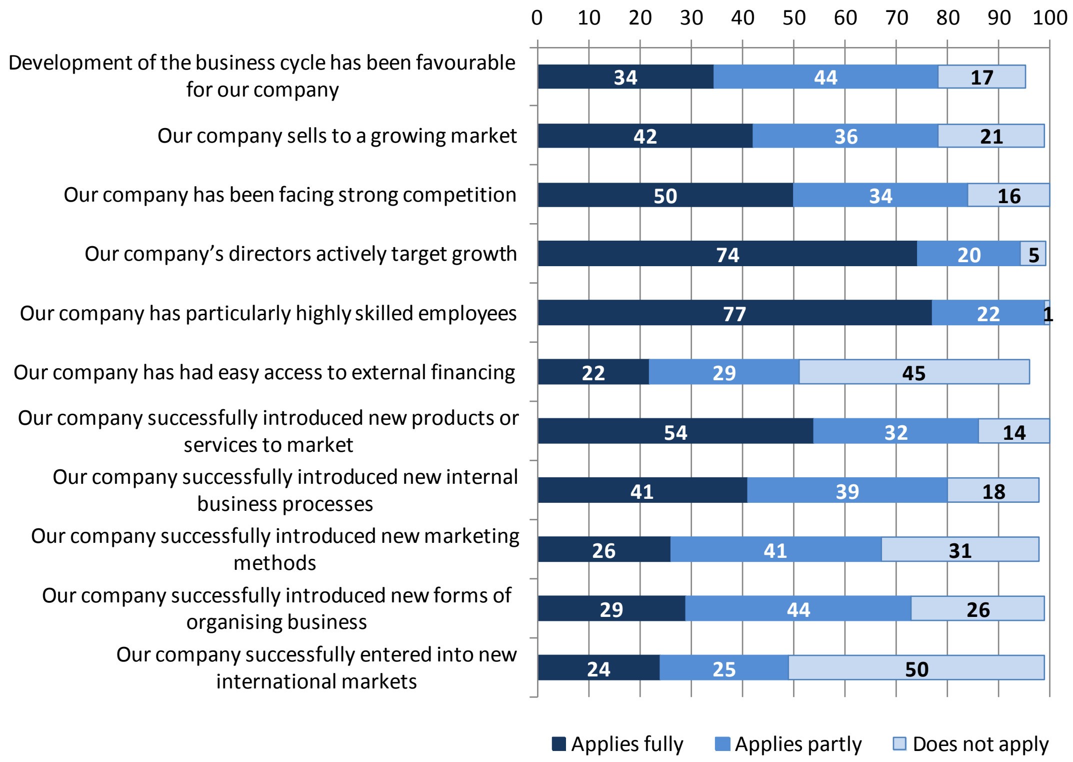
Source: DG Research and Innovation; HGIE study
Data: Empirica survey HGIE, 2013

Innovation Union Competitiveness report 2013

The most cited factors for high growth are a skilled workforce and managers actively targeting growth

The interviewees were asked the reasons for the growth of their company in the past five years. Figure III.1.13 shows that two characteristics stand out as fully applying to three quarters of the HGIEs in the sample: 'Our company has particularly highly skilled employees' (77 % 'applies fully'), and 'Our company's directors actively targeted growth' (74 % 'applies fully').

Figure III.1.13: Reasons for growth in HGIEs in % of respondents



Source: DG Research and Innovation; HGIE study
Innovation Union Competitiveness report 2013
Data: Empirica survey HGIE, 2013

A further two items apply fully to the majority of HGIEs: 'Successfully introduced new products or services to the market' (54 %), which means that product or service innovation may be, but is not always, decisive for high growth of innovative firms. Meanwhile 50 % agreed fully with the statement that the company 'Has been facing strong competition', which could mean that HGIEs' success is often achieved when striving to be better than other firms. Moreover, 41 % found that 'Our company sells to a growing market' applied fully with their circumstances, which shows the importance of market dynamics.

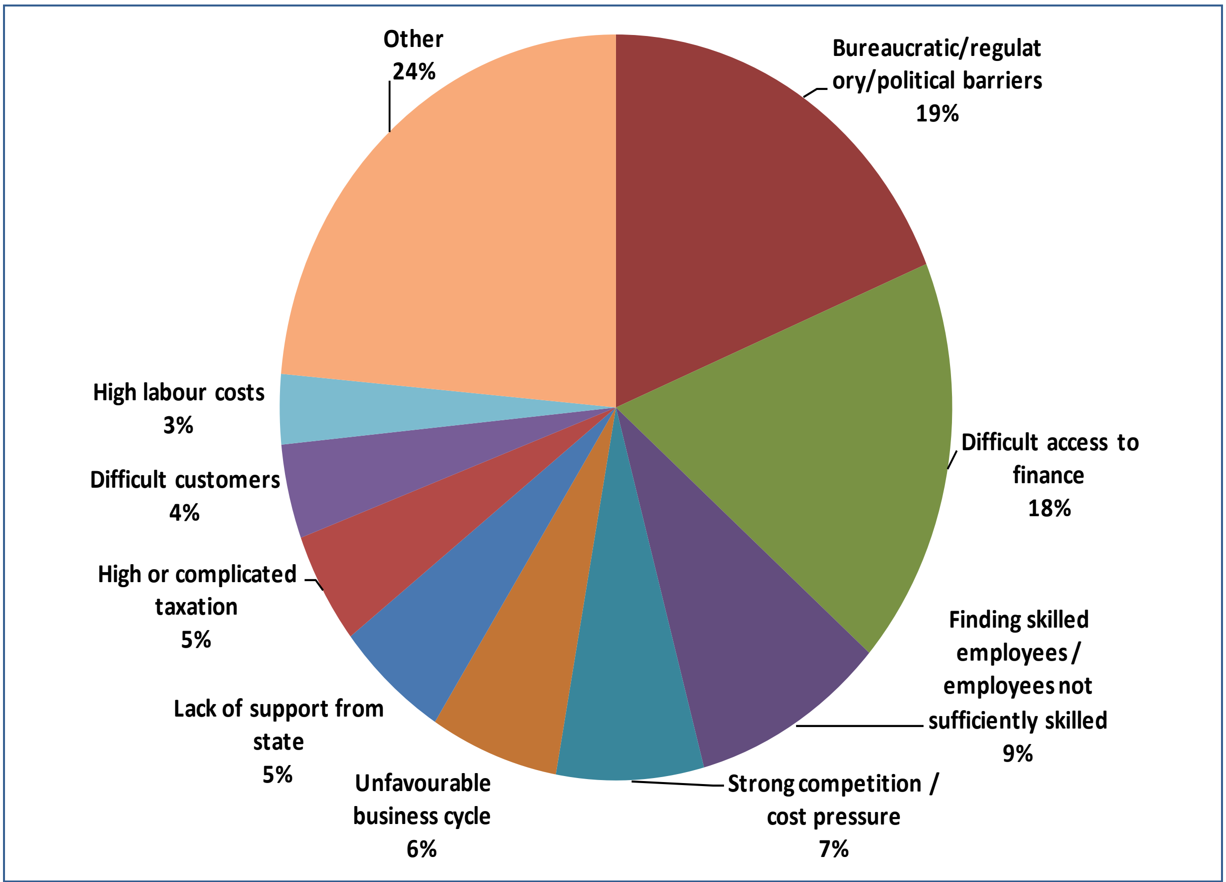
At the other end of the scale, respondents were least likely (22 %) to select 'applies fully' for 'Our company has had easy access to external financing', 24% for entering new international markets, 26% for new marketing methods and 29% for new forms of organising business.

The most cited barriers for the growth of innovative enterprises are bureaucracy, regulation, political issues and access to finance

The interviewees were asked an open-ended question about barriers to growth: 'In a few words: What is in your opinion the main obstacle in your country for innovative companies to grow?' The interviewees mentioned 662 single items; multiple answers were counted. The answers were coded into groups. Figure III.1.14 shows nine groups of responses and a bulk group for other items.

The two most important groups are: bureaucracy, regulation and political issues (including for example 'administrative hurdles' and 'frequently changing political requirements'), accounting for of 19 % of the answers, and difficult access to finance (18 %). The third most important group is: finding skilled personnel and employees insufficiently qualified (9 %). Further items are strong competition or cost pressure (7 %), an unfavourable business cycle (6 %), lack of support from the state (5 %), high or complicated taxation (5 %), difficult customers (4 %) and high labour costs (3 %). Beyond these nine items, almost a quarter (24 %) of answers relate to other barriers such as difficult or weak marketing, high risk or lack of willingness to take risks, and the interviewee him- or herself or the directors. Fourteen respondents (2 %) said there are no barriers.

Figure III.1.14: Perceived barriers for innovative companies' growth — share of barriers in % of all answers



Source: DG Research and Innovation; HGIE study Innovation Union Competitiveness report 2013
Data: Empirica survey HGIE, 2013

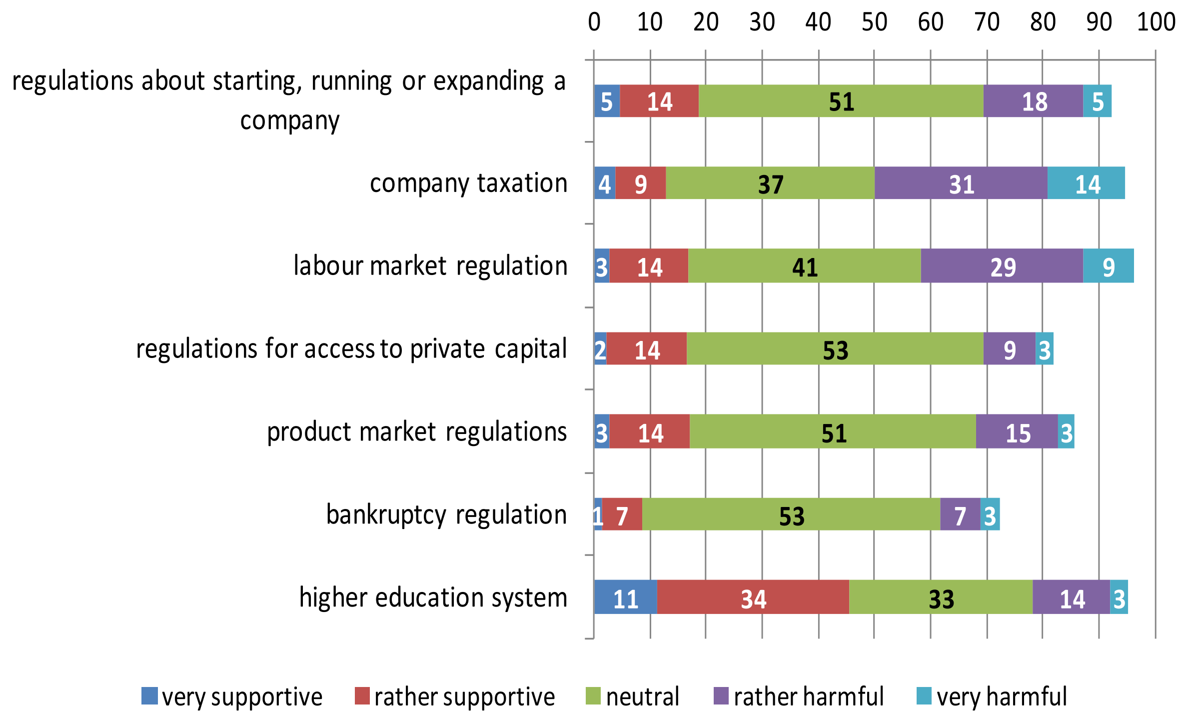
1.5. Framework conditions and the HGIEs' perceived public policy needs

In the survey, interviewees were asked about the framework conditions necessary for doing business in their country and on their need for public support measures.

Company taxation and labour market regulation are judged critically, while the higher education system is considered very or rather supportive

The HGIEs were asked to assess whether certain framework conditions for doing business in their country were supportive for growing the company. As shown in Figure III.1.15, the tendency was to assess business framework conditions as neutral or as rather harmful. Company taxation (assessed as very harmful or rather harmful by 45 %) and labour market regulations (38 % very harmful or rather harmful) were judged most critically. The following framework conditions followed, ranked by harmfulness: national regulations on starting, running or expanding a company (23 %); product market regulations (18 %) and the higher education system (17 %); regulations for accessing private capital (12 %); and finally bankruptcy regulation (10 %).

Figure III.1.15: Assessment of framework conditions for doing business in % of respondents



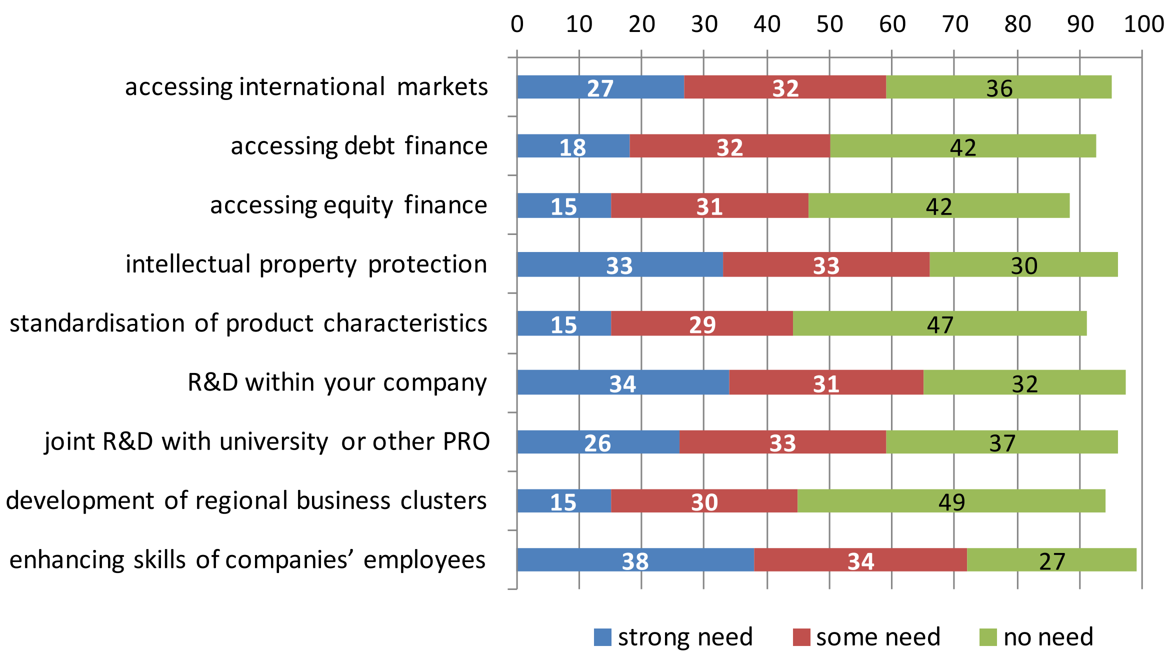
Source: DG Research and Innovation; HGIE study
Data: Empirica survey HGIE, 2013
Note: Differences to 100 % = no answer / “don’t know”

Innovation Union Competitiveness report 2013

HGIEs expressed a need for state policy to improve framework conditions in skills development, in-house R&D and intellectual property protection

The HGIEs did not articulate strong needs for policy measures to improve business conditions in certain fields. However, for each field except one there was a majority stating at least some need. As shown in Figure III.1.16, the field with the largest share of responses stating a strong need for state policy was enhancing company employees' skills: 38 % saw a strong need for policy measures in this field, a further 34 % some need. Two other fields had a relative majority of HGIEs strongly favouring policy measures: R&D in enterprises (34 % 'strong need', 31 % 'some need' and IP protection (33 % 'strong need', 31 % 'some need'). In six other fields the HGIEs did not emphasise a need for state policy: For 'Accessing international markets', 27 % saw a 'strong need' for state policy measures, 32 % saw 'some need'. The same shares apply to joint research between enterprises and public research organisations. For accessing debt finance, a fifth (18 %) saw a 'strong need' and a third (32 %) saw 'some need'. Similar shares were found for accessing equity finance (15 % 'strong need', 31 % 'some need') and standardisation of product characteristics (15 % 'strong need' and 29 % 'some need'). Only 45 % of the HGIEs saw a need for state policy to develop regional business clusters (15 % 'strong need', 30 % 'some need').

Figure III.1.16: Perceived needs for governmental policies to improve business conditions in % of respondents



Source: DG Research and Innovation; HGIE study Innovation Union Competitiveness report 2013
Data: Empirica survey HGIE, 2013
Note: Differences to 100 % = no answer / "don't know"

The assessments of business framework conditions and the needs for governmental policies differ somewhat by country

In Germany, HGIEs tend to assess framework conditions for doing business as neutral. Relatively large shares of HGIEs assess regulations for starting, running or expanding a business and company taxation as neutral. While most German respondents are positive or at least neutral about the higher education system, they are also most likely to select, 'rather harmful' or 'very harmful'. The majority of respondents do not see a need for governmental policies to support their growth. But asked about policy measures to improve the development of regional business clusters, 'some need' was the most popular answer for all countries.

In France, according to most French respondents, the framework conditions are not particularly supportive for firm growth. A relatively large share of respondents criticise regulations on company taxation, labour markets, bankruptcy, and starting, running or expanding companies. Only regulations on access to private capital and quality of higher education system score relatively well in a cross-country comparison of survey results. Within France, just as in most other countries, respondents are very positive about the quality of the higher education system. Respondents signal a need for more state policy on better access to international markets and support for R&D activities.

In the United Kingdom, respondents are most positive about the higher education systems. Regulations on starting, running or expanding are seen as (very or rather) supportive by 20 %. However, there is more discussion about the value of the bankruptcy regulation, product market regulations, regulations for access to private capital and company taxation. Only 6–8 % of the respondents see these measures as supportive. Policy measures are most needed to enhance employees’ skills and support R&D activities.

In Poland, respondents are rather critical about framework conditions for doing business in their country, particularly regarding company taxation, labour market regulation and the higher education system. However, compared to other countries in the survey, regulations on access to private capital are assessed relatively positively and market regulations are assessed very positively. In many policy fields, the majority of respondents see a 'strong need' or 'some need' for measures to support growth. In three policy fields (access to equity finance, improving regional business clusters and enhancing employees’ skills), Poland has the highest share of representatives seeing a 'strong need for state policy'.

In Switzerland, the framework conditions were assessed as more positive than in the other countries in the sample. In particular, the higher education system, taxation, labour market regulations, and regulations on starting, running or expanding businesses are considered as more supportive than in other countries. Public procurement activities are also evaluated as supportive by large shares of respondents. It is a logical consequence of the relatively high satisfaction with these framework conditions that Swiss respondents do not see much need for state policy measures to improve business conditions. The highest need for state measures is perceived for improving IP protection (39 % of respondents). Rated second was state measures for supporting R&D within a company.

In the United States, the replies suggest that the regulation on the launch and expansion of companies and the regulation on product markets are relatively unsupportive to company growth. On the other hand, labour market and bankruptcy regulations are regarded as relatively supportive. When it comes to state policy measures for improving business conditions, American respondents hardly see any need for more government involvement. With an exception for access to finance and development of regional business clusters, scores for other fields of business support are well below the cross-country average.

In South Korea, respondents tend to assess framework conditions for doing business as neutral and a little more positive than in other countries surveyed. Korean respondents express a strong need for governmental policies to support their growth; out of all countries in the sample, Korean respondents were most likely to see a 'strong need' for policy measures.

In Japan, respondents often mentioned the "mismatch" between the job skills they needed and young workers graduating from universities. In contrast to the other sample countries, the higher education system is judged rather negatively. Company taxation is assessed more negatively than the average of all sample countries. Respondent did not indicate particularly strong needs for governmental policies supporting business ecosystems for growth-oriented innovative enterprises.

1.6. Use and assessment of state support measures by high growth innovative enterprises

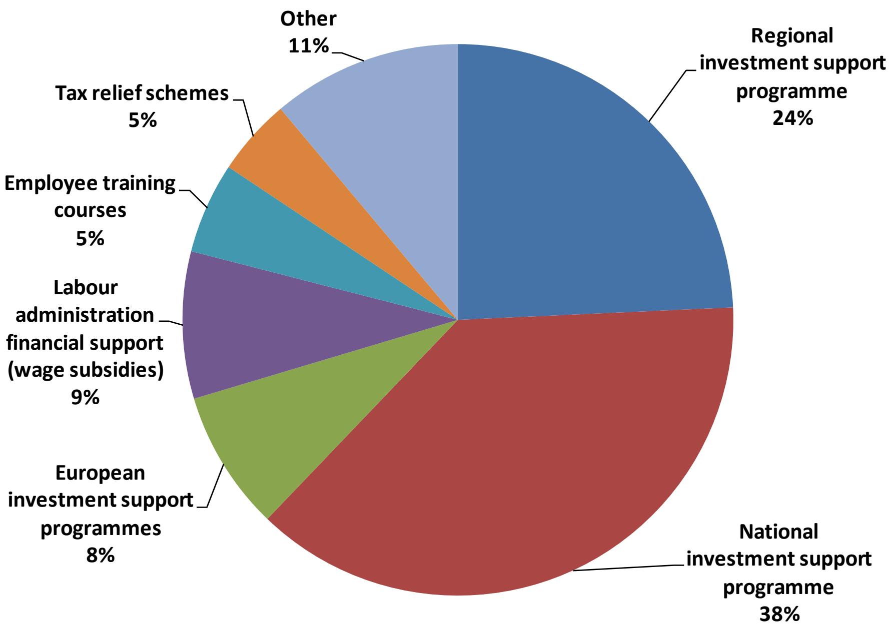
In the survey, the interviewees were asked about support measures they have made use of and their assessment of those measures.

The share of HGIEs having received state support is much higher in the EU than in non-EU countries

The survey reveals that 41 % of respondents have used specific state-support measures. Of those receiving support, direct financial support is most frequent (75 %), followed by consultancy support (18 %) and participating in state-funded offers at reduced cost (14 %). The vast majority of respondents assessed the support as helpful (90 %) and only 9 % as neutral. A tiny share of respondents (1 %) reported harmful experiences with state support. Support used was coded into groups: most important are regional, national and — in EU countries —European investment support measures, wage subsidies from the labour administration, training measures and tax relief schemes. National support programmes are found to be most frequently used (38 %), followed by regional programmes (24 %) (see Figure III.1.17). Among the policy measures used there are no obvious specific measures for high growth.

The share of HGIEs having received state support is found to be much higher in EU countries (49 %) than in non-EU countries (31 %). Levels are highest in France (62 %) and Germany (55 %), followed by Poland (39 %), South Korea (36 %), the United Kingdom (33 %) and the US (31 %). By far, the lowest share is found in Switzerland (23 %). The highest share of satisfaction with state support is found in Poland (100 %), and the lowest in South Korea (81%).

Figure III.1.17: Types of policy measures used by HGIEs in % of all answers



Source: DG Research and Innovation; HGIE study Innovation Union Competitiveness report 2013
Data: Empirica survey HGIE, 2013

9 % of HGIEs are or have been located in a science or research park, 6 % in an incubator or accelerator

The survey revealed that 9 % of respondents are or have been located in a science or research park, and of these 77 % found it helpful. Also, 6 % said they were or had been located in an incubator or accelerator, of whom 75 % found helpful. No harmful experiences were reported for either location. The most frequent benefits were networking opportunities (38 %), office space at reduced rates (36 %), and laboratory or workshop space at reduced rates (23 %). The shares of respondents located in a science or research park are highest in France (15 %) as well as Germany and South Korea (14 % each). The other countries followed way behind: Poland and Switzerland (8 %), the US (6 %) and the United Kingdom (5 %). For incubators and accelerators, shares are again highest for South Korea (11 %) and France (10 %), while Germany has the lowest share (2 %). No data can be given for Japan, due to the small number of cases.

1.7. Polices for high-growth innovative enterprises

Studies on policies to support high growth are scarce

According to Empirica (2013), the number of studies on policies to support high growth is small and, among the most prominent, are those by the OECD (2010) ([142]) and Autio et al. (2007) ([143]). The Empirica study notes that even these studies are not focused on innovative firms and do not deal in depth with the question of whether there has been market failure or possible government failure. It also questions whether resources were used efficiently.

The OECD report suggests a set of combined elements to foster high-growth small and medium-sized enterprises (SMEs): improve the business environment, encourage entrepreneurial attitudes, support training in young and small enterprises, improve access to debt and equity finance when necessary, and promote innovation and internationalisation activities of new and small firms. In practice, the OECD found that countries' policies for fostering SME growth tend to focus on R&D and access to finance, while neglecting skills upgrading and encouraging growth ambitions.

Autio et al. (2007) have produced a comprehensive analysis of policies for high growth in nine countries. They suggest that policies in support of HGEs are distinctly different from SME policies. The study mentions the following lessons learned from HGE policies in Australia, Brazil, Finland, Hong Kong, Hungary, Italy, the Netherlands, Spain and the United Kingdom: If governments seek to promote HGEs directly, the initiative needs to be selective with regard to the companies promoted, proactive in terms of scanning the environment for potential HGEs, sustained and professional, and they need to collaborate with the private sector and focus on skills.

Considerations for HGIE policies

Empirica (2013) mentions that, given the lack of independent evaluation studies on enterprise policy measures, indications about governmental policies that may be particularly successful in promoting HGIEs should be cautious. The Empirica study, considering the findings of the survey and insights from previous research ([144]), recommends, however, that policymakers take account of the following when designing such policies.

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[142] OECD, 2010, 'High-growth enterprises: What governments can do to make a difference', OECD Studies on SMEs and Entrepreneurship, OECD Publishing.

[143] Autio, E., Kronlund, M., and Kovalainen, A., 2007, 'High-growth SME support initiatives in nine countries: Analysis, categorisation, and recommendations', report prepared for the Finnish Ministry of Trade and Industry, MTI Publications 1/2007.

[144] 1) European Commission, 2011, 'Policies in support of high-growth innovative SMEs', An INNO-GRIPS policy brief by Empirica GmbH. Principal author : Stefan Lilischkis. Bonn; 2) Bravo-Biosca, A., Criscuolo, C., and Menon, C., 2013, 'What drives the dynamics of business growth?', OECD Science, Technology and Industry policy papers, No. 1, OECD Publishing; 3) INNO-GRIPS, 2011, Summary of the expert workshop 'Policies in

Industries: The share of HGIEs is fairly similar across innovative industries and in manufacturing versus service sectors.

Age: The majority of HGIEs may not be start-ups but older than 10 years. High growth takes place most often after the initial struggle of establishing the firm in the market.

Spin-offs: Many spin-offs originate from other companies, not from public research. This may call for revised policy measures to support both groups adequately.

Principal customers: Other companies were the dominant customers of HGIEs in the sample. HGIEs should thus not be expected to be widely known to the public.

International potential: For the majority of sampled HGIEs, the national market is the main market. They may thus have potential to grow further into international markets.

Main drivers: The main factors of high growth appear to be a skilled workforce and directors actively targeting growth. Thus, it may be advisable to focus education (for both employees and entrepreneurs) on fostering HGIEs. For entrepreneurs, beyond basic education, targeted high-growth consulting and coaching may be valuable.

Country and industry specificities: HGIEs' assessments of framework conditions for doing business, perceived needs for governmental policy and use of policy measures differ across countries and industry. Hence, policies for HGIEs can be based on the assumption of similarity of HGIEs' characteristics across countries and industries, but need to consider the specific situation in the country — even the region — and industry concerned.

Ecosystem: Science and research parks as well as incubators and accelerators were found to be useful locations for HGIEs. They welcomed networking benefits in particular.

Drawing all results together, Figure III.1.17 summarises the key considerations for HGIE policies of the Empirica study.

Figure III.1.17: Key considerations for HGIE policies from Empirica study

Mind HGIE characteristics:

Industry
No extraordinarily high share of HGIEs in any innovative industry

Age
High growth usually in firms older than 10 years

Origin
Small share of HGIEs are spin-offs; of these mainly from other companies

National & sectoral specificities
HGIE characteristics are similar across countries – but national and sectoral conditions for doing business and related policy needs differ

Don't mind invisibility
Most HGIEs target business customers, are not publicly known

Fine-tune HGIE policies:

Improve framework conditions
Company taxation and labour market regulation in particular

Target key barriers
- Bureaucratic hurdles
- Access to finance
- Lack of skilled employees

Foster high-growth readiness
Entrepreneurship education and coaching may ensure that new business leaders are capable and willing to aspire high growth

Foster internationalisation
Most HGIEs target national market; may grow on internationally

Support ecosystem
Networking benefits of science parks, incubators, accelerators are helpful for HGIEs

Implement thoughtfully:

Evaluate public policies
There is a serious lack of independent evaluation of enterprise policies, making it difficult to identify recommendable measures

Also consider non-HGIEs
Non-HGIEs also contribute decisively to job generation, so design effective policies also for them

Keep application simple
HGIEs often perceive applications to policy programmes as complex and time-consuming

2. Enhancing innovation-driven clusters

Highlights

Innovation-driven clusters enable fast-growing innovative enterprises

Dynamic and innovation-driven clusters enable firms to innovate and grow. They are highly correlated with technology development and entrepreneurship. This chapter proposes a methodology to enhance the dynamics of innovation-driven clusters using a life-cycle model that recognises specific needs at different stages of cluster evolution. Indicators and measures are presented to assist in describing this typology and to advocate public support policies at local, regional and national, and EU levels.

Efforts to stimulate innovation-driven clusters have to be adapted to the different development stages of existing clusters

There are certain crucial stages in a cluster evolution that warrant support or investment from public authorities. These include in particular four scenarios where premature cluster exhaustion or decline occurs when growth would have been expected: a) when decline sets in at take-off or in the early stages of exploratory expansion; b) when decline sets in later in the exploratory expansion or early exploitive expansion stages; c) when near-the-end of exploitive expansion, decline sets in much more rapidly than expected; and d) when exhaustion turns into long-term decline and transforms the cluster region into a lagging region.

The reason public authorities should consider the provision of supporting resources in these cases stems from the risk of losing much of the return on investments already made. A differentiated approach for the support of innovation-driven clusters enhances the impact on innovation and entrepreneurship activity in the cluster, which is crucial for the development of fast-growing innovative companies.

Introduction

The cluster concept is well known and often the basis for contemporary policy and practice in economic development following the work of Michael Porter (1990) ([145]). Clusters are organised around one or more industries and attract investment and related companies and organisations because they enable the capture of benefits from Marshallian positive externalities such as reduced procurement costs, strong knowledge spillovers and lower transaction costs. These and other advantages such as improved market knowledge and

[145] Porter, M.E., 1990.

information are amplified as strong internal and later external networks evolve (Porter, 1998; Rocha, 2004) ([146]).

Empirical studies by Rocha and Sternberg (2005) and Delgado et al. (2010) provide evidence that clusters also motivate and support increased new firm formation ([147]). Other evidence of a positive relationship between clusters and entrepreneurship is fairly extensive but limited with few exceptions to interpretive and case analyses. At the same time, there are major differences in the level of entrepreneurship at the national (Audretsch and Thurik, 2000), meso and local regional levels (Reynolds et al., 1994; Reynolds et al., 2001; Rocha, 2004) ([148]). Thus, geography and proximity matter in firm creation. Others argue that regions with strong clusters will 'benefit from higher start-up rates' (Rocha, 2004) ([149]).

2.1. Cluster dimensions and dynamics

Dynamic clusters may be defined as complex systems composed of multiple interdependent dimensions or as ensembles of interdependent dimensions whose values change over time. This dimensional view was first used in a study of the shipbuilding cluster in Northern Ireland by Klink and Langen in 2001 ([150]). The dimensions used by Klink and Langen together with others that have appeared repeatedly in cluster literature ([151]) create a seven-dimension manifold for analysing cluster dynamics. A life-cycle approach to clusters implies that certain states or stages are reached as the cluster moves through its life cycle. At each stage, these dimensions are expected to have specific values or qualities ([152]). The dimensional profiles provide guides for policy intervention. Based on a review of the cluster literature the seven dimensions are:

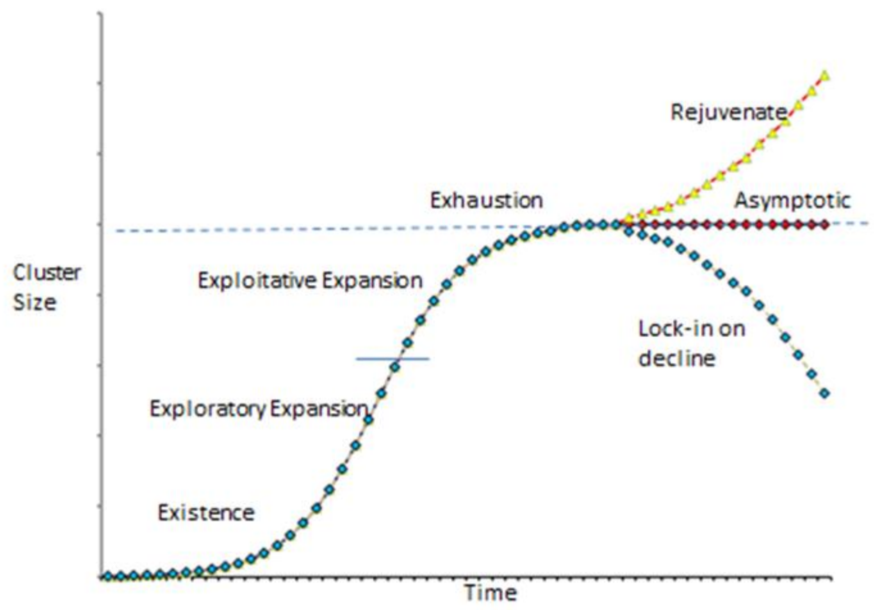
1. Spatial concentration — greater in early and more dispersed in later stages;
2. Industrial/Cluster strength — scale and scope increase; decrease in later stages;
3. Knowledge — heterogeneous in early stages; more homogeneous in later stages;
4. Entrepreneurship — greater within clusters than outside them;
5. Convergence — convergence around best practices and standards increases after the early and mid-exploitive states are reached; it is correlated with a change in the nature of knowledge creation and information from heterogeneous to more homogeneous;

[146] Porter, M.E., 1998; Rocha, H.O., 2004.
[147] Rocha, H.O. and Sternberg, R., 2005; Delgado, M., Porter, M.E., and Stern, S., 2010.
[148] Audretsch, D.B. and Thurik, A.R., 2000; Reynolds, P., Storey, D., and Westhead, P., 1994; Reynolds, P.D., Campus, S.M., Bygrave, W.D., Autio, E., and Hay, M., 2001; Rocha, H.O., 2004, *Op. cit*.
[149] Rocha, H.O., 2004, *Op. cit*.
[150] Klink, Van A. and De Langen, P., 2001.
[151] Baptista, R. and Mendonca, J., 2010; Bergman, **, 2008, *Op. cit*.; Brocker, J. and Soltwedel, R., 2010; Karlsson, C. (ed.), 2008; Martin, ** and Sunley, **., 2011, *Op. cit*.; Menzel, P.E. and Fornahl, D., 2009; Stough, R.R., 2013 (in press).
[152] While this life-cycle perspective implies a deterministic model, its use in this paper is as a benchmark for assessing the progress of a cluster or deviations from the theoretical model. No judgment is made about what the dynamics should be.

6. Network linkages — strengthen over the life cycle; decrease as clusters lock-in on decline;
7. Cooperation — minimal to modest initially and in the take-off and early growth stages, increase as scale and scope increase; remain strong until lock-in on decline progresses.

Figure III.2.1 depicts a staged life-cycle model for clusters largely derived from Bergman (2008) built on the work of others ([153]) that evidences the recent yet sustained scholarly interest in life-cycle theory as a framework for modelling cluster development and evolution.

Figure III.2.1: Cluster life-cycle analysis



Source: The Author, designed after Bergman 2008

General life-cycle theory gained recognition from its application in business, industry and technology development (Klepper, 2007; Utterback and Abernathy, 1975) ([154]). It assumes that a growth process has an origin, a take-off leading to or initiating extended growth that begins at the first inflection point of the model, after which growth occurs at an increasing rate (Figure III.1.2) hat later slows after the middle part of the cycle and rapidly declines to zero and then reaches an asymptote. At exhaustion, cluster growth may remain in stasis but usually experiences a long period of decline (lock-in) or reinvention, whereby a new cycle of growth is initiated. The state of the dimensions varies as the cluster moves through or deviates from the model framework.

[153] Bode, ** and Alig, **., 2011, *Op. cit*.; Hassink, R. and Shin, d.H., 2005; Ingstrup, M.B. and Damgaard, T., 2012; Knop, L. and Olko, S., 2011; Lefebvre, **., 2012, *Op. cit*.; Lorenzen, M., 2005; Martin, **. and Sunley, **., 2011, *Op. cit*.; Menzel, ** and Fornahl, **., 2009, *Op. cit*.; Swann, G.M.P., 2002; Tichy, **., 1998, *Op. cit*.; Bergman, **., 2008, *Op. cit*.

[154] Klepper, S., 2007; Utterback, J.M. and Abernathy, W.J., 1975.

While the life-cycle model implies a deterministic cluster process, it may evolve in a quite different and erratic fashion, may never complete the process and/or may reach an asymptote prematurely. Thus, the model provides a benchmark against which to assess cluster development. Factors that may 'cause' the cluster to deviate include natural events such as hurricanes, earthquakes, droughts, tornadoes, climate change and floods, and societal or man-made occurrences such as business cycles, new technology (especially radical ones), change in political leadership, war, post war recovery and conditions that eliminate competition (e.g. a region dominated by mafia-type leaders).

2.2. A life-cycle approach to cluster dynamics

<u>The Pre-Cluster Stage</u>

Even larger industries are mostly randomly spaced and not concentrated geographically at this stage and are relatively small (often branch plants). There are therefore no industries to support a cluster. The number of firms in the larger industries at this stage is small and their relative strength is low, indicating that industry presence in the study area is less intensive than average industry intensity in other locations. Knowledge is dispersed and highly heterogeneous, and the level of entrepreneurship is low and focused on non-productive entrepreneurship ([155]). There is no strategic convergence around a cluster concept at this stage as there is no cluster. There is limited business or industry networking. Finally, a low level of intra- or inter-industry dependence (buying and selling to each other) exists.

Support can improve workforce capability and quality, and maintain the infrastructure, support the provision of business assistance, and promote economic cooperation via, for example, promotion of collective buying or selling cooperatives. At the macro level, assistance for workforce improvement, business assistance, development planning, and infrastructure and support for lagging regions via a regional policy regime is a possibility. At best, the region can implement business attraction and retention policies and hope a segment of the economy will attract enough firms for a cluster take-off. In summary, at the pre-cluster stage, a region's economic ecosystem is under-developed as there is no basis for clustering.

<u>The Take-Off Stage</u>

At take-off, one or more industries begin to emerge and exhibit signs of clustering. An area within which most companies in the industry are contained can be identified. Yet, the density of firms is modest. The strength of the core industry and the emerging cluster is growing, demonstrating that the core industry is evolving into a lead cluster sector. It is during this stage that cross-industry cooperation begins to appear, as represented by small but increasing flows (buying and selling) between industries.

[155] Entrepreneurship to supplement one's income is an example of non-productive rather than productive entrepreneurship that is aimed at economic growth and development objectives.

Knowledge and information heterogeneity may be expanding, but only modestly as cohesion of the core industry(ies) is still in a nascent stage. Yet, that which does exist is highly heterogeneous. Entrepreneurship indicators such as start-ups may show modest increases and there may be an effort to form a business incubator. Yet most of the start-ups will continue to be of a non-productive form. Convergence around a strategy that envisions a cluster will not usually be a topic of major interest.

Networking may be evolving at this stage, but will not be well developed around the concept of an emerging cluster. There may be a few new firms formed with the goal of supplying inputs or marketing assistance to businesses in the core industry(ies), but this will be modest. There may be isolated instances of firms in the core industry(ies) cooperating on matters such as joint bidding on projects or supplying goods or services in cooperation to a market segment. Cooperation in general will tend to be at a modest level as the region is not yet focused on building the cluster.

The roles for local and regional authorities at the take-off stage include providing information about the economy regarding the emergence of a core industry(ies) and providing assistance for workforce development and infrastructure maintenance and development. They also have the opportunity to provide support for business; for example, training and promotion of buyer–seller cooperatives. Local and regional authorities should communicate to all stakeholders that cluster conditions are evolving, and convey that there is a need and opportunity for productive entrepreneurship. A major role for national and regional authorities is to provide planning and advisory assistance for regions that exhibit the potential for cluster development. Continued support for lagging regions is important, as regions with an emerging cluster may also be lagging regions.

<u>The Exploratory Expansion Stage</u>

The exploratory expansion stage emerges shortly after a successful take-off and extends until the middle part of the steep growth segment of the S-shaped life-cycle model is reached. From the middle of this segment, growth continues to accelerate but at a decreasing rate. The upper boundary of the exploratory expansion phase is the lower boundary of the exploitive expansion phase. This phase is usually the most dramatic part of the life cycle (along with perhaps rejuvenation) as it is where trial and error is at a maximum and thus start-ups and the churn of start-ups and failures is most pronounced. The churn of ideas and knowledge during this period is why this stage is called exploratory, as it is a time of testing to discover the best trajectory for the cluster.

The cluster becomes defined around one or more core industries as this stage unfolds, and the cluster boundary is easily specified using GIS techniques. Throughout this phase, more and more companies are formed or attracted to the cluster area so that density increases and proximal relations become more pronounced. The strength of the cluster also increases dramatically with considerable growth in employment, income and wealth creation. Core industry location quotients often increase to concentration levels three or more times the provincial or national average.

This phase also sees considerable new knowledge and information being created both in the industry and supporting firms. This industry churn spills over into other organisations leading to production of more patents, not only among the companies but also via the growing involvement of research institutions that find an expanding market for their research. This interrelated activity produces considerable new and diverse (heterogeneous) knowledge and information that spills over into the local and regional community. This creates a highly positive environment for entrepreneurship; the number of start-ups and spinoffs increase and become more focused on growth companies, while emphasis on non-productive business formation becomes of secondary interest ([156]).

The notion of convergence around a strategy tends to be conceptual during the early and middle parts of the exploratory expansion stage. However, later, a more formal strategy may emerge due to the continued growth of the core industry and its supporting businesses. Also, new facilitating and supporting organisations may arise, such as technology councils and venture capital or lobbying associations. In this part of the exploratory stage the focus is mostly on growing the cluster by internal processes and company attraction, including those that bring inbound foreign direct investment (FDI).

Networking in this stage evolves rapidly, with the expansion of business associations that promote cluster development and thus bring cluster industry and business representatives together in a variety of contexts; for example, training, workshops, award ceremonies, webinars, socials and speaker events. The growing cluster ecosystem includes an increasing variety of firms both in the core industry and the evolving supply chain and there are increasing flows among these as joint bidding for projects and joint delivery of products and services become increasingly commonplace. Business and related associations tend to provide forums to promote further cross-industry networking, and as cross-industry flows and buyer and supplier relations become more complex the level of cooperation increases considerably.

Given the huge dynamism in the cluster during the exploratory phase it may seem that there is little role for government. But that is not the case. Leadership from government at the local–regional level is important to continue to promote the cluster and its development. In the early parts of this phase the evolving cluster is potentially quite fragile and can sometimes rapidly fall from a seemingly sensational future to exhaustion due to unanticipated causes. Governments at the national level have standing programmes for recovery from disequillibrating events; however, local regional governments in this situation need to quickly lead efforts to access recovery resources from higher levels.

[156] Some alternative views consider an adaptive cycle and nested systems theory approach (Martin and Sunley, 2011) and the dynamics of cross cluster interaction (Engel and Palacio, 2009).

At the local and regional authorities level there are other roles to be played. In the early part of the exploratory phase there is need for government-supported grants and assurances to facilitate provision of business assistance, workforce training, entrepreneurship, and smoothing out of regulatory processes by, for example, creating one-stop services for applications, registrations and licensing. At the national or EU levels, grant programmes to assist cluster development during the latter part of the take-off and early parts of the exploratory phase are important because this is a fragile time for the cluster.

The Exploitive Stage

The gains that have occurred during the expansion stage are consolidated into a more routine portfolio of functions and processes during the exploitive expansion stage. During this stage, the geography stabilises and the bounded cluster area tends to experience a reduction in the rate of spatial expansion or even end as infilling sites become the dominant locations for expansion of existing or in-migrating companies. The density of firms tends to increase especially in the early and middle parts of the exploitation stage and stabilise in the later parts.

Industry and cluster strength continue to grow as the cluster region stakeholders build deeper network relations, but the increasing trend toward interdependence evolves at a decreasing rate. A high level of interconnectedness among core industry and the supply chain is retained. However, stability will tend to occur in the later parts of this stage.

Knowledge and information will be produced at a very high rate during the early part of the exploitive stage. A high rate of patenting and cluster-related sponsored research at universities and other research organisations tend will tend to occur during the early parts of this stage but this will decrease later. The character of knowledge and information will become more homogenous. Consequently, entrepreneurship will tend to stabilise and decrease. These patterns tend to occur because the likelihood of convergence and agreement around a strategic plan during this phase is high as the core industry and related suppliers solidify agreement on best practices and standards. Once this happens, the need or motivation for R&D and experimentation by entrepreneurs for enhancing practices, processes and widgets is of less concern. Historically, this has been a critical development in the process leading to cluster decline. It is thus important during the middle to later parts of the stage that the strategic approach includes sustainability concepts and thus regeneration of the cluster when or if maturation tends toward non-sustainable processes.

There is a slowing rate of growth. One avenue in the view of cluster stakeholders may be to gain regulatory protection and tax breaks to help the bottom line of firms in the cluster and their competitiveness. But in an era where internal and external networking exists at national and global levels it is difficult to protect a cluster from external competition. Strategic plans need to focus as much on sustainability and rejuvenation as upon establishing and maintaining agreed best practices. In short, it is important that such plans include processes and procedures to ensure there is a continued flow of knowledge and information into the regional ecosystem and thus that the renewal dynamic provided by entrepreneurship is maintained at a high level. Protection from external competition is the opposite of what is needed for ensuring rejuvenation and sustaining the cluster.

Local and regional authorities have several important roles during the exploitive expansion stage. First is providing information and data on cluster dynamics to cluster stakeholders. Second is to interpret this information and data for stakeholders by conveying in the early stages the need to find general agreement on cluster strategy and best practices. This includes explaining that the strategy needs to address the issue of economic sustainability as the cluster matures. Third, there is a continued need to streamline the regulatory environment and to facilitate compliance with measures like one-stop process facilities (online or physical). Fourth is to ensure that public infrastructure is provided and/or maintained at levels that facilitate low transaction costs for the movement of goods, services and information (bytes). There is also a continuing if not growing need to maintain workforce quality and training.

At the national level, the role of government is to provide flexible grant programmes and information to facilitate managing the cluster during the later parts of the exploitative stage. One major focus should be on sustaining the cluster and planning for its rejuvenation before it drifts into exhaustion. Maintenance of resources for productive entrepreneurship and related technological change that undergird successful innovative clusters and thus sustainability are of central importance.

The Exhaustion Phase

If efforts to rejuvenate and sustain the cluster and new growth during the later parts of the exploitive expansion stage fail, cluster growth will decline to zero and eventually into absolute decline. Given that all stakeholders of the cluster, including firms, employees, governments and non-profit associations, wish to avert a long period of decline, the focus here is on rejuvenation of the cluster.

The spatial concentration of a cluster that has reached exhaustion gradually becomes less dense as companies fold, are acquired or relocate. The spatial structure of a cluster will tend to hollow out, and industry and cluster strength will decline due to lock-in where unemployment grows and income and wealth decrease, and effective cluster networking and cooperation suffer. Knowledge and information will narrow as they become more homogenous and entrepreneurship will revert toward non-productive entrepreneurship. While a high level of cooperation may continue, it will tend to be difficult to develop a successful rebounding plan without external help. But the infrastructure and some of the industry members and associations still exist (especially in the early part of the exhaustion stage). So there are still resources to stage a comeback if organised and focused through strategic leadership.

The roles of local government and higher levels of government are major and critical to achieving rejuvenation once exhaustion sets in. That is why, in the middle and later parts of the exploitive expansion stage, it is important to seed sustained cluster development as it is easier to achieve rejuvenation when the cluster is still relatively strong. So what should governments do?

At the local and regional level it is important to continue to provide information, data and analytical support to understand the condition of the cluster. Local authorities partnered with industry and cluster associations should undertake planning to create a strategy for renewal. It is important to restore, maintain and possibly build new infrastructure. There is a need to encourage industry groups to invest in and facilitate the identification and transfer of technological innovation to the region as these will be critical elements of a plan to renew the cluster and productive entrepreneurship regardless of other aspects of the plan. Finally, there will be major workforce development needs as the plan is formed and implemented. Local government should be promoting and facilitating the creation of the infrastructure to deliver this through secondary and post-secondary educational facilities, and industry associations.

National government and the EU levels could provide grants for planning assistance and infrastructure renewal for clusters in the exhaustion stage. Existing programmes for lagging regions are usually for cluster regions in the exhaustion phase. Further, if the cluster region can claim that unanticipated disequillibrating forces have contributed to exhaustion, then disaster recovery grants and awards may be available.

3. Upgrading manufacturing industries in Europe

Highlights

The share of manufacturing industry in the European economy continues to decrease, weakening economic sustainability

The manufacturing sector in the European economy decreased in size over the period 1995–2008, the only exceptions being the medical precision and optical instruments sector and transport equipment other than automobiles or the aerospace sector. This is a challenge for Europe, since Member States with a solid manufacturing core focused on high-tech or medium-high–tech activities and with integrated value chains have proved to be more resilient to the economic downturn and better placed to achieve higher growth in times of rebound. The upgrading of manufacturing industries provides the basis for a sustainable economic recovery.

The EU is upgrading the technology content of its manufacturing industries, but in a less determined way than the US

The EU has a smaller high-tech sector than the United States. High-tech R&D intensity is also lower in the EU than in the United States. Since 1995, the R&D intensity for many manufacturing sectors in the EU has increased at an average annual growth rate of between 2 % and 4 %. This applies in particular to medium-tech or low-tech industries such as textiles, rubber and plastics, and pulp and paper, as well as to large medium-high–tech industries such as chemicals, motor vehicles, and machinery equipment. However, over the same period the average annual growth rate in R&D intensity for such manufacturing in the United States was between 4 % and 8 %. There is also a striking difference for high-tech industries such as computing machinery, medical and optical instruments, which have seen growing research effort in the United States compared to stagnant or decreasing R&D in the EU.

Policies for upgrading manufacturing industries must be differentiated by sector

As the upgrading dynamics and the enablers for innovation differ between industry segments, a sector-differentiated policy is required to foster upgrading and innovation in manufacturing industries. The EU is a world leader in general purpose machinery and machine tools, where Sweden, Austria and the Netherlands have the highest R&D, higher than that of Japan and the United States. However, research at the level of individual firms varies significantly between European countries, both in the automobile industry and in the chemicals industry. This partly reflects differentiated products but may also indicate different corporate cultures with regard to integrating R&D investment in growth strategies. Firms consider funding and skilled personnel as being the most frequent enablers of innovation. However, the relative importance of different drivers and enablers differs between industries.

3.1. Overview of the EU's R&D dynamic in manufacturing industries

Previous chapters in this report have described how the knowledge intensity of the European economy differs from that of the United States ([157]). The EU has a smaller high-tech sector than the United States, with corresponding research and development also lower. Although there has been a modest catching-up in the last 15 years, it is not enough to maintain top competitiveness in the European manufacturing industry overall. A growing number of countries in the world are upgrading their manufacturing industries, injecting knowledge and investments in both high-tech and medium-tech industries.[158] Europe's long-term competitiveness is at stake. Several European countries with a solid manufacturing sector that is focused on high-tech and medium-high–tech sectors have shown greater resilience in the current economic crisis ([159]).

The European manufacturing industry is shrinking, although modestly upgrading in terms of R&D intensity. The competitive effect of these efforts depends partly on the upgrading efforts of main competitors outside Europe

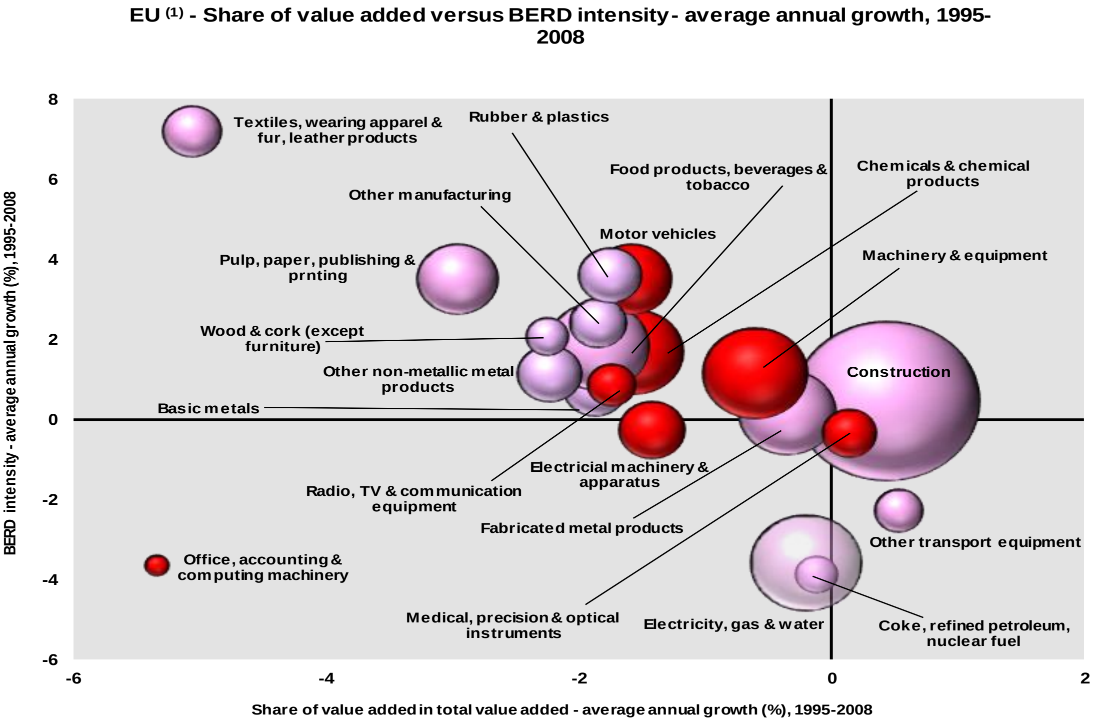
Figure III.3.1 shows that the share of the manufacturing industries in the European economy has lost weight in the economy over the period 1995–2008. For the period 1995–2008, up to the economic downturn, the majority of the manufacturing sectors reduced their share of value added in the European economy, with the exception of transport equipment other than automobiles and aerospace, construction, and medical, precision and optical instruments (illustrated by the leftward move of the sectors in Figure III.3.1). All the other sectors show negative growth. The positive aspect is that during the same period most sectors increased their R&D intensity. This promising trend is visible both for sectors that are already highly R&D intensive (red coloured) and the medium- and low-tech sectors such as textiles or pulp and paper industries.

[157] See Chapter III on Structural change, the introductory chapter 'Europe's competitive position in research and innovation' and Chapter I.3 on business investments in research and innovation.

[158] The term « injecting knowledge into the economy » refers to a form of upgrading, enhancing productivity. This can take the form of developing new processes or products new-to-the-market, capitalising on R&D investments and human resources of the firm. It can also take the form of absorption of existing or new technologies into the production in new-to-the-firm innovation of products, process, organisation and business models.

[159] An analysis of the evolution of the manufacturing industries in each European country can be found in the publication 'Research and innovation performance in EU Member States and Associated countries, 2013', European Commission, 2013.

Figure III.3.1: Evolution of R&D-intensity and structure of EU industry, 1995-2008



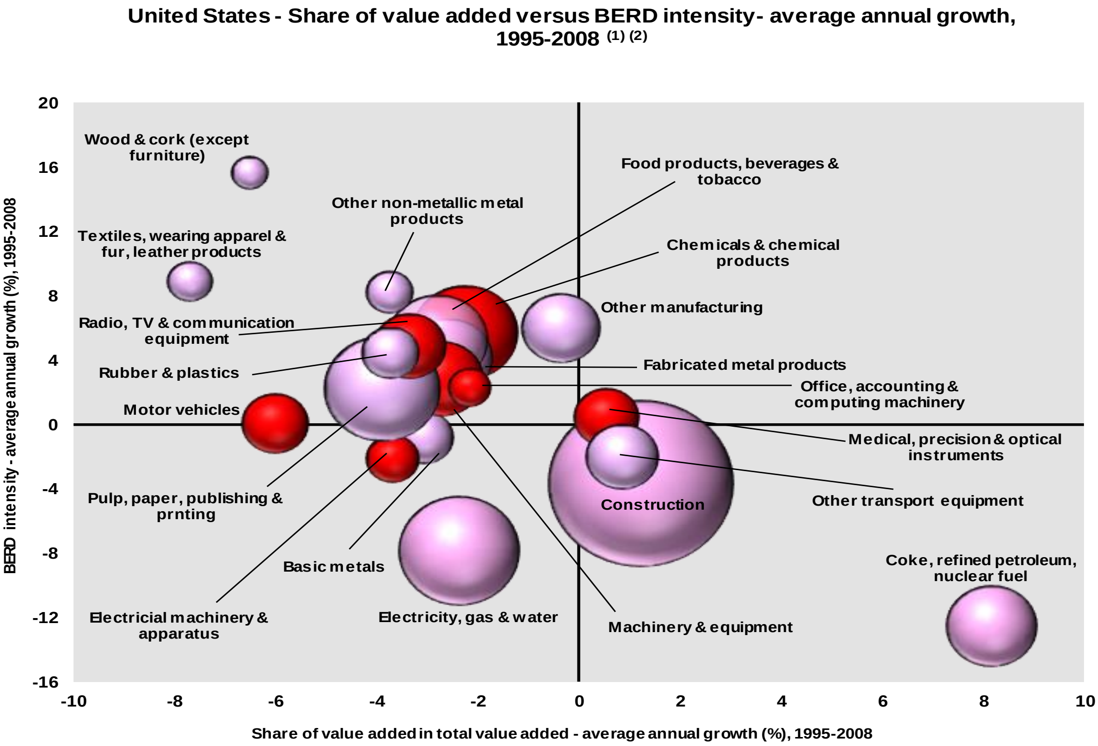
Source: DG Research and Innovation - Economic Analysis unit
Data: OECD
Notes: (1) (i) EU does not include BG, EE, CY, LV, LT, LU, MT, RO; (ii) Elements of estimation were involved in the compilation of the data.
(2) High-Tech and Medium-High-Tech sectors are shown in red. 'Other transport equipment' includes High-Tech, Medium-High-Tech and Medium-Low-Tech.

The competitive effect of this upgrading depends partly on the level of upgrading in each sector in the US, Japan, China and other knowledge-intensive economies.

The US economy displays a similar evolution but with more dynamic upgrading of most manufacturing sector

The United States is facing similar challenges to the EU. The US economy has also registered a relatively modest structural change during the period of 1995–2008 with a contraction of the manufacturing sectors of the economy coupled with a timid upgrading of R&D effort in several industries. However, while average annual R&D growth for most European manufacturing sectors was in the range of 2–4 %, US manufacturing upgraded more intensively, with average annual R&D growth in the range of 4–8 %. At sector level, some differences can be observed when comparing with the EU. The size of the industries varies as well as the evolution of their R&D.

Figure III.3.2: Evolution of R&D and evolution of US industry, 1995-2008



Source: DG Research and Innovation - Economic Analysis unit
Data: OECD
Notes: (1) Coke, refined petroleum, nuclear fuel, Electricity, gas and water, Medical, precision and optical instruments, Other manufacturing: 1995-2007; Construction: 1996-2007; Pulp, paper, publishing and printing: 1999-2007; Wood and cork (except furniture): 1999-2008.
(2) There is a break in series between 2003 and 2004 which affects BERD for Pharmaceuticals, Office, accounting & computing machinery, and Radio, TV and communication equipment,
(3) High-Tech and Medium-High-Tech sectors are shown in red. 'Other transport equipment' includes High-Tech, Medium-High-Tech and Medium-Low-Tech.

Focussing on the high-tech and medium-high–tech sectors (in red in Figure III.3.2), the most striking difference is the 'Office, accounting and computing machinery' and the 'Medical precision and optical instruments' sectors, which are larger in the United States. And while these two industries are upgrading their R&D in the United States, they display a decreasing level of R&D in the EU. The chemicals industry is upgrading its R&D in both continents but this process is twice as dynamic in the United States. On the contrary, the sectors 'Electrical machinery and apparatus' and 'Motor vehicles' are larger in the EU economy and they have both maintained or upgraded their R&D better than their competitors in the US economy. This sub-section will present a more detailed overview of the R&D dynamics in these three strongholds of the European economy ([160]).

[160] Other chapters of the Innovation Union Competitiveness 2013 report presents the research and innovation dynamics in health, ICT and other growing industries (see Chapters II.1, II.4, II.5 and III.5).

The United States has more firms active in the health and ICT sectors and they are more R&D intensive than their competitors in the EU

The European Industrial scoreboard collects data at the company level, focussing on the most R&D-intensive enterprises in the EU and the United States. These data provide a complementary picture to the business enterprise research and development (BERD) data in Figures III.3.1 and III.3.2, illustrating the different sector structures in the EU and in the United States. While the BERD data are based on territory, focussing on the R&D dynamics of firms located in the EU, the Industrial scoreboard data are based on the location of the headquarters, counting all firms headquartered in the EU including their R&D investments in other continents or countries. Industrial scoreboard data are more recent than the business R&D data by manufacturing sector provided by Eurostat. There are also differences in terms of data sources and indicator constructions.

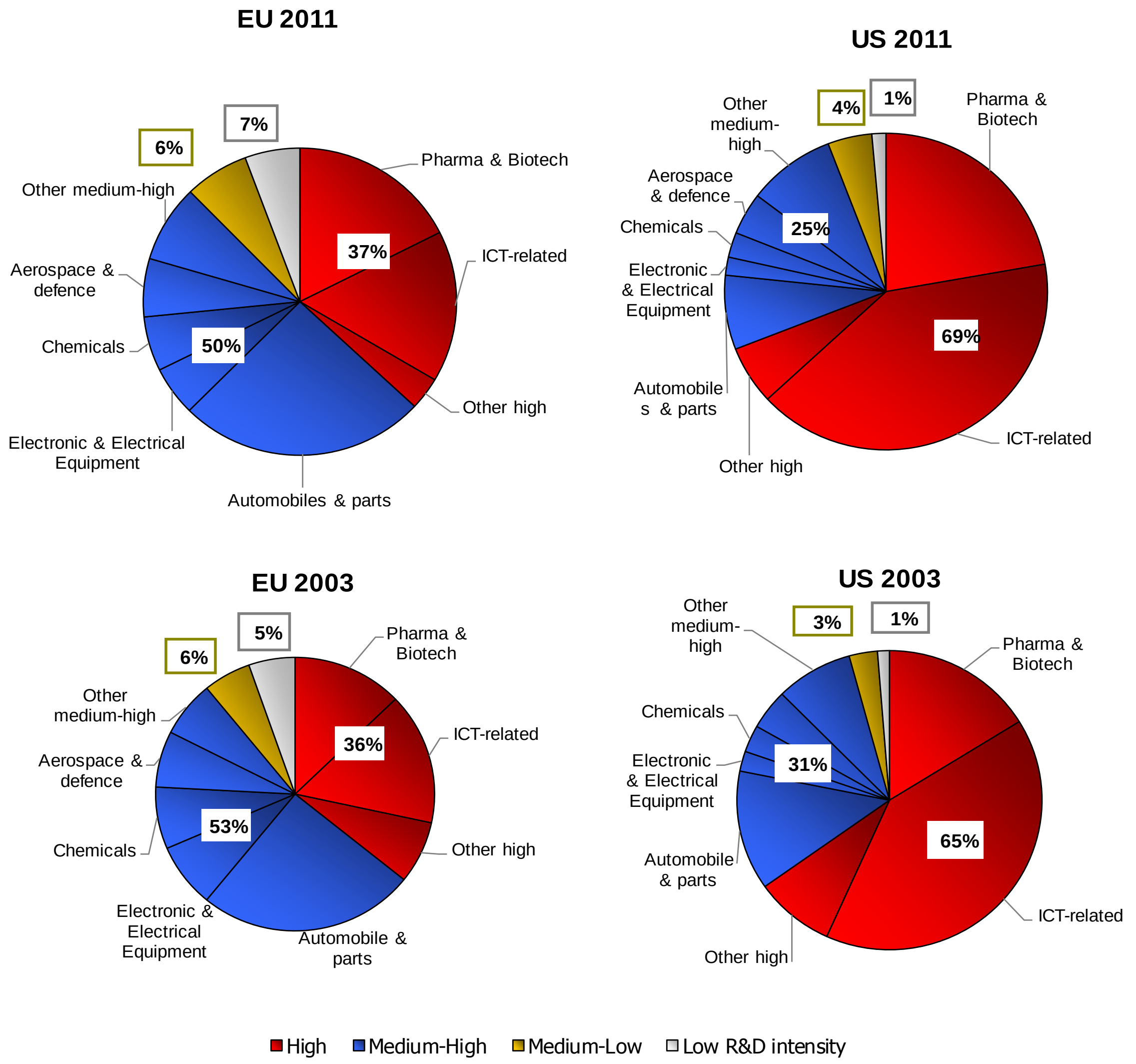
Overall, the EU remains specialised in medium-high R&D-intensive sectors that account for half of European companies' R&D investment. By contrast, more than two thirds of United States companies' R&D investment is clustered in highly intensive R&D- sectors (in particular health and ICT), as evidenced in the structural composition of EU-based and US-based companies in 2003 and 2011. The structural difference between the EU and the United States has been reinforced over the 2000–2011 period. There are contrasting differences between the EU firms and the US companies, in particular for the two sector groups mentioned: 1) health-related sectors including pharmaceuticals and biotechnology, and health care equipment and services, and 2) ICT-related sectors including technology hardware and equipment, and software and computer services.

- The United States has twice as many companies as the EU in health and 3.5 times more companies in ICT.
- In terms of R&D activities, US companies outperform their EU competitors in similar proportions, investing 2 times more in health and 3.3 times more in ICT.
- In terms of net sales, the EU shows slightly higher average sales per company than the United States in the health sector but much lower in ICT.

As a result of the R&D investment and net sales figures, the average R&D intensity of the EU companies is higher in ICT and somewhat lower in health ([161]). Figure III.3.3 also reveals that over the period 2003–2011, the high-tech industries in the United States have expanded more (from 65 % to 69 % of the scoreboard companies), while the EU experienced a lower expansion. The scoreboard companies operating in the medium-high sectors have decreased in numbers both in the EU and US economies.

[161] The 2012 EU Industrial R&D Scoreboard (http://iri.jrc.ec.europa.eu/docs/scoreboard/2012/SB2012.pdf).

Figure III.3.3: Sector composition of the EU and the US R&D-intensive enterprises



Source: 2012 EU Industrial R&D investment scoreboard

If Europe is to face the growing global competition in manufacturing industries by other means than lowering salaries and other costs, then EU policies need to spur upgrading of their knowledge intensity at a faster pace than the main competitors. The world has seen the emergence of the BRIC countries (Brazil, Russia, India, China) with massive investments in R&D and other intangibles. The delocalisation of production in global value chains (GVCs) yields larger profits at the higher end of the value chain. European firms are being forced to upgrade their knowledge management within each sector in order to gain competitive advantage and gain added value in the higher components of the value chain. These efforts must to a larger extent build on the specific innovation drivers in each industry fostering sector-sensitive framework conditions.

3.2. Sector-specific business strategies for R&D investments

Europe is relatively specialised in medium-tech and medium-high–tech manufacturing sectors, with few high-tech sectors like pharmaceuticals and aircraft. Time series data on 25 sectors covering the past decade ([162]) reveal that the EU-28 holds competitive international positions, although not always as world leader, in at least 15 sectors:

- High-tech manufacturing sectors such as pharmaceuticals and aircraft;
- KIS sectors such as telecommunications, computer services, R&D services ([163]);
- Medium-high-tech manufacturing sectors such as basic chemicals; general purpose machinery and machine tools; electrical motors, generators and transformers; motor vehicles;
- Medium-low-tech manufacturing sectors: plastics; non-metallic minerals;
- A mixture of medium-high and medium-low–tech manufacturing sectors: electricity distribution and control apparatus, electricity, gas, water supply;
- A mixture of low-tech and medium-tech manufacturing sectors: food and beverages and production of relevant machinery; textiles and production of relevant machinery;
- Low-tech sectors: construction.

In these sectors, the European position seems quite strong in the short term and the value added has been rising constantly. Each of the two high-tech manufacturing sectors, pharmaceuticals and aircraft, employed around half a million people at the end of the decade and showed a neutral or increasing employment trend. The three KIS sectors where Europe is competitive employed a much larger number of employees (two to seven times larger). The two largest of these sectors kept an increasing employment trend even during the economic crisis, while the third showed a negative tendency.

There are considerable differences among European countries in innovativeness and knowledge, reinforcing the perception that large improvements can still be accomplished inside and across sectors. This requires a mix of horizontal industrial innovation policies coupled with sector-specific policies sensitive to specific innovation drivers in each industry sector. The need to building differentiated framework conditions for each relevant sector is an impending challenge. In the following sub-section, we will present evidence-based support for this approach, first describing more in detail the specific R&D dynamics in three important sectors in the European economy and then, in a second step, an overview of the main institutional settings, enablers and barriers for R&D and innovation in different industries.

[162] Study financed by DG Research and Innovation, 2013, « R&D investments and structural changes in sectors ».
[163] For a more detailed description of these sectors, see Chapter III.5.

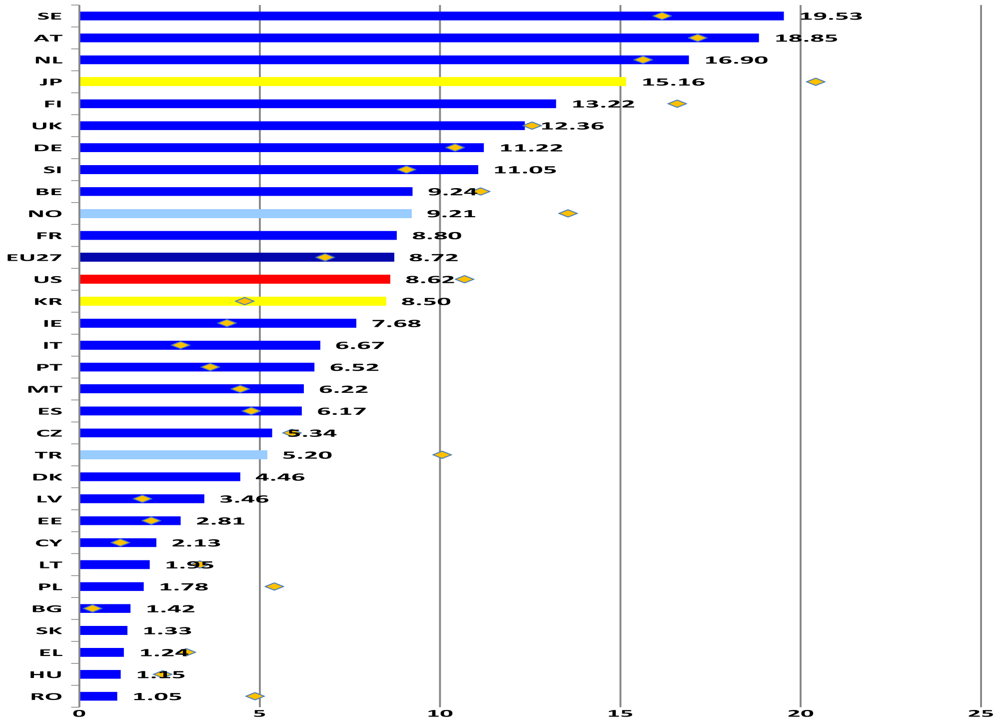
The EU is world leader in general purpose machinery and machine tools, where Sweden, Austria, the Netherlands, Finland, the United Kingdom and Germany show the highest levels of R&D

The EU is the largest producer of mechanical equipment in the world, surpassing both the United States and Japan. In terms of value added, within the EU, Germany, Italy, France and the United Kingdom are the largest producers in the machinery market (representing 70 % of total value added in this industry in the EU) and account for more than 80 % of total BERD in the sector. Germany contributed more than a third of the EU's value added generated in the sector in 2009. The general purpose machinery and machine tools sector also contributes substantially to the gross domestic product (GDP) of Austria, the Czech Republic, Sweden and Finland. Although the sector showed a moderate increase in production over the last decade, it was heavily affected by the last economic crisis.

Small and medium-sized companies play an important role in the sector due to the highly specialised and customised demand for products. For this reason, innovation is strongly demand-based since new products are typically customised to meet specific client needs. Many innovative ideas originate directly from client specifications. Nevertheless, half of the EU's value added for the sector is produced by large companies. Being considered as a medium-high R&D sector, evidence indicates that R&D investments are more important in bigger firms. The sector shows comparatively high levels of R&D and acts as a partial technology provider for scale-intensive industries like the automobile industry, textiles, printing and reproduction, rubber production and plastics.

The European countries with the strongest R&D in the sector are Sweden, Austria, the Netherlands, Finland, the United Kingdom and Germany. Comparable levels can be found in Japan and the United States. According to the Industrial scoreboard, the companies headquartered in Europe with the highest R&D expenditures in the sector are ALSTOM (France), Sandvik (Sweden), Ingersoll-Rand (Ireland) and ABB (Switzerland). Major players headquartered outside Europe are IHI (Japan) and Parker-Hannifin (United States).

Figure III.3.4: R&D in the machinery sector in 2000 *(diamonds)* and 2009



Data: OECD, Eurostat, UNIDO, National Bureaus

In some European countries, R&D in the automotive sector has doubled between 2000 and 2009

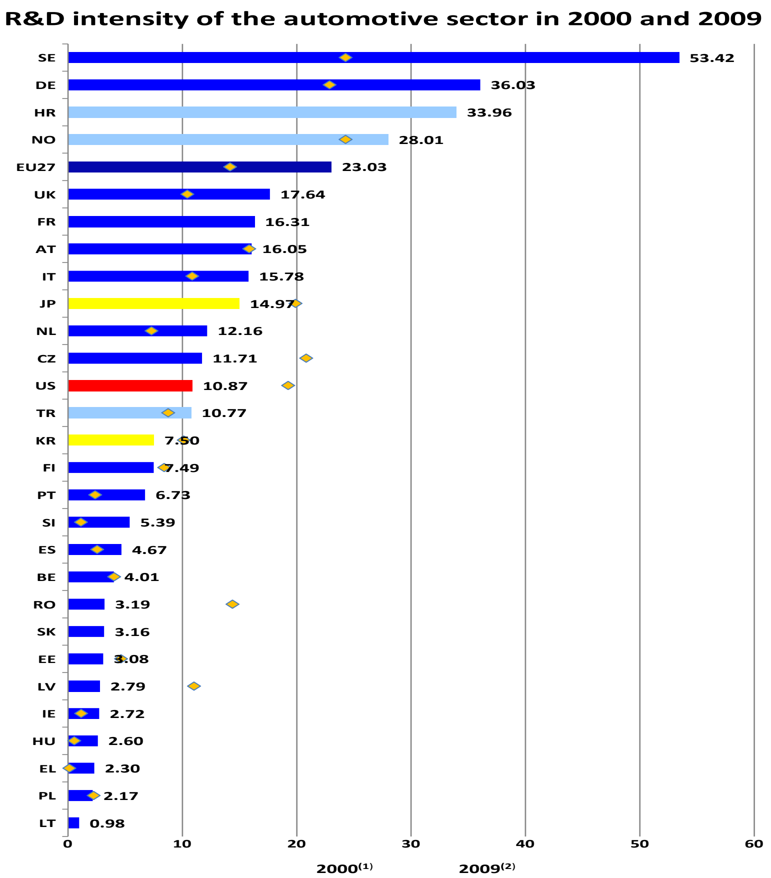
The EU as a whole is a strong player on the global automotive scene but faces fierce competition from the United States and developed Asian countries. In terms of value added, Germany is by far the largest producer in the automotive sector within the EU. Germany contributed more than 45 % of the EU's value added generated in the sector, followed by Italy, France and the United Kingdom. Taken together, these four countries account for almost 70 % of total value added in the automotive sector.

Innovation expenditures in the automotive sector are considerably above the average, but are frequently driven by technological novelties from outside the sector, as is the case with machinery and equipment (see the sub-section above). Most of the value added (60 % to 70 %) of a modern car is now provided by a multi-tier system of suppliers. Vertical integration in automotive production is very heterogeneous. The difference between passenger cars and commercial vehicles is of considerable relevance for innovation and market development. For the period 2000–2006, the value added of the sector in the EU increased on average by 4.3 % but suffered a downturn in 2006–2009, reflecting the impact of the economic crisis that hit the automotive sector in Europe.

The sector is dominated by medium-sized and large firms. In 2007, 88 % of the value added of the automotive sector of the EU was generated by firms with 250 or more employees. In Italy and the United Kingdom, which are two of the main automotive-producing countries in the EU, the share of value added by very large firms is lower, ranging at about 77 % and 78 %, respectively. Small and medium-sized enterprises (SMEs) generate about 50 % or more of value added in Denmark, Finland, Norway and Lithuania, but overall none of these countries are important producers in the sector.

The automotive sector has a particularly high level of R&D expenditure and is a leader in privately funded R&D in Europe. R&D intensity in the automotive sector is higher than in aerospace for example, and much higher than the plastic and machinery sector. In Figure III.3.5, countries are ranked according to their R&D effort in the year 2009. The countries with the strongest R&D in the automobile sector in Europe are Sweden, Germany, Croatia and Norway. R&D intensity in eastern and southern European countries is considerably below the EU average. By 2009, research in the automotive sector in Sweden had more than doubled compared to its level in 2000. It had also increased in Germany, Norway and the EU in general while, for the same period, it decreased in the United States, Japan and South Korea.

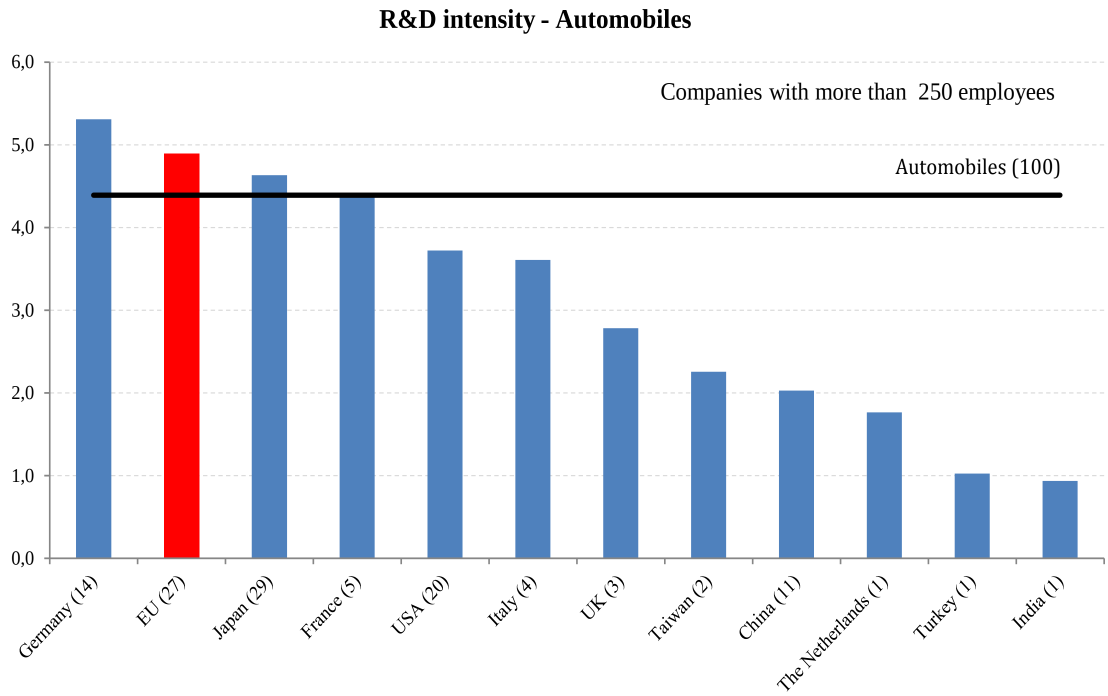
Figure III.3.5: R&D intensity in the automotive sector, 2000 and 2009



R&D at company level within the same industry segment varies significantly between countries

Europe-based automobile sector companies listed in the Industrial scoreboard (following the ICB classification) show different levels of R&D depending on where they have their headquarters. This may be an indication of differing business strategies for research and innovation (R&I) investments between countries. In fact, R&D intensity varies from 5 % in Germany, for Volkswagen, to levels below 4 % in Italy and the United Kingdom.

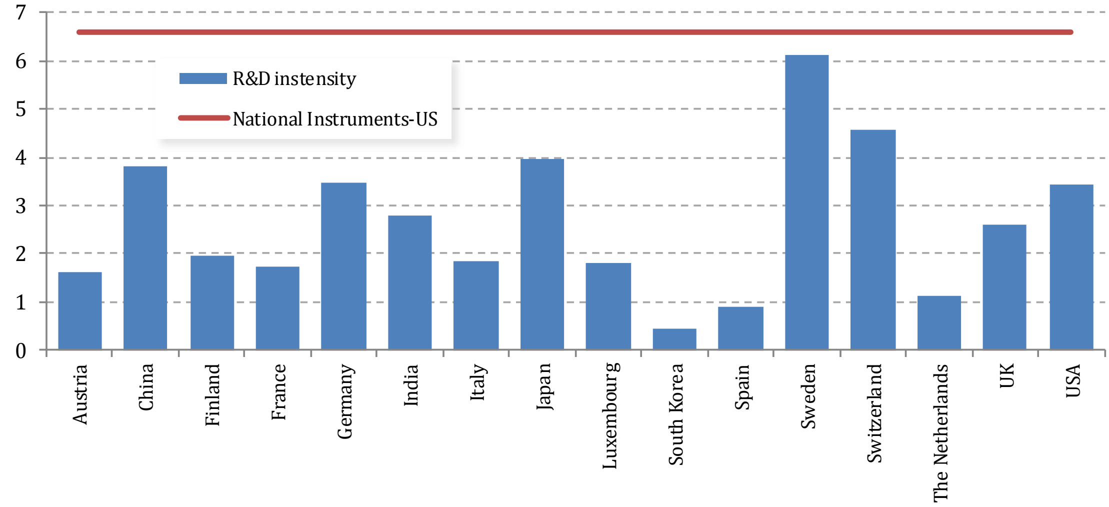
Figure III.3.6: R&D at company level in the automobile sector



Source: DG Research and innovation – Economic Analysis Unit
Data: 2012 EU Industrial R&D Scoreboard

A very different situation is observed in the commercial vehicle and truck sector, where companies from Sweden and Switzerland show levels of R&D much higher than, for example, firms located in the Netherlands, Spain, Finland or France. Surprisingly, Chinese-located companies reach R&D levels similar to those reached by firms located in Japan, and higher than all the other EU countries with the exception of Sweden and Switzerland.

Figure III.3.7: R&D at company level in commercial vehicles and trucks (2753)



Source: DG Research and innovation – Economic Analysis Unit
Data: 2011 EU Industrial R&D Scoreboard

Innovation in the automotive sector is affected by a combination of different factors. In particular, public funding and size of firm seem to correspond with differing levels of R&D and innovation. As regards innovation propensity, cooperation arrangements are also an important driver of innovation. Finally, firm size has a positive effect on R&D and innovation levels. In particular, smaller firms tend to show fewer propensities to engage with R&D and innovation.

R&D in the chemicals sector is highest in developed Asian countries, followed by the EU and the United States

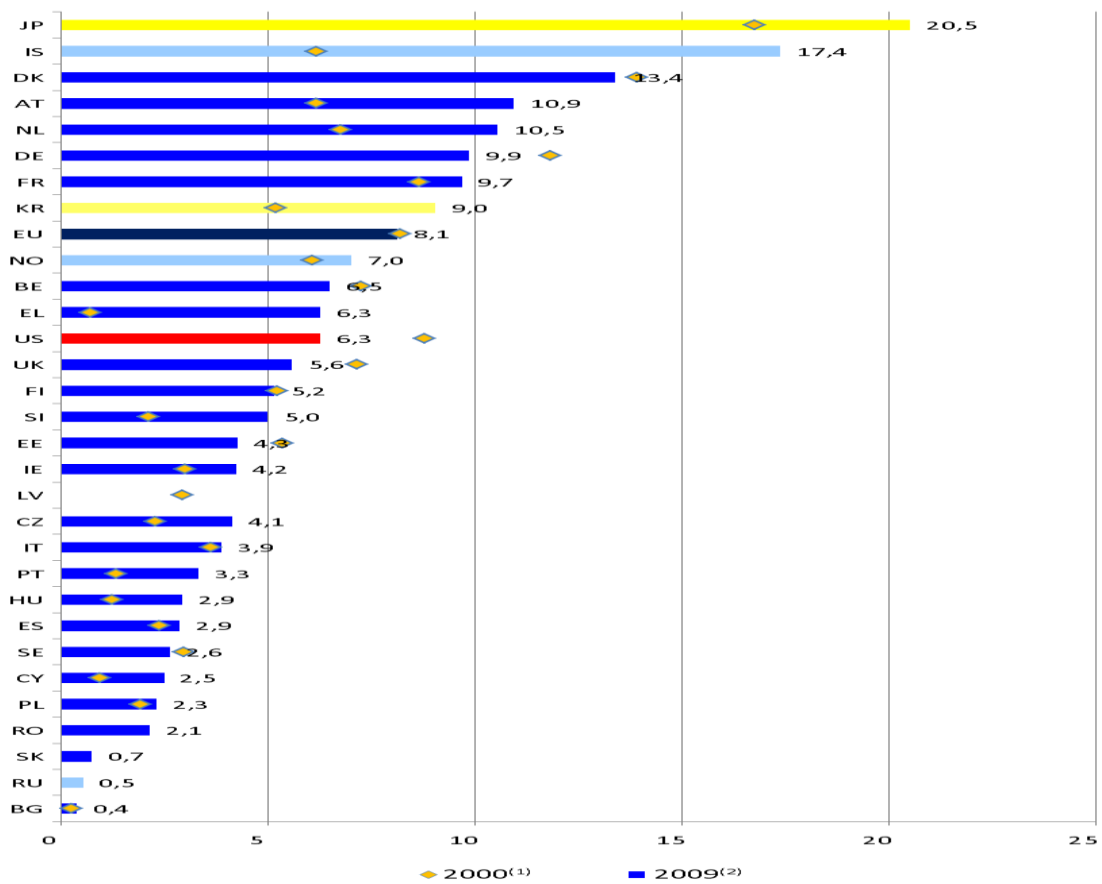
The basic chemicals, paints and glues sector (except pharmaceuticals) is a medium-high-tech sector that is science and R&D-driven. It is a mature and consolidated sector dominated by large firms (two thirds of total value added is produced by large firms). The sector experienced moderate growth during the period 2000–2006 (in average 2.4 %/year) and declined slightly in 2006–2010 (on average – 1.4 % annually), while showing recovery signs in 2010. Although value added increased, employment has been decreasing since 2000 as the sector is becoming more capital intensive and achieving moderate productivity gains.

In Europe the chemicals sector is highly concentrated; eight countries produce 90 % of the total value added, with Germany being the largest producer. Besides Germany, in terms of specialisation and economic growth the sector is important in Sweden, the Netherlands, Belgium and Lithuania. In Eastern Europe, where the chemicals sector is small but growing, numbers of high-growth enterprises can be found (e.g. in Slovakia, Bulgaria, Slovenia, Estonia, Latvia and the Czech Republic). In terms of international competition, out of the top

25 largest players globally ([164]), only eight have headquarters in the EU; the rest are located in the United States or Japan.

Figure III.3.8 shows the ranking (2009) of countries according to their R&D in the chemicals sector (not including pharmaceuticals). The sector is highly R&D intensive with an average R&D of 8.1 % in the EU. In comparison with Asian countries (Japan and South Korea), R&D in the EU chemicals sector has lagged behind, but it is well ahead of the 6.0 % value shown for the United States. Japan has reached a very high level of investment in R&D, which is also verified in the subsequent graph from the Industrial scoreboard.

Figure III.3.8: R&D in the chemicals sector in 2000 and 2009



Data: OECD, Eurostat, UNIDO, National Bureaus
Notes: (1): 2001 (EU, DK, FI, LV,NO); 2002 (AT, BG,EE);
(2): 2007 (BG,FI,EL,SE,SK), 2008 (PL,RO,UK,US,NO); 2006(DK).

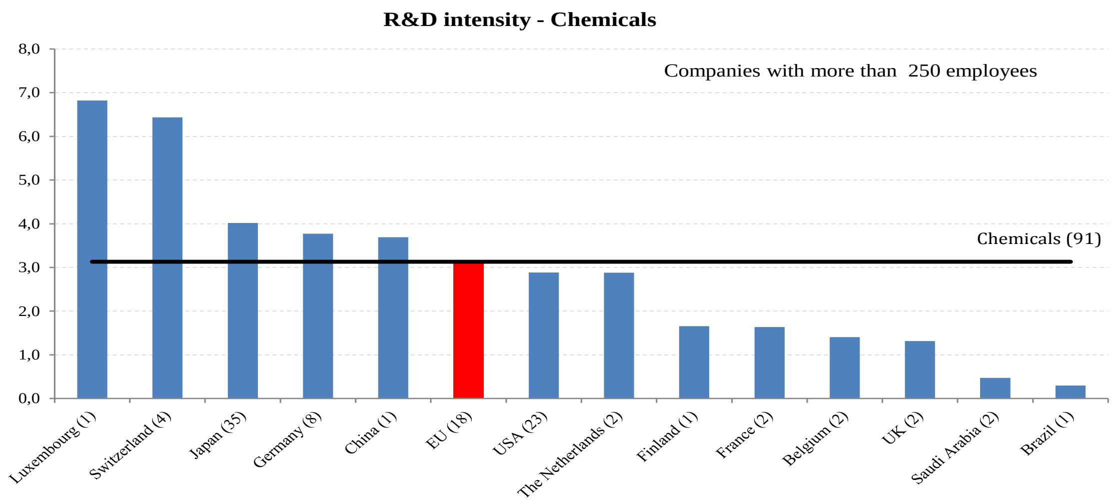
[164] The 2012 EU Industrial R&D Scoreboard (http://iri.jrc.ec.europa.eu/docs/scoreboard/2012/SB2012.pdf). Note: Each company is allocated to the country where its headquarters are located.

The chemicals sector demonstrates different levels of R&D engagement depending on the product and the country

Most R&D investment in the chemicals sector is intramural R&D and most of the innovation takes place in new products (46 %) and production methods (37 %). Evidence indicates that similar factors affect both R&D and innovation in the chemicals sector. In the case of R&D, the perceived importance of increased market share, lack of demand for innovation and public funding (local and national) tend to moderate investments in this activity. For innovation, the importance of increase in market share, flexibility and capacity of production, demand for innovation and public funds play a major part in driving innovation. Firm size is also strongly associated with both R&D investment and innovation. And there are differences between countries in terms of their capability to profit from innovation. The countries that benefit consistently from industrial innovation in the sector include the Czech Republic, France, Lithuania and Sweden.

In the 2012 EU Industrial R&D Scoreboard, two companies from Germany (Bayer and BASF) are part of the worldwide top 25 R&D investors (all sectors). In the top 25 of the chemicals sector, only five European companies are listed (DSM and AKZO Nobel from the Netherlands, Solvay in Belgium, L'Oreal and L'Air Liquide in France). This top 25 list in the chemicals sector is dominated by Japanese and American companies. The basic chemicals sector (chemicals, paints and glues) concerns traditional chemical products that are produced on a large scale. At present, the variety of products produced in the sector explains the very different R&D involvement of the producing companies per country, caused by the degree of specialisation inside the sector. For example, Bayer is registered as a chemical company but is also very active in medical and pharmaceutical products, explaining the company's high R&D investments.

Figure III.3.9: R&D intensity at company level in the chemicals sector



Source: DG Research and innovation – Economic Analysis Unit
Data: 2012 EU Industrial R&D Scoreboard

3.3. Sector-specific innovation drivers

The analysis above illustrates the diversity of R&D-based innovation dynamics depending on industry sector. However, within each industry segment there tends to be an optimal level of R&D intensity towards which most competitive firms strive ([165]). In this context, the above analysis of the machinery, automotive and chemicals sectors shows large national differences in R&D level, both for countries and for firms. Some countries tend to have institutional settings more favourable for business models based on R&D investments. Sector-specific research and innovation policies must therefore take account of these underlying institutional frameworks with a view to incentivising firms to opt for knowledge-based and sustainable business models.

Institutional settings drive innovation but their effect varies between sectors

The institutional setting in a sector comprises the social, market, regulatory and policy pressures for or against innovation. Four generic institutional setting indicators are identified in this analysis: the advancement of regulations or standards, the competitiveness of the market (or the dominance by established enterprises), the sophistication of demand for innovations, and the pressure to reduce environmental impact ([166]). Depending on the industry segment, each of these factors influences innovation to some extent.

The empirical evidence is based on the European Community Innovation Survey (CIS). Firms were asked whether their product (goods and services) and process innovations met regulatory requirements and if their innovations reduced environmental impact or improved health and safety. Regarding the hampering factors of the institutional setting, firms were asked whether their innovation activities were hampered due to the market dominance of established firms or if they did not innovate because there was a lack of demand for innovations. In a sample of 25 different sectors, these four indicators are perceived as affecting the innovative activities to a different extent depending on the sector. For many industry sectors, the domination by incumbent firms acts against innovation and is considered the main obstacle. On the other hand, a large number of sectors consider the need to meet standards and regulations of higher importance for their innovation efforts, as in the cases of the automotive ([167]), pharmaceuticals and recorded media sectors.

Certain traditional sectors like food and beverages, textiles and chemicals, but also telecommunications, manufacture of office machinery, reproduction of recorded media and related manufactured goods, as well as services for computer and related activities, claim that the market dominance of established firms is the main hampering factor for their innovation activities. Surprisingly, in a majority of the industry sectors, firms considered a lack of demand for innovations as of reduced importance for their activities. Environmental impact

[165] See also the European Science, Technology and Competitiveness report, 2008/2009.

[166] Based on the Community Innovation Survey (CIS 2006).

[167] In the case of the automotive sector, the most important regulations concern safety standards, environmental compatibility, norms and standardisation as well as intellectual property rights regulations.

for a progress towards a greener production (also directly connected with regulations and with meeting the EU targets by 2020) is of higher importance for sectors for which the goods are directly linked with environmental sustainability. This is the case for chemicals, recycling collection, purification and distribution of water sectors, and also important to a lesser extent for the automotive, aerospace, food and beverages, rubber and plastics sectors, as well as services for R&D.

Figure III.3.10: Institutional settings driving innovation in the sector

	Demand for innovation	Standards and regulations	Competition	Reducing Environmental impact (towards a greener production)
Food & beverages	Less relevant	52 %	46 %	49 %
Textiles	30 %	37 %	41 %	Less relevant
Reproduction of recorded media and related manufactured goods sector	Less relevant	Less relevant	73 %	Less relevant
Manufacturing of basic chemicals, paints and glues	Less relevant	56 %	48 %	60 %
Pharmaceuticals	Less relevant	55 %	47 %	48 %
Rubber and Plastics	Less relevant ([168])	42 %	42 %	44 %
Manufacturing of other non-metallic mineral products	20 %	Less than 20 %	40 %	Less than 20 %
General purpose machinery	23 %	46 %	40 %	40 %
Manufacture of office machinery and computers	Less relevant	Less relevant	47 %	Less relevant
Manufacture of electric motors, generators and transformers	Less relevant	48 %	40 %	Less relevant
Manufacture of Electricity Distribution and Control Apparatus	Less relevant	30 %	30 %	
Manufacture of Electronic Valves and Tubes and Other Electronic Components	25 %	???	30 %	Less relevant
Manufacture of medical and surgical equipment and orthopaedic appliances	Less relevant	45 %	42 %	36 %
Manufacture of instruments and appliances for measuring, checking, testing, and optical instruments and photographic equipment	Less relevant	40 %	40 %	40 %
Automotive	23 %	40 %	40 %	48 %
Aerospace	Less relevant	43 %	40 %	40 %
Recycling	Less relevant	43 %	33 %	52 %
Performance in the collection, purification and distribution of water	Less relevant	56 %	Less relevant	57 %
Construction	40 %	22 %	34 %	Less relevant
Cargo handling and storage	35 %	37 %	30 %	41 %
Telecommunications	Less relevant	30 %	48 %	Less relevant
Services for computer and related activities	Less relevant	29 %	43 %	Less relevant
Manufacture of lighting equipment and electric lamps	Less relevant	51 %	43 %	45 %

[168] Given that data are not available for countries dominating the machinery and equipment production sector, we cannot expect a true representation of the entire sector. The vast majority of responding firms belonged to small- to medium-sized component producers in the sector.

	Demand for innovation	Standards and regulations	Competition	Reducing Environmental impact (towards a greener production)
Manufacture of television and radio transmitters and receivers	Less relevant	38 %	42 %	35 %
Services for research and development	Less relevant	46 %	42 %	46 %

Funding and skilled personnel are the most frequent capabilities and enablers of innovation while the importance of other enablers differs between industries

Establishing adequate institutional drivers is not enough. For effective innovation and upgrading to take place, policies must also enhance a firm's capacity to innovate. The capabilities and enablers of innovation are therefore considered as critical factors for an effective upgrading, and they are also sector-sensitive. Evidence from the CIS reveals that despite a favourable business environment and the appropriate institutional setting, the lack of knowledge and capabilities to actually innovate is an important hampering factor. There is sufficient empirical evidence in the literature to state that the higher the capabilities the higher the propensity to innovate ([169]). However, the type of capability and the impact of increased capabilities on innovation differ depending on the industry segment.

For this analysis, several indicators were chosen to indicate the lack of capabilities or enablers hampering innovation ([170]): lack of outside funds, lack of qualified personnel, lack of information on technology, lack of information on markets and difficulty in finding cooperation partners. Different sectors perceive these indicators differently. However, the lack of external funding (and even more so the lack of internal funding, as evidenced by CIS 2006) and the lack of qualified personnel are shared concerns by companies in the majority of the 25 sectors, highlighting them as clearly hampering innovation. This last aspect is also highlighted by firms in the service sector, where specialised staff and specific skills are crucial to an even larger extent than in the manufacturing sectors ([171]). For the majority of the sectors reviewed, the firms surveyed did not stress the lack of information on technologies as hampering their innovative output, although for some industry segments it applied to 30 % of the cases.

The difficulty in finding cooperation partners was also in general highlighted by 30 % of the firms, and in particular by firms providing services for computer and related activities (50 % of these firms considered that finding partners for cooperation was important for their innovation). Some sectors present a higher sensibility in what concerns access to funding; this is the case for services for R&D, services for computer and related activities, food and beverages, and in general the manufacture of machinery and instruments.

[169] Sector Study prepared for the Directorate-General for Research and Innovation (DG RTD) ; Montalvo, 2006 and Wehn, 2003.

[170] Other indicators were also used in the CIS, such as lack of funds within the company or the group of enterprises, lack of information on markets or cooperation arrangements on innovation activities. Figure III.3.11 only focuses on four indicators.

[171] See also Chapter III.5.

Figure III.3.11: Barriers to capabilities and enablers of innovation

	Lack of external funding	Difficulty in finding co-operation partners	Lack of information on technologies	Lack of qualified personnel
Food & beverages	50 %	30 %	30 %	50 %
Textiles	43 %	30 %	30 %	43 %
Reproduction of recorded media and related manufactured goods sector	48 %	Less relevant	Less relevant	42 %
Manufacturing of basic chemicals, paints and glues	36 %	Less relevant	32 %	30 %
Pharmaceuticals	37 %	30 %	Less relevant	30 %
Rubber and Plastics	45 %	30 %	Less relevant	44 %
Manufacturing of other non-metallic mineral products	40 %	30 %	30 %	41 %
General purpose machinery	44 %	10 %	Less relevant	45 %
Manufacture of office machinery and computers	33 %	29 %	27 %	33 %
Manufacture of electric motors, generators and transformers	40 %	30 %	Less relevant	40 %
Manufacture of Electricity Distribution and Control Apparatus	40 %	30 %	Less relevant	29 %
Manufacture of Electronic Valves and Tubes and Other Electronic Components	31 %	Less relevant	Less relevant	30 %
Manufacture of medical and surgical equipment and orthopaedic appliances	41 %	Less relevant	Less relevant	40 %
Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, industrial process control equipment and optical instruments and photographic equipment	44 %	Less relevant	Less relevant	46 %
Automotive	38 %	Less relevant	26 %	38 %
Aerospace	43 %	Less relevant	Less relevant	43 %
Recycling	37 %	25 %	25 %	38 %
Performance in the collection, purification and distribution of water	48 %	Less relevant	Less relevant	32 %
Construction	33 %	Less relevant	Less relevant	33 %
Cargo handling and storage	28 %	Less relevant	Less relevant	28 %
Telecommunications	41 %	Less relevant	Less relevant	46 %
Services for computer and related activities	45 %	50 %	Less relevant	41 %
Manufacture of lighting equipment and electric lamps	46 %	28 %	36 %	46 %
Manufacture of television and radio transmitters and receivers	37 %	Less relevant	Less relevant	41 %
Services for research and development	63 %	30 %	Less relevant	40 %

4. Specialisation and innovation in global production chains

Highlights

The EU is still competitive in terms of income from the globalisation of production

Up to 2008, the EU maintained its world share of Global Value Chain (GVC) income, which represents the income earned by the EU from the consumption of world manufactured products. In contrast to other advanced economies, the EU still holds a manufacturing GVC share above its overall GDP share in the world economy. The EU also improved its performance with respect to GVC income in business services although it is still lagging behind the US in this respect. However, since 2008, the EU share in manufacturing global value chain income has been slowly declining.

Within manufacturing, the EU's higher share of GVC income was mainly driven by its position in medium-high and high-tech manufacturing industries. However, this positive performance was achieved only by a subset of EU countries, which successfully maintained and even expanded their competitive positions in higher-tech manufacturing, and was driven by increasing integration of production within the European single market.

The economic crisis has weakened intra-European integration; value chains are increasingly moving outside of Europe

The EU as a whole, as well as its individual Member States, has become more integrated in world production networks with a higher level of vertical specialisation. For the eastern European countries, this integration process was to a large extent based on intra–EU integration. However, the economic crisis has changed these trends significantly. While extra–EU integration is still expanding, driven by GVC links to China and other growing economies, intra–EU integration of production has declined.

Highly skilled labour, R&D intensity and innovation enhance global value chain income

This econometric study has focused on the relative role of knowledge and innovation as a basis for comparative advantage in global value chain income. The study revealed some differences with respect to EU intra- and extra-vertical specialisation patterns. Highly skilled labour, R&D intensity and innovation are positively related to higher GVC income. More advanced countries (i.e. those countries characterised by higher labour productivity and endowment with skilled workers, as well as higher R&D expenditure) tend to deliver value-added intensive inputs to assembly countries. They also have lower imports of value added. However, local advantages as well as cost considerations for skilled workers still play very important roles in attracting global value chains to a target country for production relocation.

Introduction

At a global level and inside Europe, the fragmentation of production has increased significantly. EU firms and industries are more and more engaged in international production activities within the EU but also globally. Offshoring and offshore outsourcing is becoming increasingly important, and consequently trade between countries is gaining a larger share in support industries (e.g. parts and components). Therefore national exports and production of final goods and a country's exports have a larger import component.

For many countries this leads to a higher degree of vertical specialisation, with each country specialising in a particular production stage within industries. In this sense, a country or region can reap income not only by competing at the industry level but also at the level of production activities, allowing for finer-grained specialisation patterns of countries or regions. This is made possible by sourcing other inputs from abroad. Innovation and gains in competitive advantages through differentiation of products, cost reductions, productivity gains, and international vertical integration allowing for specialisation at several stages of the production process, can play an important role in raising a country's income.

From the perspective of the EU, production fragmentation and specialisation of different countries and regions into certain production activities can yield overall benefits for all partners involved. Successful examples for such a strategy are the evolution of the automobile cluster comprising Germany, Austria and a number of eastern European countries like the Czech Republic, Slovakia and Hungary, which have integrated their respective production lines. Such a successful division of labour by production integration, FDI flows and smart specialisation patterns has allowed countries and regions to increase their incomes and also made it possible to compete successfully at the level of the specific goods produced along these value chains. Such integration scenarios within the EU overlap with production fragmentation at world level, where China in particular has become an important player. Thus, attention also has to be paid with respect to extra-EU integration patterns that might replace or complement intra-EU integration.

This section first analyses the distribution of income generated by global value chains (GVC) and the current position of individual EU Member States in this respect. Trends and changes over time for the period 1995–2011 for countries and goods are also shown. Second, it examines the variables that determine GVC income generation and reveals the relative importance of locational, cost-related and innovation factors. The section draws on the world input–output tables (WIOD) calculating the income a country generates for a specific product or final output sold to the final market elsewhere in the world. The WIOD has been created recently within the EU's Seventh Framework Programme (FP7) and provides WIODs for 41 countries and 35 industries over the period 1995–2011 (for details, see Timmer, 2012 and Dietzenbacher et al., 2013).

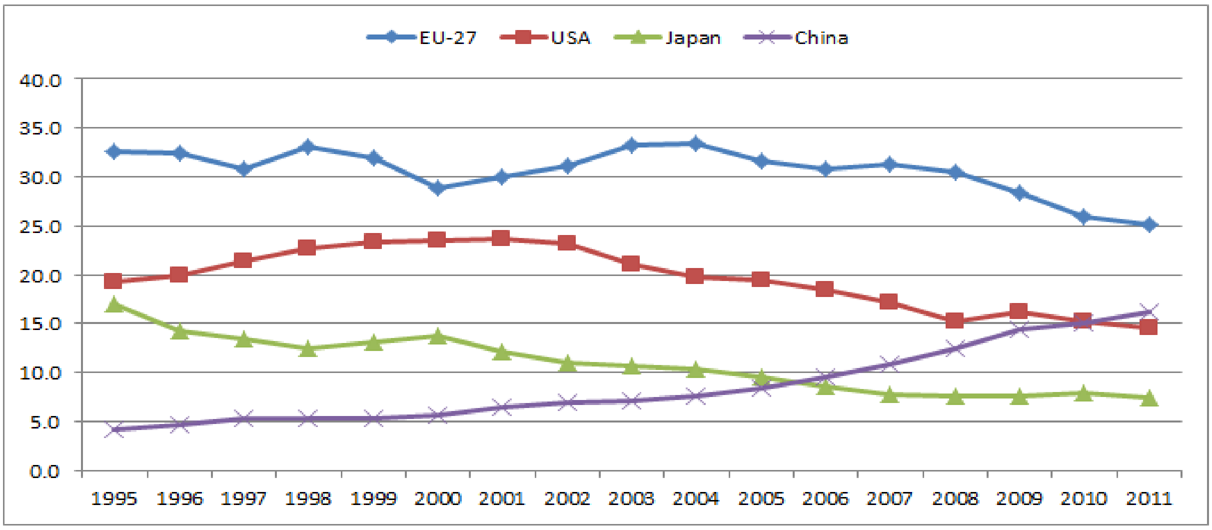
4.1. World distribution of manufacturing global value chain income

Before going into more detail, it is interesting to look at the broader sectoral trends focussing on manufacturing GVC income, by first comparing the performance of the EU with other major economies like the United States, Japan and China. Figure III.4.1 presents the value added that the EU and its competitors earn in world-total sales of manufacturing final products as a percentage of total-world manufacturing GVC income over the period 1995–2011.

The EU maintained its world share of Global Value Chain income up to 2008, after which it lost its relative weight

The share of the EU has been roughly constant at 33 % on average until 2008 when it started to decline. At the same time, the shares of the United States and Japan have been on a declining trend over a long period, which for Japan can be observed over the whole period and for the US starting at around 2000. By contrast, China's share increased from about 5 % in 1995 to more than 15 % in 2011.

Figure III.4.1: World shares of manufacturing global value chain (GVC) income



Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
WIOD; author's calculations; graph adapted from Timmer et al, 2012

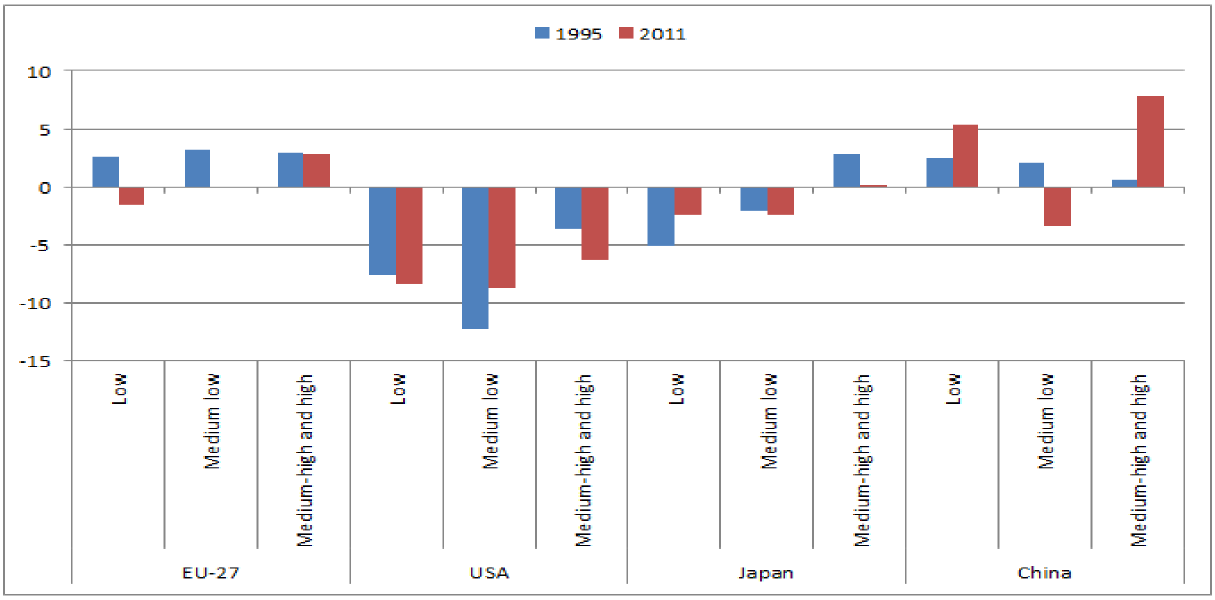
The EU has lost competitiveness in low and medium-low sectors but remains competitive in medium-high-tech and high-tech sectors

From a competition perspective, it is more interesting to consider the contributions of the particular sectors relative to a country's overall GDP share, in order to identify competitive advantages. Figure III.4.2 therefore presents the deviations of the shares of GVC income to the EU-27 overall GDP share in the world economy for the manufacturing sector split into low-tech, medium-low-tech, and medium-high-tech and high-tech sectors. More importantly, there are some trends in these three broad manufacturing sectors that deserve attention.

In the low-tech and medium-low-tech sectors, the EU in 1995 showed somewhat higher GVC income share compared to the overall GDP share, which turned negative in 2011. This means that EU industries contribute less to world manufacturing of these products relative to their share in world GDP. From this perspective, the EU has lost competitiveness in GVCs in these sectors, which may not be too surprising given the fact that developing and emerging economies are more likely to be able to specialise in these sectors when climbing up the value chain.

In the medium-high-tech and high-tech sectors, the EU maintains shares that have remained more or less above its overall share in world GDP. Thus, even though the EU has lost GVC income shares, it did so in relation to its overall shares in world GDP. This is quite different from the position of the United States, which - despite existing gaps in 1995 - shows a decline in the low-tech, medium-high tech and high-tech industries, though gaining shares (in relative terms) in the medium-tech industries. Japan more or less preserves the gap of 2 % in the medium-low-tech industries, yet loses in the medium-high-tech and high-tech industries and gains in the low-tech industries. Finally, China gains in relative shares in the low-tech and even more so in the medium-high-tech and high-tech industries, but loses out in the medium-low-tech industries.

Figure III.4.2: Deviations of manufacturing GVC income by broad industry groups, in percentage points



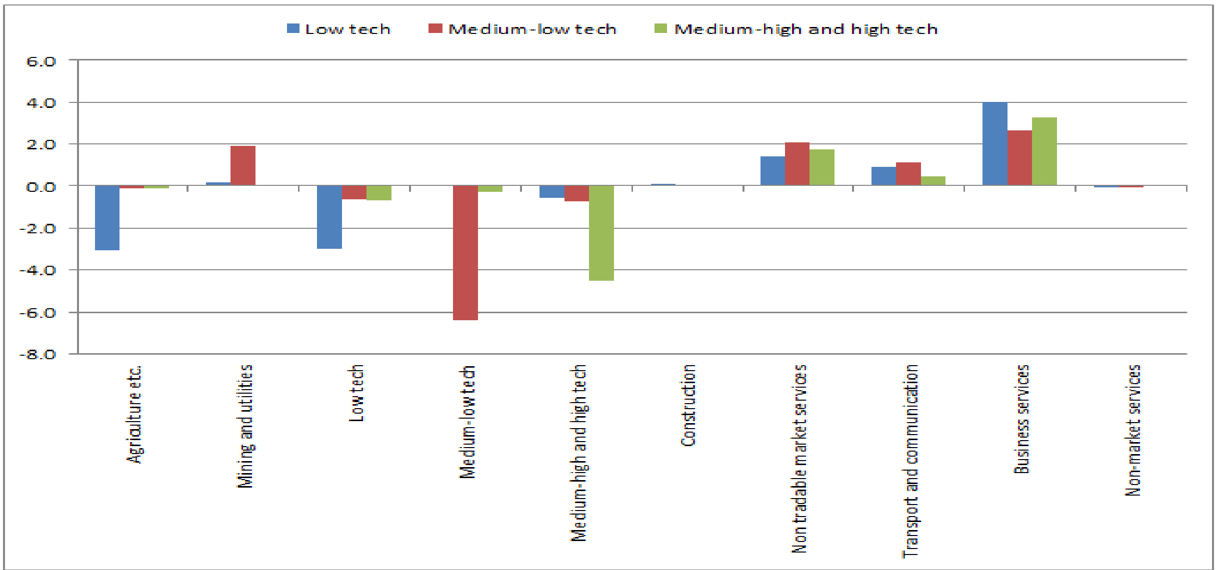
Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: WIOD; author's calculations

The EU is specialising and gaining competitiveness in business and other market services

The second important dynamic is taking place in the business services sector. Whereas in 1995 this sector was contributing below the EU world share in GDP by about 3 %, this deviation vanished and even turned slightly positive in 2011, indicating that the EU was specialising directly and indirectly in delivering to the output of business services. However, looking at US performance we find that the United States kept a rather strong position of GVC income relative to its share in world GDP of about 8–9 %, whereas Japan was catching up from a gap that was and is even larger than that of the EU. China loses out in that sector as the gap widens from -1.2 % in 1995 to -5.8 % in 2011.

This evolution is also visible when considering the changes in value added in GVC income over the period 1995–2011. In fact, a country's contribution to manufacturing, for instance, an electronic product might over time shift towards the provision of services like design rather than material inputs. Figure III.4.3 highlights the changes over time in the structure of EU manufacturing GVC income by presenting the differences in the shares between 1995 and 2011 in percentage points. Most strikingly, the contribution of EU value added creation was declining substantially for GVC income in all three manufacturing industry groups. These shares declined in the low-tech industries by 3 % and even more so by about 6 % and 4 % respectively in the medium-low-tech, and medium-high-tech and high-tech industries. Also, the shares of the other industries in GVC income also declined, though much less with about 0.5 percentage points. By contrast, the share of service activities, particularly business services, became a more important part of the manufacturing GVC income by broad industries.

Figure III.4.3: Changes in value added structures of GVC income of broad manufacturing sectors in EU-27, 1995-2011



Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: WIOD; author's calculations

The first important implication from these shifts of activities within GVCs in a particular country — and in particular the shift towards services — is that inter-industry linkages of production of manufacturing products become more important and production becomes more service intensive in general. Therefore, not only is the performance of an industry in one sector important for its relative success, but also its performance in other industry sectors. For example, service activities like design, R&D, marketing, repair and maintenance are becoming success factors broadening the aspects of industrial policies. A second point might be that the decline of EU industry inputs can be driven by patterns of (narrow) offshoring; that is, activities within the industry are offshored to other countries. Although there might be direct losses from the shifting of activities abroad, such a scenario might have positive effects on a country's and a sector’s competitive position (international patterns of vertical specialisation). This also reflects a specialisation of countries along the value chains into higher value added intensive activities (like services).

4.2. EU Member States' positions in Global Value Chain income

Figure III.4.4 presents each country's share of manufacturing GVC income in the broad manufacturing sectors, together with the differences to their shares in world GDP in 1995 and 2011 and the change over this period in percentage points.

Figure III.4.4: EU Member States global value chain (GVC) income shares by broad manufacturing industry groups in %, 1995 and 2011

	Low tech				Medium-low tech				Medium-high and high tech				Business services			
	Share in GVC		Deviation		Share in GVC		Deviation		Share in GVC		Deviation		Share in GVC		Deviation	
	1995	2011	1995	2011	1995	2011	1995	2011	1995	2011	1995	2011	1995	2011	1995	2011
Belgium	1.04	0.68	0.10	-0.04	1.22	0.95	0.29	0.23	1.08	0.75	0.14	0.03	0.78	0.85	-0.15	0.13
Bulgaria	0.10	0.11	0.05	0.04	0.05	0.09	0.00	0.02	0.03	0.05	-0.01	-0.01	0.02	0.02	-0.02	-0.05
Czech Republic	0.26	0.34	0.08	0.05	0.31	0.39	0.13	0.10	0.19	0.53	0.01	0.23	0.14	0.21	-0.05	-0.08
Denmark	0.75	0.41	0.18	-0.03	0.46	0.42	-0.11	-0.02	0.45	0.38	-0.12	-0.07	0.45	0.44	-0.12	0.00
Germany	7.67	4.31	-0.53	-0.72	10.19	6.32	1.99	1.28	11.46	9.04	3.26	4.00	6.60	4.67	-1.60	-0.37
Ireland	0.40	0.41	0.18	0.10	0.19	0.21	-0.02	-0.10	0.27	0.42	0.06	0.12	0.17	0.28	-0.05	-0.03
Estonia	0.03	0.04	0.01	0.01	0.01	0.02	0.00	-0.01	0.01	0.02	-0.01	-0.01	0.01	0.02	-0.01	-0.01
Greece	0.52	0.42	0.10	0.01	0.26	0.33	-0.16	-0.08	0.10	0.09	-0.32	-0.32	0.32	0.22	-0.10	-0.19
Spain	2.41	1.96	0.44	-0.13	1.48	1.30	-0.49	-0.79	1.67	1.57	-0.30	-0.52	1.15	1.87	-0.82	-0.22
France	4.29	3.04	-0.74	-0.83	4.41	3.38	-0.62	-0.49	4.90	3.52	-0.13	-0.35	5.53	4.34	0.50	0.47
Italy	5.16	3.64	1.48	0.61	4.38	2.84	0.70	-0.19	4.02	3.11	0.33	0.08	2.92	2.38	-0.76	-0.65
Cyprus	0.04	0.02	0.01	-0.01	0.02	0.01	-0.01	-0.02	0.01	0.01	-0.02	-0.03	0.03	0.03	0.00	0.00
Latvia	0.03	0.04	0.01	0.00	0.01	0.02	0.00	-0.02	0.01	0.02	-0.01	-0.02	0.01	0.04	0.00	0.00
Lithuania	0.04	0.09	0.01	0.03	0.03	0.07	0.01	0.01	0.01	0.03	-0.01	-0.03	0.01	0.03	-0.02	-0.03
Luxembourg	0.06	0.07	-0.01	-0.02	0.07	0.06	0.01	-0.02	0.06	0.07	-0.01	-0.02	0.09	0.14	0.02	0.06
Hungary	0.24	0.22	0.09	0.03	0.20	0.29	0.06	0.10	0.13	0.36	-0.02	0.16	0.11	0.13	-0.04	-0.07
Malta	0.02	0.01	0.01	0.00	0.02	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.01	-0.01	-0.01
Netherlands	1.76	1.32	0.38	0.14	1.71	1.46	0.33	0.29	1.22	1.13	-0.16	-0.05	1.72	1.59	0.34	0.41
Austria	0.80	0.54	0.03	-0.04	1.03	0.65	0.27	0.07	0.69	0.69	-0.08	0.11	0.53	0.51	-0.24	-0.07
Poland	0.75	1.02	0.29	0.32	0.52	1.03	0.07	0.33	0.36	0.74	-0.09	0.04	0.23	0.61	-0.22	-0.09
Portugal	0.58	0.37	0.21	0.05	0.29	0.22	-0.08	-0.11	0.22	0.19	-0.14	-0.13	0.24	0.31	-0.12	-0.01
Romania	0.25	0.42	0.13	0.16	0.17	0.36	0.04	0.10	0.11	0.23	-0.02	-0.03	0.06	0.10	-0.06	-0.16
Slovenia	0.09	0.06	0.03	-0.01	0.08	0.06	0.01	-0.01	0.08	0.09	0.01	0.02	0.05	0.06	-0.02	0.00
Slovak Republic	0.10	0.14	0.03	0.01	0.08	0.17	0.02	0.04	0.07	0.21	0.00	0.07	0.05	0.13	-0.02	-0.01
Finland	0.48	0.30	0.06	-0.05	0.37	0.28	-0.05	-0.08	0.46	0.37	0.04	0.02	0.32	0.25	-0.10	-0.10
Sweden	0.74	0.55	-0.08	-0.19	0.61	0.56	-0.20	-0.18	1.12	1.06	0.30	0.32	0.73	0.69	-0.09	-0.04
United Kingdom	3.75	2.29	-0.04	-1.09	4.82	2.90	1.03	-0.47	4.00	2.61	0.21	-0.76	4.17	4.70	0.39	1.33

Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: WIOD; author’s calculations

One group of European countries with close production links has been successfully improving its position in the medium-high-tech and high-tech industries

In the medium-high-tech and high-tech industries, national shares relative to overall GDP shares increased particularly in Austria, the Czech Republic, Germany, Hungary, Poland and Slovakia together with Ireland and the Netherlands, with some others showing less significant but still positive changes. In other countries, particularly the United Kingdom, Spain, France and Belgium, these shares were on a decline relative to their overall GDP shares, thus indicating that these countries provide fewer inputs — directly and indirectly — to the output of medium-high–tech and high-tech industries.

For the low-tech industries, relative GVC shares declined in almost all countries, particularly in Spain, the United Kingdom and Italy. This is also more or less the case in the medium-low-tech industries, where almost all countries lost in relative terms. In this case, the United Kingdom but also Germany and Italy lost in relative terms, whereas some countries could significantly gain (e.g. Denmark, France, Greece and Poland).

When looking at (Figure III.4.4 in more detail, there are three aspects worth highlighting. First, Germany seems to possess an outlier position in the medium-high–tech and high-tech industries. This group includes machinery (NACE 29), transport equipment (NACE 34t35) apart from Chemicals (NACE 24), and electrical and optical equipment (NACE 30t33). Particularly for the first two industries, Germany had a comparative advantage already in 1995, which it expanded over the period considered.

The second important aspect is that the set of countries also experiencing relative gains in these sectors — the Czech Republic, Austria, Hungary, Poland, the Netherlands and Slovakia, to name the most important ones — are closely related to Germany by being neighbours or have successfully integrated (e.g. Slovakia) into these sectors' production linkages. The third aspect is that almost all Member States have lost relative shares in the low-tech sectors. For the medium-low-tech sectors the evidence is more mixed: for example, Germany, Spain, Italy and the United Kingdom lost in relative shares whereas other countries like Poland, Denmark and France experienced small gains. Moreover, Spain, Italy and the United Kingdom lost in relative terms in all three groups relatively strongly, though relatively less in the medium-high-tech and high-tech sectors.

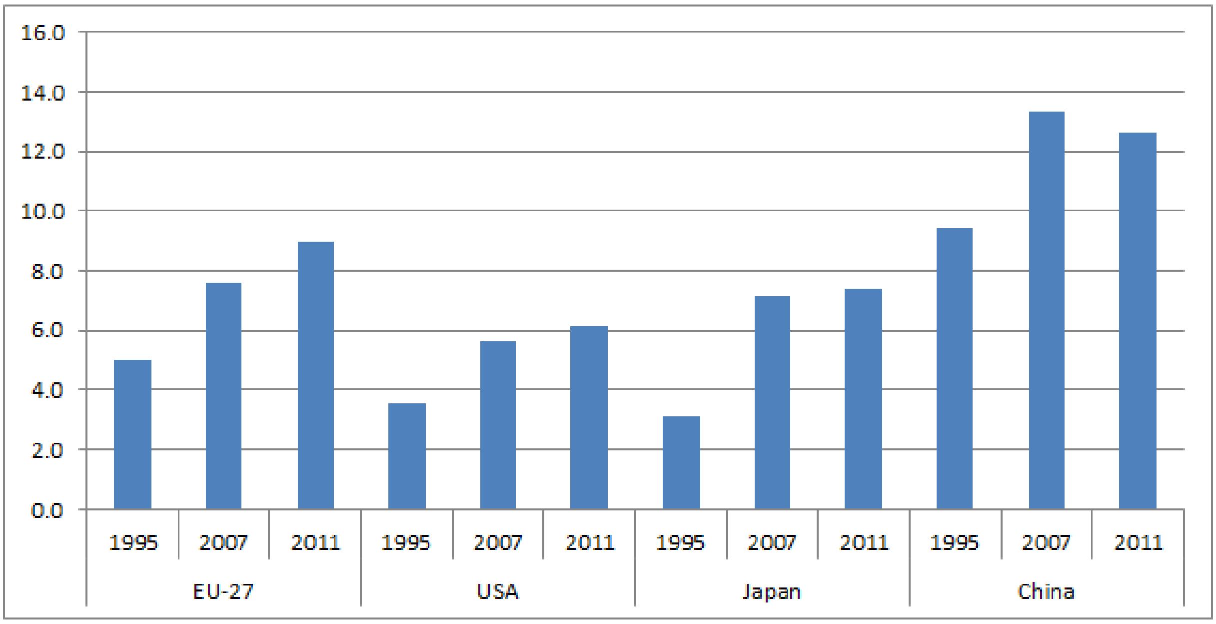
4.3. Patterns of vertical specialisation of the EU and its Member States

Individual EU Member States differ to a large extent in the way they are engaged in European and global production networks. Some countries' industries might benefit from offshoring production activities or stages across the border, allowing them to use their own resources more efficiently and to better perform in global competition. Such more efficient use of resources can either imply specialisation in particular activities for production of a certain output (vertical specialisation), or moving activities to other industries or products. This increasingly deepening integration of production can be measured as the share of foreign value added that is included in the production of a country's final goods production (which are either domestically consumed or exported) or a country's final exports.

All major economies have moved towards a higher vertical specialisation

It might be worth considering how the EU compares to its main competitors like the United States, Japan and China. Figure III.4.5 provides such a comparison for selected years. In all cases, vertical specialisation is increasing with the shares doubling for the EU and the United States and increasing even more strongly for Japan. Comparing the levels, it turns out that the EU is more integrated as compared to the United States and at similar levels with Japan and China (showing the largest shares) ([172]). Examining the performance of the (weighted) aggregate of individual Member States reveals that these shares are much higher, pointing towards the importance of intra-EU integration processes.

Figure III.4.5: Vertical specialisation in final goods production for EU and major competitors, in %



Source: DG Research and Innovation – Economic Analysis Unit　　Innovation Union Competitiveness report 2013
Data: WIOD; author's calculations

EU Member States increased their vertical specialisation up to 2007

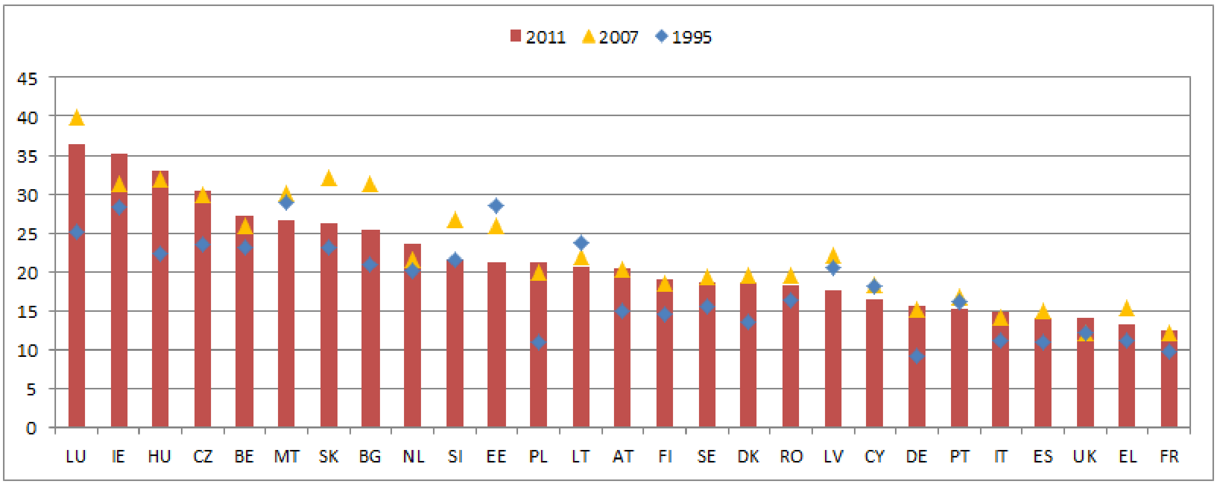
However, these numbers hide large variations across countries both with respect to levels and to the dynamics. To consider both these dimensions, Figure III.4.6 presents these shares in selected years for the individual Member States. Generally, larger countries tend to be less

[172] When first aggregating the EU Member States and performing the calculations, the shares of the EU and the US become rather similar at slightly less than 15 % % (for exports) in 2011; in this case, the figure for Japan would be 17 % % and that for China about 22 % %.

integrated in this sense due to the fact that such economies also show lower openness and tend to be less specialised. More interesting therefore are the dynamics.

The graph shows that for most countries there has been a visible increase in vertical specialisation up to 2007, with a few exceptions like the Baltics, Cyprus, Malta and Portugal, in the case of final goods production. This decline in vertical specialisation seems to be mostly driven by a crisis effect as the shares before 2007 tended to be rather stable for these countries. A similar aspect can be argued for Slovenia, which shows increasing shares up to 2007 and after that a decline to the 1995 level. All other countries, however, experienced strong increases in the foreign value-added content of final goods production, which for some countries is particularly pronounced. In Poland, for example, the share increased from 11 % to more than 20 %, while Hungary saw an increase from 22 % to 33 %. In the larger countries the changes are less strongly pronounced, with the exception of Germany.

Figure III.4.6: Levels and changes in vertical specialisation in final goods production, 1995 and 2011



Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: WIOD; author's calculations

The integration of production inside the EU increased up to 2007–2008, but weakened during the crisis period, to the benefit of China

Intra–EU production integration has been strong when compared to extra–EU relations. There was an increasing trend towards stronger integration within the EU up to 2007 or 2008. For final goods the difference increased from about 7.5 % in 1995 to about 8.5 % in 2008, but then declined to about 7.5 % in 2010 with signs of picking up again in 2011. Figure III.4.7 plots the difference between these two indicators for individual Member States. The results show that there is no uniform pattern across countries. Over the period 1995–2007, intra–EU vertical specialisation increased more strongly than the extra component in eight Member States only, and even declined in some countries (Estonia, the United Kingdom, Lithuania, Malta, the Netherlands and Portugal).

The countries with strongly increasing vertical ties within the EU are Austria, Bulgaria, Cyprus, Hungary, Ireland, Luxembourg, Latvia and Romania. One reason for this is that emerging countries outside Europe, particularly China, gained importance and therefore are impacting on extra-EU vertical specialisation. For example, for the EU the share of value added sourced from China for production of extra-EU exports increased from less than 4 % in 1995 to 13.5 % in 2011, with similar increases observed for the United States and Japan. Over the crisis period intra-EU vertical specialisation decreased in all countries, whereas extra–EU vertical specialisation was still increasing.

Figure III.4.7: Changes in intra- versus extra-EU vertical specialisation by EU member states in percentage points, 1995-2007 and 2007-2011

	1995-2007		2007-2011	
	extra	intra	extra	intra
Belgium	2.5	0.3	2.9	-1.7
Bulgaria	1.6	8.9	0.3	-6.3
Czech Republic	3.8	2.6	2.3	-1.7
Denmark	3.4	2.6	1.5	-2.4
Germany	3.4	2.5	1.0	-0.5
Ireland	0.1	2.9	6.1	-2.2
Estonia	1.5	-4.1	-0.2	-4.5
Greece	4.1	0.1	0.1	-2.2
Spain	3.2	0.8	0.1	-1.0
France	1.7	0.6	0.7	-0.4
Italy	2.5	0.6	1.9	-1.2
Cyprus	-0.6	0.8	1.4	-3.3
Latvia	-0.7	2.2	-0.2	-4.2
Lithuania	-1.4	-0.4	0.9	-2.3
Luxembourg	5.4	9.3	2.1	-5.8
Hungary	4.4	5.3	2.0	-1.0
Malta	4.0	-2.7	-0.8	-2.8
Netherlands	1.7	-0.3	3.0	-0.8
Austria	2.1	3.3	1.5	-1.5
Poland	4.7	4.4	2.5	-1.3
Portugal	1.6	-1.1	-0.4	-1.1
Romania	1.1	2.2	-0.9	-0.4
Slovenia	3.0	2.2	0.8	-5.7
Slovak Republic	5.9	2.9	-1.9	-3.8
Finland	3.1	0.8	1.9	-1.4
Sweden	2.3	1.5	1.9	-2.6
United Kingdom	1.0	-1.0	1.8	-0.1

Source: DG Research and Innovation – Economic Analysis Unit   Innovation Union Competitiveness report 2013
Data: WIOD; author's calculations

These country-specific magnitudes of vertical specialisation also depend on a country's structure of production and exports. Therefore, an analysis at a more detailed level of industry reveals some further insights into the patterns of vertical specialisation. The highest shares but also the largest increases are shown by industries such as coke, refined petroleum and nuclear fuel (NACE 23), but also within the higher-tech industries like transport equipment (NACE 34t35), electrical and optical equipment (NACE 30t33), and chemicals and chemical products (NACE 24). Amongst this group are also basic metals and fabricated metals (NACE 27t28) and air transport (NACE 62). This group is then followed by mostly other manufacturing and transport industries.

4.4. The role of highly skilled workers, R&D and innovation for comparative advantage in global value chains

What then determines a country's position in the global value chain? Case study evidence on vertical specialisation patterns of more advanced countries show that they tend to be better performing in higher-tech manufacturing industries, better endowed with skilled workers and counting on more innovation potential. At the same time, advanced countries might source lower-tech inputs from the other countries. This has to be seen as a mutual process. Countries offshore their activities such as assembly and simultaneously deliver value added for further production; for example, advanced countries that send high-tech intermediates to assembly countries. Countries and industries relate therefore both upstream and downstream to other countries to a varying degree, which allows them to specialise in activities along the value chains for which they have comparative advantages.

The objective in this last part of the section is to deepen this knowledge using an econometric analysis (see Methodological annex for full datasets) examining the determinants of national or industry engagements in the international fragmentation of production or their position in GVCs. The determinants of vertical specialisation with respect to countries delivering value added *to* other countries have been considered simultaneously with determinants using value added *from* other countries. Of particular interest is the role of innovation factors, like human capital, the level of technological development, and R&D expenditures, as opposed to cost factors like labour costs and location factors like home and host market size, distance and other gravity variables ([173]).

Highly skilled labour, R&D intensity and innovation are positively related to higher GVC income. They also allow lower import of value added

The results suggest that value added flows across countries are larger according to the size of the trading partners, with an indication that backward linkages play a more important role than forward ones in this fragmentation process. However, when considering intra-EU relations only, forward linkages become more important, indicating the stronger integration in production networks within Europe.

[173] Further cost factors that could influence vertical specialisation patterns are tax rates, energy costs and the differential costs of capital. Further innovation variables could be infrastructure variables. These are not yet explicitly considered due to data constraints. However, insofar as these are time-invariant, such factors would be captured by the dummy variables.

In such a scenario higher labour productivity levels increase value added flows across countries. When considering intra-EU flows, the results indicate that higher labour productivity levels are an important determinant only for the countries delivering value added to other countries (e.g. higher-tech inputs delivered to assemblers). The better a country is endowed with capital and skilled labour the less it is importing value added. By contrast, countries better endowed with capital and skilled labour tend to deliver more value added to other EU countries, as might be expected from the existence of production networks in high-tech sectors and compatible with the effects on labour productivity. Higher wage costs generally impact negatively on value added flows across countries, which is particularly the case with respect to highly skilled workers. Finally, with respect to R&D, higher R&D expenditure spurs value added flows to other countries, whereas higher R&D expenditures imply lower vertical specialisation; that is, lower foreign value-added content of production.

Generally, the results suggest that countries that are relatively better endowed with skilled workers and perform more R&D tend to be important suppliers of value added for production purposes to other countries, as would be expected from production fragmentation in high-tech industries that provide inputs to assembling countries. More advanced countries thus tend to establish more backward linkages in general in industries for which such linkages are important, like higher-tech manufacturing industries.

Innovation activities in a broader sense (i.e. also including productivity and endowment indicators) may enhance the capacity of EU firms and regions to position themselves at the higher value added segments in these global value chains, and hence reap higher shares of GVC income. Innovation has the potential to raise the competitive advantage from productivity gains, allowing cost reductions in the production process that can enhance the location of specific GVC segments in a country. In this sense, specialising along the value chains (together with a broader clustering of activities within Europe) might help the involved regions to specialise in certain activities without necessarily needing to develop whole industry segments. Such initiatives might also be helpful in re-establishing intra–EU integration patterns after the crisis.

5. Innovation in services

Highlights

Innovation in services has different dynamics to innovation in manufacturing

Innovation in services is different from innovation in manufacturing industries. It is less R&D intensive and more focused on highly skilled people. The innovation process is more circular with a strong role for users and suppliers. Networking and formal partnerships as well as co-creation and open source licensing are more important. The range of activities is very broad and heterogeneous, covering process innovation as well as innovation in organisation, business models, marketing and integrating services and goods.

Specific attention is needed for high-tech knowledge-intensive services

In the most knowledge-intensive service sectors, technology and R&D coupled with a highly skilled workforce play crucial roles in nurturing competitiveness. High-tech knowledge-intensive services have high growth rates and are highly innovative. Many of these business areas make intensive use of ICT, or develop new ICT solutions, but there is also strong growth in engineering services addressing societal challenges such as health or environmental solutions. These service segments are more internationalised with a growing trade and exposure to international competitiveness. The most advanced European countries face intensive competition from firms in the United States, Japan and India. Services for computer and related activities are growing in the European economy, both in terms of value added and employment, while telecommunication services have experienced growing value added but a decreasing employment trend over the period 2000–2009.

Services are closely linked to manufacturing, and policies are moving toward an integrated approach to service innovation

Innovation in services cannot be analysed independently from manufacturing. A very dynamic avenue for innovation is the integration of services and manufacturing offering new business models and comprehensive solutions that push a general shift in the economy from the provision of goods to the provision of solutions integrating goods and services. Innovation activities in large multinational corporations are being reorganised around open business lines with departments working over borders and across sectors.

Faced with this transformation of the service economy, several Member States have taken a growing interest in how to adapt existing and traditional innovation policies to address the specific needs of the heterogeneous service sector. The most developed policies are evolving from a targeted approach that focused primarily on innovation in services to a more integrated approach where strategies for service innovation are embedded in traditional manufacturing-focused innovation policies.

5.1. Characteristics of the innovation process in services

The service sector is taking an increasing role in the economy. It today contributes significantly to GDP and value added, represents a source of employment and growth, and is considered the modern motor of the new knowledge-based economy ([174]).

Innovation in service is different from innovation in the manufacturing industries

Innovation in services is mainly driven by people, both employees and customers. In this context, the EU has distinctive strengths and large potential in a skilled population, industrial heritage, culture and design required by the services sector to create a solution-oriented approach, which is considered necessary to match the needs deriving from societal challenges. Indeed, services and in particular knowledge-intensive services are highly dependent on qualified personnel, requiring specific qualifications such as language skills and intercultural capabilities. These capabilities are very different from those required in the manufacturing sectors. Finding the right skills is important to cover the diversity of services, particularly since services sectors cover a very broad range of business activities. Effective service innovation therefore requires policymakers to match the skills with the specific needs of service innovation.

Networking with suppliers and users, formal partnerships and community interactions represent drivers in co-creation innovation, in which firms develop strategies for market growth, positioning and financial reward. In the services sector, innovation can take forms that go beyond normal organisational or product innovations. For example:

- new channels for customer interaction;
- new business models;
- new services applications embedded in manufactured products;
- proximity of users provided by platforms of interaction.

The technological aspects of innovation in the service sector are mostly driven by information technology (IT) applications or engineering services, coupled with non-technological components. In this context, business expenditure on R&D tends to be significantly lower in services than in manufacturing. Manufacturing expenditure on R&D amounts to at least 2 % of value added, while in services it is only around 0.5 % on average.

However, in contrast with R&D expenditure in manufacturing, which has registered only limited growth in the last decade, in services is growing rapidly. In fact, there are enormous differences between service sectors: those with high levels of technology input (computer

[174] This chapter is based on the OECD report 'Innovation in services: The role of R&D and R&D policies', co-funded by the European Commission in the context of the INNOSERV project, OECD, Directorate for Science, Technology and Industry (OECD DSTI), 2012.

services, telecommunications, R&D and engineering services), those which invest more in R&D, and those where innovation is predominantly based on factors other than R&D. Even if they are increasing their R&D activity, service firms are collaborating less with science producers. Service innovation requires other kinds of knowledge than science, for instance skills in elaborating new business models or work organisation, and this knowledge is not easily transferred. Moreover, knowledge transfer of science to the services industry is less developed than knowledge transfer to the manufacturing industry.

This chapter will first present the evolution and innovation dynamics in knowledge-intensive business services, with a more detailed description of three service sectors of high strategic importance given their impact on efficiency and productivity gains for other services and manufacturing sectors. There are also services sectors that operate more broadly than the national context, espousing international outreach coupled with growth, which is important for the trade balance and overall competitiveness of the economy.

The chapter will thereafter present the trends in services to blend with manufacturing in view of commercialising solutions. This trend is presented with case studies based on an OECD survey, given that the statistical instruments are not yet adapted to measure this expanding practice. Both of these avenues, enabling and embedded services, highlight the need for more comprehensive innovation policies that foster the integration of services and manufacturing. A pure service economy is more of a statistical artefact. In reality, services and manufacturing are mutually dependent and reinforcing. Some countries have recognised this reality and are currently testing different innovation policy models, as shown in the last section of this chapter.

5.2. High-tech and knowledge-intensive services

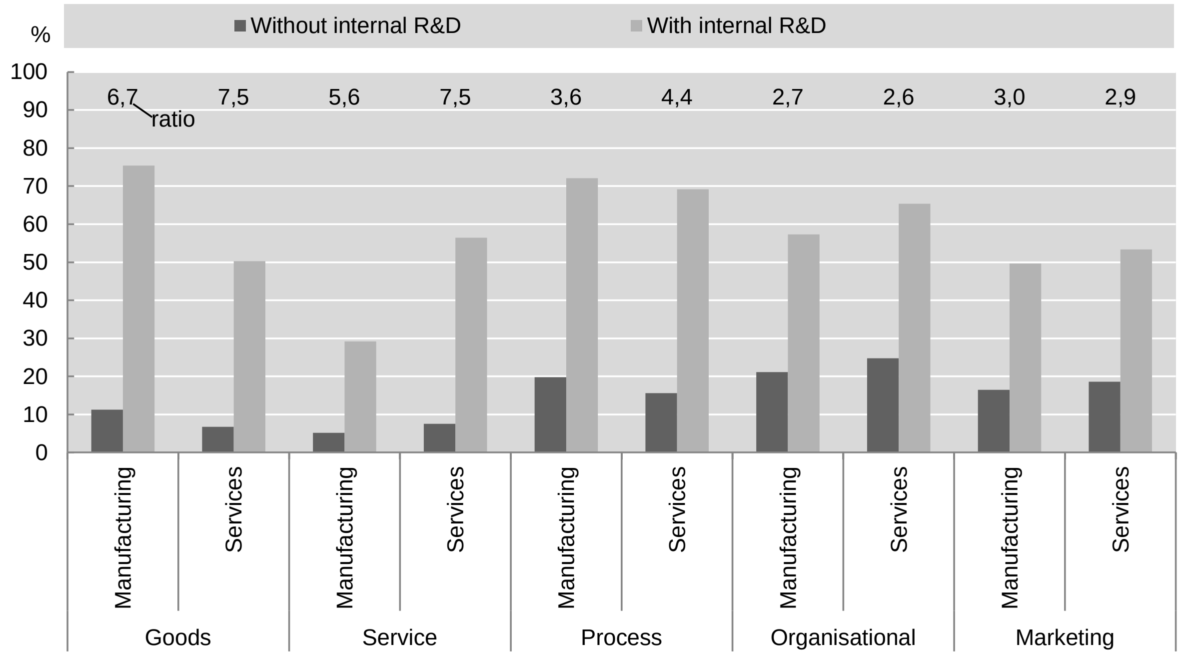
The services sector is a very broad category covering a wide range of business fields. For some service industries, knowledge and technologies are more important in a firm's business models. The knowledge-intensive business services sector exhibits higher innovation propensities than other sectors in most countries. However, there are large differences between European countries in terms of innovation forms and strategic combinations. In the United Kingdom, for example, the most frequent innovation mode is 'wider innovating', although other innovation modes are also common. In Italy, 'networked innovating' is most common, while in Spain 'process modernisation' is more used in the services sector (an innovation mode that is less prominent in most other countries).

Innovative firms in knowledge-intensive services are strongly engaged in process, organisational and market innovation, alongside innovation in goods and services

Figure III.5.1 shows that the innovative firms in the services sector are more strongly active in process, organisational and marketing innovation. This is a different profile compared to the manufacturing firms, which are predominantly active in goods and process innovation.

However, as for the manufacturing sector, service firms that perform R&D internally are more innovation oriented than firms operating without internal R&D.

Figure III.5.1: Share of innovative firms by R&D status, broad sector and type of innovation, 2006-08



OECD calculations based on CIS 2008 micro data (Eurostat), 2012

In the Czech Republic, Hungary, Estonia, France, Finland, Italy and Slovenia, high-tech knowledge-intensive services have greater weight in the service sector

The high-tech knowledge-intensive services category includes scientific research and development, telecommunications, computer programming, consultancy, information service activities, motion picture, video and television programme production, sound recording and music publishing, as well as programming and broadcasting activities (according to NACE Rev. 2).

Technology-based innovation is more important in the high-tech service sectors. High-tech knowledge intensive services (high-tech KIS) are an important contributor to the total value added in the service sectors. On average in Europe, they contribute 5.7 % of the total, but this share varies between countries. The share of high-tech KIS in total service value added is higher in the Czech Republic, Hungary, Estonia, France, Finland, Italy and Slovenia, and much lower in Cyprus, Lithuania and Austria. Interestingly the countries that are more research intensive, like Germany, Denmark or Sweden, are not the ones achieving higher shares of value added in the high-tech KIS. The profiles of the Czech Republic, Estonia, Hungary and Slovenia seem to reflect a type of innovation model and a higher degree of specialisation in services with a stronger component in high-tech. These countries are also among the biggest investors in intangibles as percentage of GDP ([175]), reaching or even surpassing the values of countries that are more knowledge intensive, like Sweden, the Netherlands or Finland.

Figure III.5.2: The weight of knowledge-intensive services

Services Value Added - Total and High-Tech KIS
(millions of euro)

	Services Value Added			
	Total	High-Tech KIS	High-Tech KIS as % of Total	Year
Belgium	234810	12697	5,4	2009
Czech Republic	85694	7134	8,3	2011
Denmark	156652	8878	5,7	2010
Germany (1)	1553480	69540	4,5	2010
Estonia	8521	647	7,6	2010
Spain	667759	36720	5,5	2008
France	1380459	92110	6,7	2010
Italy	1016443	66360	6,5	2010
Cyprus	12471	598	4,8	2010
Lithuania (1)	16669	799	4,8	2010
Hungary	53655	4338	8,1	2010
Netherlands (1)	389892	21240	5,4	2010
Austria	174572	7794	4,5	2009
Portugal	110627	5773	5,2	2009
Slovenia	20963	1334	6,4	2010
Finland	107263	7233	6,7	2010
EU (2)	6016646	*343287*	*5,7*	2009
Norway	166631	9066	5,4	2010

Source: DG Research and Innovation
Data: Eurostat
Notes: (1) DE, LT, NL: Motion picture, video, television programme production; programming and broadcasting activities not included.
(2) EU does not include BG, IE, EL, LV, LU, MT, PL, RO, SK, SE, UK.

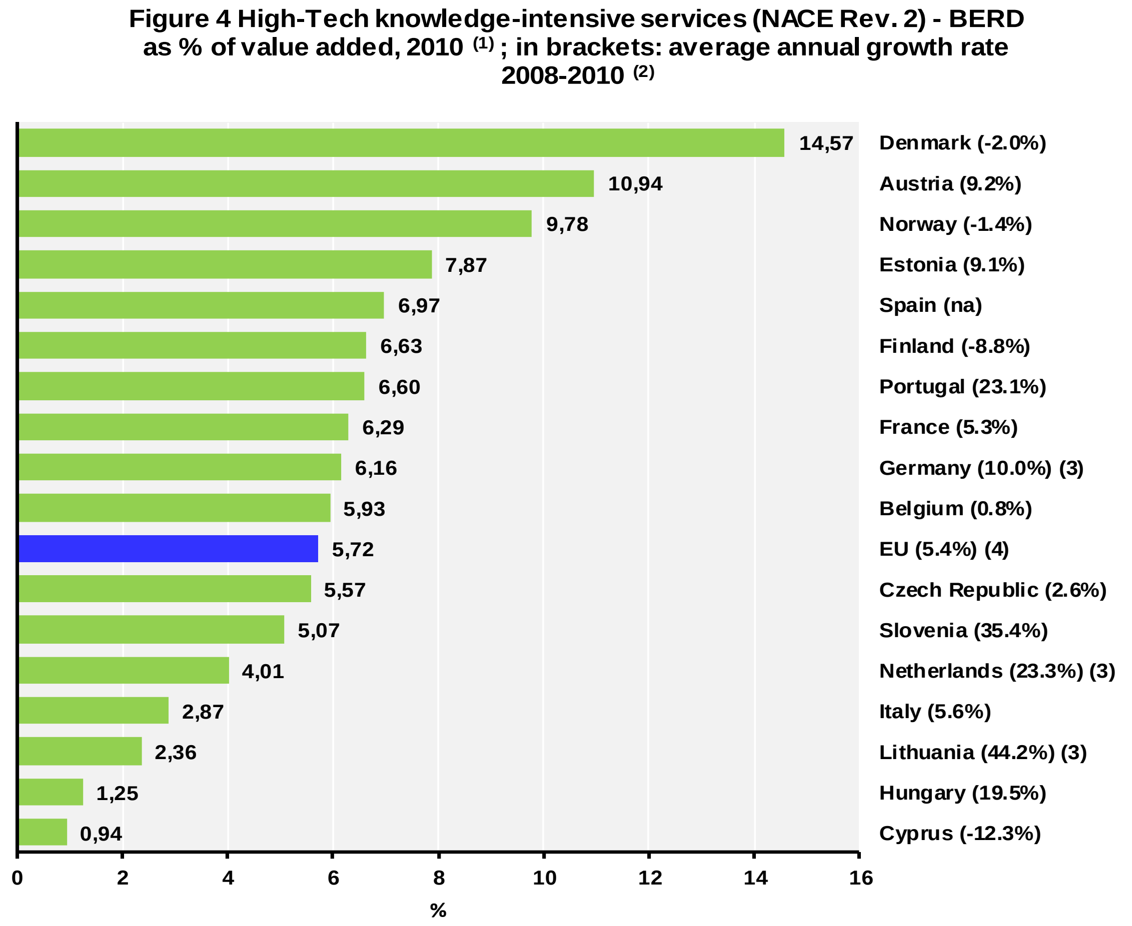
Business R&D intensity in the high-tech knowledge-intensive services is highest in Denmark, Austria, Norway and Estonia. Growth rates are highest in countries with lower R&D intensity, such as Lithuania, Slovenia and the Netherlands, but also in Portugal

These sectors can reach very high BERD intensities, in most cases higher than in manufacturing sectors, potentially playing a strategic role in contributing to progress towards a more knowledge-intensive economy. As in the manufacturing sector, for the high-tech

[175] See IUC 2011, Figure I.5.4 'Investment in intangibles as % of GDP'.

knowledge-intensive services sector there are significant differences in the BERD intensity across countries, as shown in Figure III.5.3.

Figure III.5.3: R&D in high-tech knowledge-intensive services



Source: DG Research and Innovation

Innovation Union Competitiveness Report 2013

Data: Eurostat

Notes: (1) ES: 2008; BE, AT, PT, EU: 2009; CZ: 2011.

(2) CZ: 2005-2011; AT: 2006-2009; PT: 2007-2009; DE, EE, IT: 2007-2010; BE: 2008-2009; DK, FR: 2009-2010.

(3) DE, LT, NL: Motion picture, video, television programme production; programming and broadcasting activities are not included.

(4) EU was estimated and does not include BG, IE, EL, HR, LV, LU, MT, PL, RO, SK, SE, UK.

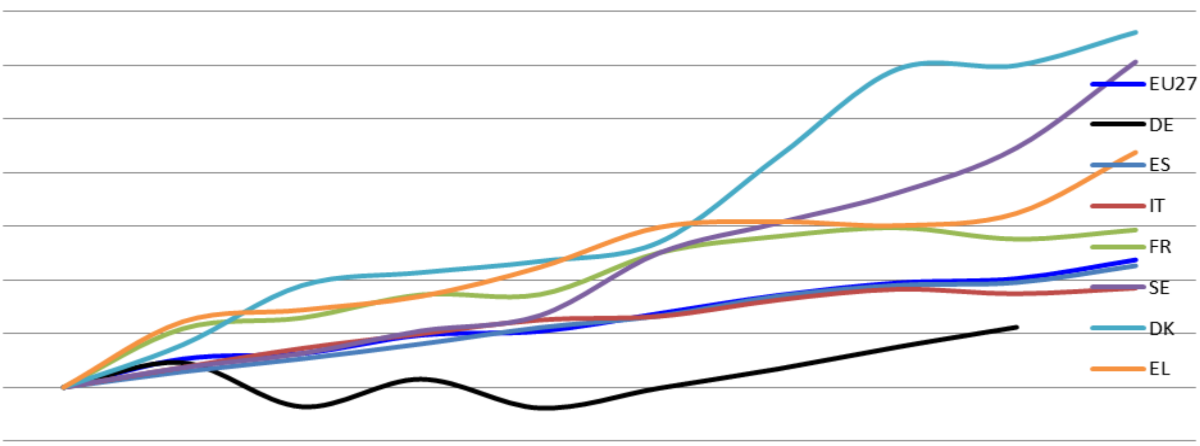
High-tech knowledge intensive services in Denmark or in Austria, for example, have very high business R&D involvement, well above the EU average of 5.72 % (14.57 % and 10.94 %, respectively), and more than five times higher than the same group of sectors in Cyprus, Hungary, Lithuania or even Italy (all these countries with figures that vary between 0.94 % and 2.87 %). However, the growth rate of business R&D intensity in these service industries is much higher in countries with lower BERD intensity, indicating a catching-up process.

For Portugal and Spain, the high values evidenced for BERD intensity (and the growth 2008–2010) reflect the results of efforts to catch up in terms of knowledge intensity within these sectors. Concerning the evolution over the period 2008–2010, and for the countries for which we have data, the R&D intensity in high-tech KIS decreased in Finland, Norway and Denmark in these three years, while France and Germany registered positive growth. Several catching-up countries have strongly increased their R&D intensity in high-tech KIS (Slovenia, Lithuania and Hungary) and so has the Netherlands, with a very high growth of 23.3 % over the period 2008–2010.

Telecommunications industries are increasingly service based with important innovation activity both within and outside the organisation. Their share of the economy is growing but employment is slightly decreasing

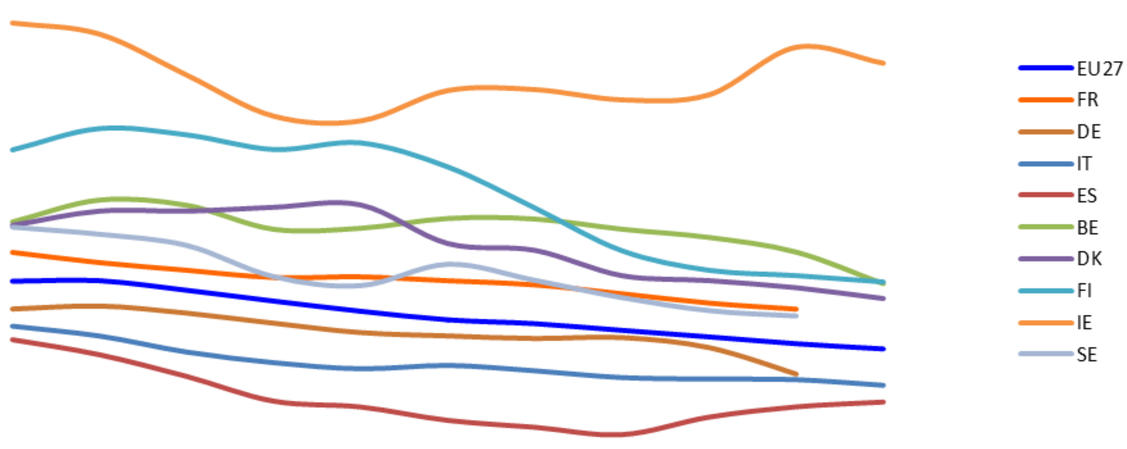
The telecommunications sector is a knowledge-intensive service sector that was significantly affected by the global economic downturn, with employment showing a tendency to decrease over time. The sector is dominated by large companies and is in relative terms particularly important in the southern and eastern European countries, such as Cyprus, the Czech Republic, Greece, Portugal, Slovakia and the three Baltic States, but also in Ireland and the United Kingdom. The telecommunications sector is rapidly changing and competitors from outside the industry are leading this change, in particular internet players, high-tech and IT companies, device manufacturers, applications and service providers, and media companies in search of new revenue opportunities as telecom operators. The EU value added in the sector was EUR 184 billion in 2009; France accounted for almost 15 % of the total, followed by Germany (14 %) and Italy (13 %). Between 2006 and 2009, average growth rates for value added in the EU dropped from an annual growth rate of 7.5 % to 4.4 % in the preceding period 2000–2006.

Figure III.5.4: Growth of real value added in telecommunications in 2000-2009



Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Eurostat; OECD

Figure III.5.5: Employment in the telecommunications sector in 2000-2009



Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Eurostat; OECD

Between 2007 and 2009 the share of HGEs in this service industry decreased in most European countries, with the exception of Italy, Sweden and Romania. The birth rate of companies is high and the survival rate generally above 50 % throughout the EU. However, there are significant differences across countries. In 2008, while the survival rate for Slovenia was an astonishing 95.6 % and for Austria 92.6 %, for the Netherlands, Switzerland and Italy it was around 50 %.

Contrary to many other sectors, in telecommunications the division between intra- and extramural R&D spending is of similar levels. Innovation is a major concern for the telecommunications sector and the most important types of innovation are in services (37 %), innovation in support to services (24.5 %) and new production methods (18 %). There is a positive correlation between R&D investments and the firm size: large and medium-sized companies spend much more in R&D than the smaller companies. Cooperation and size are important drivers of R&D investment. Finally, production capacity and flexibility, and the aim to increase market share, are also important drivers of innovation in this sector.

The Mobile Heights cluster in Sweden ([176])

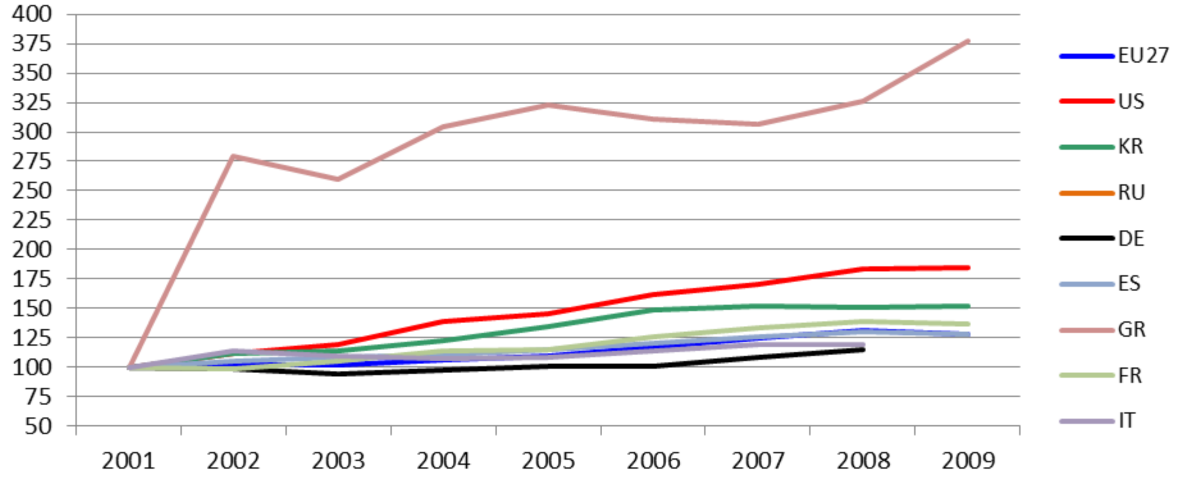
The Mobile Heights cluster in southern Sweden was created to strengthen the competitiveness of member organisations by putting together world-class research, education and entrepreneurship in the fields of mobile communications. Specific objectives are focused on a regional dimension, attracting new talent and human resources, creating favourable conditions to the growth of member organisations, increasing research in the universities of the region and enhancing the number of students enrolled in relevant university programmes. The cluster covers a geographical triangle composed of the cities of Malmö, Lund and Helsingborg. By covering the entire value chain of mobile communications, hardware, software and services, the members of the cluster get access to a dynamic and inspiring environment where members seek to cross-fertilise perspectives and ideas in order to generate world-class innovation and growth. This initiative meets the challenges that Sweden faces of a slowdown in the firms' knowledge dynamics, something not expected in a country that is an innovation leader situated in the high level of research performance.

Services for computer and related activities are a growing sector both in terms of value added and employment, but the leading EU Member States face intensive competition from United States, Indian and Japanese firms

The sector comprising computer services and related activities is very knowledge intensive and a vital component of the European economy. Firms of many different sizes, small, medium and large, are active in the sector. Most countries in the EU show employment shares in the sector that are increasing at a slow but stable rate over time. In terms of specialisation and importance for economic growth, the sector is highly relevant for Denmark, Finland, France, Sweden and the United Kingdom. The economic crisis impacted the sector significantly, with the average growth rate of EU value added dropping from 4.4 % (2000–2006) to 3.2 % (2006–2009). Even so, this is a very dynamic sector, with high growth perspectives. However, the income generated in the EU is accomplished with much more staff than in the United States, indicating a lower productivity level. For the period 2007–2009, the EU decreased its labour productivity in the sector – 0.6 %, while, for the same period, the United States increased its productivity by 3.3 %.

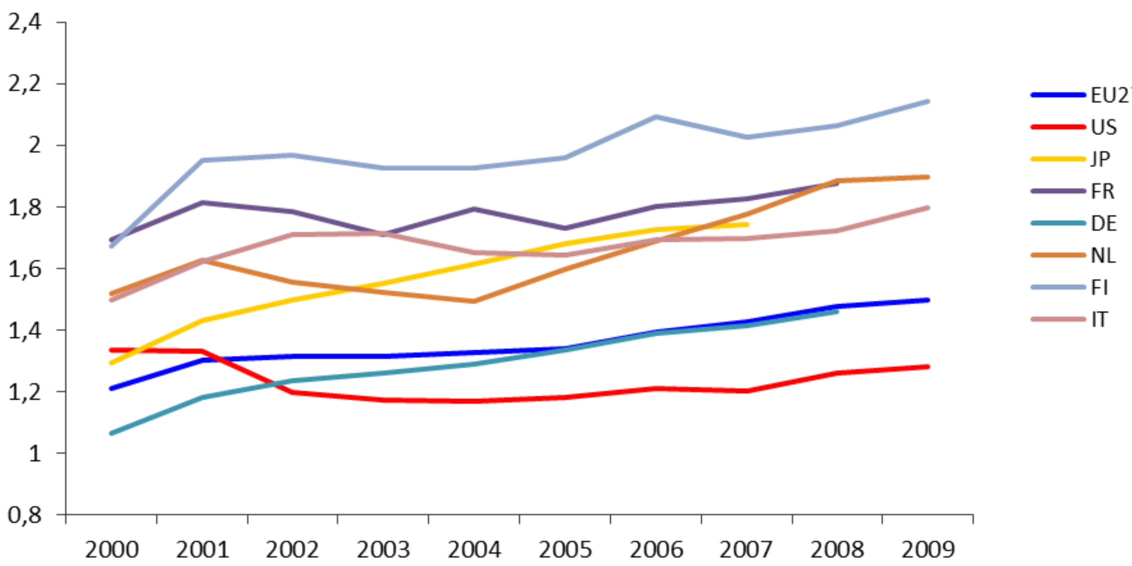
[176] Karlsson, L.T. and Stankovski, P., *The Mobile Heights, Creating the Mobile Future*.

Figure III.5.6: Growth of real value added in services for computer and related activities sector in 2000-2009



Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Eurostat; OECD

Figure III.5.7: Evolution of employment in services for computer and related activities in 2000-2009



Source: DG Research and Innovation – Economic Analysis Unit Innovation Union Competitiveness report 2013
Data: Eurostat; OECD

Overall, western and northern European countries present a higher degree of consolidation of firms, with larger firms, while firms in eastern European countries are smaller. Birth rates indicate a vibrant market, in particular in some eastern European countries and in the Netherlands. The prevalent types of innovation are new services, new products and innovation in support activities. Investment in R&D seems to relate positively and significantly with the pursuit of market share and receipt of public funding. There also seems to be a positive relation in R&D investment with firm size.

The 2011 EU Industrial R&D Investment Scoreboard shows the worldwide top 20 R&D investors in services for computer and related activities. Indian, Japanese and US companies are especially predominant (even with the massive decline of Japanese companies between 2009 and 2010). Among the top 20 companies, six firms have their headquarters in the EU; two Spanish companies (Amadeus and Indiras Systems) are among the top 10.

5.3. The move from products to solutions coupling manufacturing and services

The integration of services with the production of goods opens up a wide range of innovations that are transforming the economy

Service innovation of higher value added is often integrated with manufacturing and production activities. Firms no longer only offer products or new processes but also solutions based on a combination of products and integrated services. A more intensive interaction between customers and suppliers stimulates tailor-made solutions for the customers with subsequent market segmentation. This implies that the innovation process extends beyond R&D activities, to market research, business model development and design. Services linked to the production of goods (such as guarantee, customisation, customer-driven design, usage of the good, etc.) have become crucial in increasing value added throughout the value chain. By offering complementary services to the goods produced, firms can differentiate themselves from competitors and enter new market niches.

Growing shares of innovation takes place inside large multinational corporations, which tend to view innovation as open business lines adapting to emerging markets. Departments work over borders and across sectors producing products that combine goods and services. Companies have transformed the way of doing business with an increasingly dynamic role for the final user, either for products or for services. Customer wishes and needs are incorporated rapidly into new products, obliterating the classical separation between product lines with the services providers.

Hybrid models: How manufacturing firms combine goods and services

Bombardier Transportation, a global provider of trains and related services and equipment, is an excellent example of how a manufacturing company changed its strategy by looking at services, not as a support function (eventually provided through an outsourcing contract), but as an innovative, profitable and standalone business.

To win a train sales contract, Bombardier had to develop the concept of an innovative service contemplating a complete package of total care for more than 70 trains, on a daily basis, and combining reliable service with lower cost. Bombardier was in charge of providing all the services related to the train, from the cleaning and repairing of the interior of the trains, to the general maintenance, including the most complex components. This was a new world of activities for the manufacturing company Bombardier. It took some time for the company to fully adapt to the process. Even if the early stages proved to be very hard, the company initiated a transition through management, and operational and technological innovations that transformed the service unit into one of the most profitable and successful ones in the company. Based on this success, the business model of the whole firm was revised and specific projects were developed to better understand the new service-based business models. It led to the design of other service innovations supported by a sophisticated digital centre.

References:
OECD, 2012, 'Innovation in services: The role of R&D and R&D policies', the INNOSERV project, OECD, Directorate for Science, Technology and Industry (OECD DSTI).
Visnjic, I., Turunen, T., and Neely, A., 'When innovation follows promise: Why service innovation is different and why that matters', University of Cambridge.

This new focus on innovation requires close linkages between the KIS and the manufacturing sectors. The existing knowledge is better used when manufacturing and service activities converge or complement each other. These hybrid models can also be applied to improve cost efficiency in the entire value chain ([177]).

5.4. Innovation policy initiatives for services

In Europe, many Member States are reviewing their policies and instruments to support innovation in services since these instruments were traditionally conceived for innovation in manufacturing companies. Policies are being adapted and new instruments and programmes are created to support innovation in the growing services sectors.

[177] Relevant evidence on this dynamic in different manufacturing sectors can also be found in the sector study "R&D investments and structural changes in sectors", by a research consortium including TNO, Intrasoft, Fundacion Labein, Joaneum research and Rand Europe and financed by Directorate-General for Research and Innovation, European Commission.

National policies on service innovation are shifting from targeting only services to an integrated approach that fosters services embedded in a broader innovation policy

Based on a survey with national policymakers, the OECD ([178]) has made a synthetic typology of the different policy developments at national level fostering service innovation. Four different types of policy responses emerge:

1) Embedding service innovation in the existing R&D and innovation policies (e.g. by focussing on providing broader societal solutions to ageing, sustainability of cities, etc.). R&D and innovation are intrinsic dimensions of all R&D innovation policies across sectors and the specificities of the services are gradually integrated in the policy mix.
2) Targeting the specific process of service innovation. This implies continuous policy learning, adapting to the strengths and specialisation profile of a country, which determine the type of the service R&D and innovation policy to be applied.
3) Adopting a norm-adoption approach, which explicitly mentions service R&D and innovation? However, here the policies have not developed specific innovation strategies for services but focus mostly on traditional manufacturing activities and R&D.
4) Shifting to an awareness-based approach, which contemplates the peculiarities of services innovation but with no implementation of specific policies.

The policy approaches of EU Member States and countries outside Europe to innovation in services are different, but they are also in transformation. Germany, Sweden and Finland have moved towards an embedded policy approach to service innovation. Germany embeds its service innovation in the 'High-tech strategy 2020', helping companies to integrate production-related services into their innovation and value-creation processes. Germany has opted for a technology-focused approach, well in accordance with the economic specialisation of the country (in 2011, manufacturing represented 17.4 % of total employment). Sweden has elaborated a national strategy for increased service innovation. The focus is on improving the framework conditions, such as knowledge and competences building for service innovation, a digital infrastructure support and an effort to foster the internationalisation of service innovations. This is an example of a targeted approach to reach the embedment of the service economy in the overall activities. Finland is moving from a targeted adoption to an embedded policy. The country has adopted a demand and user-driven policy to innovation aiming at enlarging its scope and boosting market conditions for novel products and services. The R&D support is modified towards a broader concept of services. Today, almost half of Tekes' support to R&D support is directed to services.

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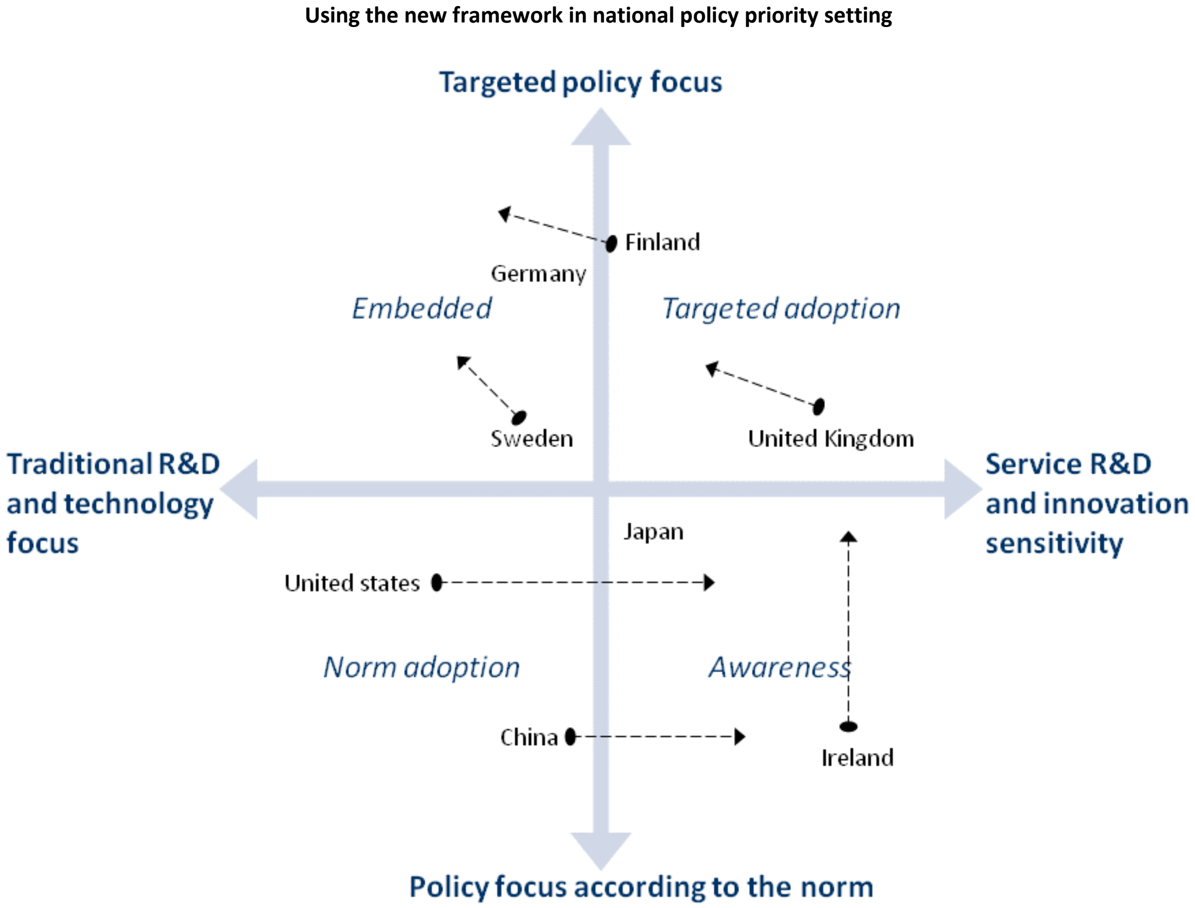
[178] This section is based on the OECD report 'Innovation in services: The role of R&D and R&D policies', co-funded by the European Commission in the context of the INNOSERV project, OECD, Directorate for Science, Technology and Industry (OECD DSTI), 2012.

Figure III.5.8: Evolution of national policies fostering service innovation



Source: OECD secretariat based on INNOSERV qualitative content analysis of national sources

The United Kingdom has opted for an integrated strategy enhancing all key drivers of service innovation. This policy is part of the UK's 2020 vision for growth, which includes the boosting of professional and business services. Ireland is changing its policy of service innovation from an awareness approach to a more targeted policy. A high-level expert group has presented new recommendations in a report to the government, titled 'Catching the wave, a services strategy'.

The United States and China are moving from a norm adaptation approach to an awareness approach to service innovation. A recent study in the Unites States focused on how the federal government should support the emerging discipline of 'service science'. In China, a strategy released in 2010/2011 aimed to solidly establish the high-tech service industry by 2020. The objective is to boost domestic demand and generate jobs.

Methodological Annex

Symbols and abbreviations

Country codes

BE	Belgium	SE	Sweden
BG	Bulgaria	UK	United Kingdom
CZ	Czech Republic	EU	European Union
DK	Denmark	IS	Iceland
DE	Germany	LI	Liechtenstein
IE	Ireland	NO	Norway
EL	Greece	CH	Switzerland
ES	Spain	HR	Croatia
FR	France	MK	The former Yugoslav Republic of Macedonia
IT	Italy	TR	Turkey
CY	Cyprus	IL	Israel
LV	Latvia	ERA	European Research Area
LT	Lithuania	US	United States
LU	Luxembourg	JP	Japan
HU	Hungary	CN	China
MT	Malta	KR	South Korea
NL	Netherlands	IN	India
AT	Austria	TW	Chinese Taipei
PL	Poland	SG	Singapore
PT	Portugal	RU	Russian Federation
RO	Romania	AU	Australia
SI	Slovenia	CA	Canada
SK	Slovakia	ZA	South Africa
FI	Finland	BR	Brazil
		RoW	Rest of the World

Other abbreviations

: 'not available'

\- 'not applicable' or 'real zero' or 'zero by default'

I. INVEST: KNOWLEDGE-DRIVEN COMPETITIVENESS

R&D Intensity
Definition: Gross Domestic Expenditure on R&D (GERD) as % of Gross Domestic Product (GDP)
Sources: Eurostat, OECD

Gross Domestic Product (GDP)

Definition: Gross domestic product (GDP) data have been compiled in accordance with the European System of Accounts (ESA 1995). Since 2005, GDP has been revised upwards for the majority of EU Member States following the allocation of FISIM (Financial Intermediation Services Indirectly Measured) to user sectors. This has resulted in a downward revision of R&D intensity for individual Member States and for the EU.
Source: Eurostat

Gross Domestic Expenditure on R&D
Definition: Gross domestic expenditure on R&D (GERD) is defined according to the OECD Frascati Manual definition. GERD can be broken down by four sectors of performance:
(i) Business Enterprise Expenditure on R&D (BERD);
(ii) Government Intramural Expenditure on R&D (GOVERD);
(iii) Higher Education Expenditure on R&D (HERD);
(iv) Private non-Profit expenditure on R&D (PNPRD).

GERD can also be broken down by four sources of funding:
(i) Business Enterprise;
(ii) Government;
(iii) Other national sources;
(iv) Abroad.

Sources: Eurostat, OECD

Public expenditure on R&D
Definition: For the purposes of this publication, Public expenditure on R&D is defined as Government Intramural Expenditure on R&D (GOVERD) plus Higher Education Expenditure on R&D (HERD).
Sources: Eurostat, OECD
Private expenditure on R&D
Definition: For the purposes of this publication, Private expenditure on R&D is defined as Business Enterprise Expenditure on R&D (BERD) plus Private non-Profit expenditure on R&D (PNPRD).
Sources: Eurostat, OECD

BERD Intensity
Definition: Business Enterprise Expenditure on R&D (BERD) as % of Gross Domestic Product (GDP)
Sources: Eurostat, OECD

Public sector R&D Intensity
Definition: Public expenditure on R&D (GOVERD plus HERD) as % of GDP.
Sources: Eurostat, OECD

Government budget for R&D
Definition: The government budget for R&D is defined as government budget appropriations or outlays for R&D (GBAORD), according to the OECD Frascati Manual definition. The data are based on information obtained from central government statistics and are broken down by socio-economic objectives in accordance with the nomenclature for the analysis and comparison of scientific programmes and budgets (NABS).
Source: Eurostat

Structural Funds
Definition: Structural Funds are funds intended to facilitate structural adjustment of specific sectors, regions, or combinations of both, in the European Union. Structural Funds for RTDI include data from sectors involving research and development, technological innovation, entrepreneurship, innovative ICT and human capital.
Source: DG REGIO.

Purchasing Power Standards (PPS)
Definition: Financial aggregates are sometimes expressed in Purchasing Power Standards (PPS), rather than in euro based on exchange rates. PPS are based on comparisons of the prices of representative and comparable goods or services in different countries in different currencies on a specific date. The calculations on R&D investments in real terms are based on constant 2000 PPS.
Source: Eurostat

Value Added
Definition: Value added is current gross value added measured at producer prices or at basic prices, depending on the valuation used in the national accounts. It represents the contribution of each industry to GDP.
Sources: Eurostat, OECD

Venture Capital
Definition: Venture Capital investment is defined as private equity being raised for investment in companies. For data between 2000 and 2006, management buyouts, management buy-ins, and venture purchase of quoted shares are excluded. Venture Capital includes early stage (seed + start-up) and expansion and replacement capital. As of 2007 data are broken into the

following stages: Seed; Start-up; Later stage venture; Growth; Rescue/Turnaround; Replacement capital; Buyouts.
Source: Eurostat, EVCA

Higher Education
ISCED (International Standard Classification of Education)
ISCED 5: Tertiary education (first stage) not leading directly to an advanced research qualification.
ISCED 5A: Tertiary education programmes with academic orientation.
ISCED 5B: Tertiary education programmes with occupation orientation.
ISCED 6: Tertiary education (second stage) leading to an advanced research qualification (PhD or doctorate).

Human Resources for Science and Technology (HRST), R&D personnel and researchers
The Canberra Manual proposes a definition of HRST as persons who either have higher education or persons who are employed in positions that normally require such education. HRST are people who fulfil one or other of the following conditions:

a) Successfully completed education at the third level in an S&T field of study (HRSTE - Education);
b) Not formally qualified as above, but employed in a S&T occupation where the above qualifications are normally required (HRSTO - Occupation).

HRST Core (HRSTC) are people with both tertiary-level education and an S&T occupation. Scientists and engineers are defined as ISCO categories 21 (Physical, mathematical and engineering science professionals) and 22 (Life science and health professionals).
The Frascati Manual proposes the following definitions of R&D personnel and researchers:

- R&D personnel: "All persons employed directly on R&D should be counted, as well as those providing direct services such as R&D managers, administrators, and clerical staff." (p.92);
- Researchers: "Researchers are professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned." (p.93). R&D may be the primary function of some persons or it may be a secondary function. It may also be a significant part-time activity.

Therefore, the measurement of personnel employed in R&D involves two exercises:

- measuring their number in headcounts (HC): the total number of persons who are mainly or partially employed in R&D is counted;
- measuring their R&D activities in full-time equivalence (FTE): the number of persons engaged in R&D is expressed in full-time equivalents on R&D activities (= person-years).

Public and Private sector researchers
Definition: For the purposes of this publication, Public sector researchers refer to researchers in the government and higher education sectors. Private sector researchers refer to researchers in the business enterprise and private non-profit sectors.
Source: Eurostat, OECD

II. REFORM: EXCELLENCE AND KNOWLEDGE CIRCULATION

Excellence in research (S&T)

Definition: It is a composite indicator developed in order to measure the research excellence in Europe, meaning the effects of European and National policies on the modernization of research institutions, the vitality of the research environment and the quality of research outputs in both basic and applied research. This core indicator is a composite of four variables:

- The share of highly cited publications in all publications where at least one of the authors has an affiliation in a given country (10% most highly cited publications considered, full counting method; source: Science Metrix calculations using Scopus data)
- Number of top scientific universities and public research organizations in a country divided by million population (world top 250 scientific universities and top 50 public research organizations considered; source: Leiden Ranking and Scimago Institutional Ranking)
- Patent applications per million population (PCT patent applications by country of inventor, 3-year moving average; source: OECD, Eurostat)
- Total value of ERC grants received divided by public R&D performed by the higher education and government sectors (transformed by using the natural logarithm, multi-year projects divided equally over time; source: DG-RTD, ERC)

The value of the composite indicator (a country score) is a geometric average of the four variables normalized between 10 and 100 using the min-max method and taking into consideration the two time points simultaneously.

Source: Group of Research and Innovation Union Impact, RTD-JRC (Ispra): Composite Indicator of Research Excellence, 2012.

Framework Programme

Definition: The Framework Programmes (FP) for Research and Technological Development are the EU's main instruments for supporting collaborative research, development and innovation in science, engineering and technology. Participation is on an internationally collaborative basis and must involve European partners. The first Framework Programme was launched in 1984. The seventh Framework Programme (FP7) covers the period 2007-2013.

Source: DG Research and Innovation

Index of financial success in FP

Definition: The share of the total EC financial contribution received by the participants from a country in the selection in total EC financial contribution to all participants in the selection normalize by the share of the country's GDP.

The formula used to calculate this index is

$$Index_{financial\_success_{Cf}} = \left(\frac{F_{Cf}^{EC}}{\sum_C F_{Cf}^{EC}}\right) / \left(\frac{GDP_C}{\sum_C GDP_C}\right)$$

where

F_{Cf}^{EC}	=	EC financial contribution received by the participants from the country *C* in the field *f*
$\sum_{C} F_{Cf}^{EC}$	=	Total EC financial contribution received by the participants from all the countries in the field *f*
GDP_C	=	the GDP value corresponding to the country *C*

Source: DG Research and Innovation

Index of participation in FP

Definition: The share of the participants from a country in the selection in total number of participants in the selection normalize by the share of the country's GDP.

The formula used to calculate this index is

$$Index_{participants_{Cf}} = \left(\frac{P_{Cf}^{EC}}{\sum_C P_{Cf}^{EC}}\right) / \left(\frac{GDP_C}{\sum_C GDP_C}\right)$$

where

P_{Cf}^{EC}	=	Number of participants from the country *C* in the field *f*
$\sum_{C} P_{Cf}^{EC}$	=	Total number of participants from all the countries in the field *f*
GDP_C	=	the GDP value corresponding to the country *C*

Source: DG Research and Innovation

Patent Cooperation Treaty (PCT) Patents

Definitions: The Patent Cooperation Treaty (PCT) is an international treaty, administered by the World Intellectual Property Organization (WIPO), signed by 133 Paris Convention countries. The PCT makes it possible to seek patent protection for an invention simultaneously in each of a large number of countries by filing a single "international" patent application instead of filing several separate national or regional applications. Indicators based on PCT applications are relatively free from the "home advantage" bias (proportionate to their inventive activity, domestic applicants tend to file more patents in their home country than non-resident applicants). The granting of patents remains under the control of the national or regional patent offices. The PCT patents considered are 'PCT patents, at international phase, designating the European Patent Office'. The country of origin is defined as the country of the inventor. If one application has more than one inventor, the application is divided equally among all of them and subsequently among their countries of residence, thus avoiding double counting. "PCT is an option for possible future patenting, that provides the applicant with a further delay before deciding to apply or not. The delay can be 6 to 12 months. The relation between the PCT option and patent value is not predictable (Grupp and Schmoch, 1999). The PCT process provides the advantage of a longer investigation of the technological potential of the invention, and in case of a negative assessment, the application can be withdrawn before entering into expensive regional (EPO) phase. Having passed this test, the PCT applications that are continued towards entering the regional phase are likely the ones of higher value. However, the argument can be reversed in the way that inventions with unclear market potential are passed through the PCT route, whereas those with an unquestionable potential are directly applied at the regional phase, since the direct path is cheaper." (Guellec & van Pottelsberghe, 2000).

Societal challenges patents comprise climate change mitigation patents and health technology patents. Climate change mitigation patents comprise patents for renewable energy, electric and hybrid vehicles and energy efficiency in buildings and lighting. Health technology patents comprise patents for medical technologies and pharmaceuticals.

Environment-related technologies

Definition: patent applications to EPO per billion GDP in current PPS€

The environment-related technologies refer to the following thematic areas:

A. General environmental management
B. Energy generation from renewable and non-fossil sources
C. Combustion technologies with mitigation potential
D. Technologies specific to climate change mitigation
E. Technologies with potential or indirect contribution to emissions mitigation
F. Emissions abatement and fuel efficiency in transportation
G. Energy efficiency in buildings and lighting

Health-related technologies

Definition: patent applications to the EPO per billion GDP in current PPS€

The health-related technologies refer to medical technologies and pharmaceuticals: surgery, dentistry, prostheses, transport / accommodation for patients, physical therapy devices, containers, medical preparations, sterilization, media devices, electrotherapy, chemical compounds.

Source: OECD

Licence and patent revenues from abroad

Definition: The export part of international transactions in royalties and license fees.

Source: Eurostat, TRADE

The NUTS classification

Definition: The Nomenclature of Statistical Territorial Units (NUTS) is a single coherent for dividing up the European Union’s territory in order to produce regional statistics for the Community. NUTS subdivides each Member State into a whole number of regions at NUTS 1 level. Each of these is then subdivided into regions at NUTS level 2 and these in turn into regions at NUTS level 3.

Source: Eurostat

Scientific Publications

Definition: Publications are research articles, reviews, notes and letters published in referenced journals which are included in the Scopus database of Elsevier. A full counting method was used at the country level. However, for the EU aggregate, double counts of multiple occurrences of EU Member States in the same record were excluded.

Source: Scopus (Elsevier); treatments and calculations: Science Metrix

Methodology of co-publication analysis

The methodology used for the co-publication analysis involved three types of analysis:

a) Single country publications cover co-publications that involve domestic partners only; this is the sum of all papers written by one or more authors from a given country (and non-nationals resident in that country). Although the literature usually distinguishes between domestic single publications (including one or more authors belonging to the same institution) and domestic co-publications (i.e. authors within the same country but from different main organisations), for the aim of the current analysis the sum of the two categories have been used under the heading of "single country publications".

b) EU transnational co-publications refer to international co-publications which involve at least one author from an EU country. This category includes both co-publications by authors from at least two different EU Member States (as defined by research papers containing at least two authors' addresses in different countries) and co-publications between one or several authors from the EU together with at least one author from a country outside the EU.

c) Extra-EU co-publications is a sub-category of the broader EU transnational co-publications. It refers exclusively to international co-publications involving at least one EU author and at least one non-EU author, as defined by the authors' addresses in different countries.

An important methodological issue is the way in which a co-publication is quantified. The full counting method has been used in this report, meaning that a single international co-published paper is assigned to more than one country of scientific origin. If, for example, the authors' addresses signal three different countries in the EU, the publication is counted three times – once for each country mentioned. Therefore, in a matrix of co-publications between countries, the number of publications mentioned is not a completely accurate indicator of the number of publications being co-authored, but rather how often a country or region is involved in co-publications.

Public-Private co-publications

Definition: Number of public-private co-authored research publications. The private sector excludes the private medical and health sector.

Source: CWTS / Thomson Reuters

Bibliometric indicators

Country Level

- **Pubs** (FULL): The number of peer-reviewed scientific publications written by authors located in a given country.
- **SAP**: The total number of country single author publications.
- **SCCP**: The total number of domestic only co-publications (i.e., single country co-publications).
- **ICP**: The total number of international co-publications involving the given country and a third country's authors.
- **ERACP**: The total number of international co-publications involving at least one author in the given country and at least one author from EU27, EFTA or candidate countries (although Israel is part of the ERA, it is not included here).
- **EU27CP**: The total number of international co-publications involving the given country and one or more EU27-only authors.
- **Non-EU27CP**: The total number of international co-publications involving the given country and one or more non-EU27 only authors.
- **EU27 & Non-EU27 CP**: The total number of international co-publications involving the given country, at least one author from an EU27 country and at least one author from a non-EU27 country.

EU27 Level (Aggregated)

- **Pubs** (FULL): The total number of EU27 publications.
- **SAP**: The total number of single author publications of EU27 MS.
- **SCCP**: The total number of single country co-publications of EU27 MS.
- **ICP**: The total number of international co-publications involving any EU27 MS and a third countries authors.
- **EU27CP**: The total number of international co-publications involving EU27 MS only.
- **EU27 & Non-EU27 CP**: The total number of international co-publications involving EU27 and non-EU27 countries.
- **One EU27 & Non-EU27 CP**: The total number of international co-publications involving one EU27 MS and at least one non-EU27 country.
- **Many EU27 & Non-EU27 CP**: The total number of international co-publications involving many EU27 MS and at least one non-EU27 country.
- **ERACP**: The total number of international co-publications involving at least one EU27 MS and at least one author from EFTA and/or candidate countries.
- **USCP**: The total number of international co-publications involving at least one EU27 MS and at least one author from the US.
- **Non-USP**: The total number of EU27 publications without a US author (this includes SAP, SCCP and any ICP without a US author).

For each of the above categories of publications/co-publications, the following indicators have been applied:

- **Growth index (GI)**: The GI represents the ratio between the yearly average in the percentage of a given country's output in one of the above categories in 2008–2011 over the same average in 2004–2007. In other words, the GI is a measure of the increase in the share of a given type of publications/co-publications in a particular area. A GI value above one means that a given entity experienced an increase in its output in this research area during the second half of the study period compared to the first half; an index value below one means the reverse.

- **Average of Relative Citations (ARC)**: The ARC is an indicator of the scientific impact of papers produced by a given entity (e.g., a country) relative to the world average (i.e., the expected number of citations). The number of citations received by each publication is counted for the year in which it was published and for the three subsequent years. For papers published in 2000, for example, citations received in 2000, 2001, 2002 and 2003 are counted. To account for different citation patterns across fields and subfields of science (e.g., there are more citations in biomedical research than in mathematics), each publication's citation count is divided by the average citation count of all publications of the corresponding document type (i.e., a review would be compared to other reviews, whereas an article would be compared to other articles) that were published the same year in the same subfield to obtain a Relative Citation count (RC). The ARC of a given entity is the average of the RCs of the papers belonging to it. An ARC value above one means that a given entity is cited more frequently than the world average, while a value below one means the reverse. The ARC is computed for the 2000–2008 period only since publications in 2009, 2010 and 2011 have incomplete citation windows.

  At the country level, the following indicators of scientific collaboration were also computed:
- **Average Number of Collaborating Countries per Paper**: To measure the diversity of countries with which a given country collaborates, the average number of collaborating countries (located within or outside the ERA) with which it collaborated per paper was computed.
- **Average Number of Foreign Co-authors per Paper**: To appreciate the size of a country's international teams on a project basis, the number of foreign co-authors (located within or outside the ERA) involved on a country's papers was averaged to obatin a score per paper.
- **Collaboration index (CI)**: There is often a power-law relationship between an entity's (i.e., country) number of papers and its number of co-publications (or collaborations). In cases where a power law relationship exists between two variables, it is often interesting to use a scale-adjusted indicator instead of a percentage to obtain a different perspective on cooperation by accounting for the relative size of entities being compared; percentages, like the percentage of publications authored in collaboration, assume a linear relationship.

  When both indicators are log transformed, power law relationships can be analysed using linear regression models. Therefore, the approach used to compute the CI consists of performing a log-log linear regression analysis between the number of co-authored publications and the number of publications at a specific aggregation level (e.g., countries) in order to estimate the constants (a and k) of the power law relationship:

$$Expp\ (M) = a * (M \hat{\ } k)$$

where:
Expp = the expected number of co-authored papers of an entity (e.g., a country) based on the regression model; and
M = the observed number of publications of the entity (e.g., country) being measured.
The log-log linear regression analysis is performed using reduced major axis (RMA) to estimate the constants (*a* and *k*) of the regression model. The indicator is simply the ratio of observed to expected co-authored publications. When the indicator is above 1, an entity produces more publications in collaboration than expected based on the size of its scientific production, while an index value below 1 means the reverse. The GI was also applied to this indicator.
This indicator was also computed asymmetrically for each country appearing in Scopus by FP7 thematic priority to subsequently extract the collaboration affinity of any country in the world towards collaborating with each ERA country. The regressions were only computed when a country had at least 30 partners in a given research area and period of time. In analysing the integration of the ERA, this measure of affinity was only used when regression could be performed in both periods being compared (i.e., 2004–2007 and 2008–2011).

Source: Science-Metrix/Scopus (Elsevier)

Scientific Specialisation

Definition: The relative scientific specialisation index (RCA) is calculated for 28 disciplines on the basis of publications from 2000-2002 and 2004-2006. The fields 'multidisciplinary' and 'social Sciences'' have been excluded. The formula used is the hyperbolic tangent function for the ratio of the share of a domain or discipline in a country compared to the share of the domain in the total for the world: $RCA_{ki} = 100 \text{ x } \tanh \ln \{(A_{ki}/\sum_i A_{ki})/(\sum_k A_{ki}/\sum_{ki} A_{ki})\}$, with A_{ki} indicating the number of publications of country k in the field i, whereby the field is defined by 28 scientific disciplines used in the classifications.
LN centres the data on zero and the hyperbolic tangent multiplied by 100 limits the RCA values to a range of +100 to -100. Scores below -20 are considered a significant under-specialisation in a given scientific field, scores between -20 and +20 are around field average and mean no significant (under-)
specialisation, and scores above +20 mean a significant specialisation in a given field. The RCA indicator allows the assessment of the relative position of a field i in a country beyond any size effects. Neither the size of the field nor the size of the country has an impact on the outcome of this indicator. Therefore, it is possible to directly compare countries and fields.
Source: ISI, Science Citation Index; treatments and calculations: Fraunhofer ISI

Specialisation index (SI)

Definition: This is an indicator of the intensity of research for a given economic sector, as defined by a sample of representative companies, in a given research area (subfield) relative to the intensity of the reference entity (world, entire output as measured by the database) in the same research area. In other words, when a sector is specialised in a subfield, it places more emphasis on that field at the expense of other research areas. The SI formula is the following:

$$SI = \frac{\left(X_s / X_T\right)}{\left(N_s / N_T\right)}$$

where

X_s	=	Papers from sector *X* in a given research area *s* (e.g., NACE 15&29.53 in food sciences)
X_T	=	Papers from entity *X* in a reference set of papers (e.g., NACE 15&29.53 in Scopus)
N_s	=	Papers from the reference entity *N* in a given research area *s* (e.g., world in food sciences)
X_T	=	Papers from the reference entity *N* in a reference set of papers (i.e., world in Scopus)

A given sector is specialised relative to the reference entity if the index value above one, and the reverse if the index value below one. The value of this indicator is directly related to the relevance of the subfield for the sector (the greater value of the indicator the greater relevance of the subfield for the sector).

Source: Science-Metrix/Scopus (Elsevier)

Matching scientific subfields to FP7 thematic priorities

The matching process was undertaken using expert decisions supported by different statistics. The documents were also used to extract relevant keywords that were searched in Scopus. Statistics were produced to identify the association between the thematic priorities (through keywords) and the fields and subfields (through the classification of the articles retrieved).

FP7 Thematic Priorities	Science-Metrix Field	Science-Metrix SubField
1. Health	Biomedical Research	All subfields
	Clinical Medicine	All subfields
	Psychology & Cognitive Sciences	All subfields
	Public Health & Health Services	All subfields
2a. Food, Agriculture and Fisheries	Food, Agriculture and Fisheries	All subfields
2b. Biotechnology	Enabling & Strategic Technologies	Biotechnology
	Enabling & Strategic Technologies	Bioinformatics
3. Information and Communication Technologies	Information and Communication Technologies	All subfields
4a.Nanosciences and Nanotechnologies	Enabling & Strategic Technologies	Nanoscience & Nanotechnology
4b. Materials (excluding	Enabling & Strategic	Materials

FP7 Thematic Priorities	Science-Metrix Field	Science-Metrix SubField
nanotechnologies)	Technologies	
	Chemistry	Polymers
4c. New Production Technologies	Engineering	Industrial Engineering & Automation
	Engineering	Operations Research
4d. Construction and Construction Technologies	Built Environment & Design	All subfields
5. Energy	Enabling & Strategic Technologies	Energy
6. Environment (including Climate Change)	Earth & Environmental Sciences	Environmental Sciences
	Engineering	Environmental Engineering
	Earth & Environmental Sciences	Meteorology & Atmospheric Sciences
	Earth & Environmental Sciences	Oceanography
	Biology	Ecology
7a. Aeronautics	Engineering	Aerospace & Aeronautics
7b. Automobiles	Engineering	Automobile Design & Engineering
7c. Other Transport Technologies	Economics & Business	Logistics & Transportation
	Engineering	Mechanical Engineering & Transports
	Engineering	Civil Engineering
8a. Socio-Economic Sciences	Communication & Textual Studies	Communication & Media Studies
	Economics & Business	All subfields except Logistics & Transportation
	Social Sciences	All subfields
8b. Humanities	Anthropology, Archeology & History	All subfields
	Communication & Textual Studies	Languages & Linguistics
	Communication & Textual Studies	Literary Studies
	Philosophy & Theology	All subfields
	Visual & Performing Arts	All subfields
9. Space	Engineering	Aerospace & Aeronautics
10. Security	Enabling & Strategic Technologies	Strategic, Defence & Security Studies

The resulting matching scheme matches S&T field(s) and/or subfield(s) to each thematic priority. All themes have been matched to at least one relevant field/subfield. No S&T field or subfield has been matched with more than one theme, with the exception of Aerospace & Aeronautics, which has been matched to both Space and Aeronautics. It is impossible to split Aerospace & Aeronautics into two subfields, even when using a match based on journals, because many journals present research on both aerospace science and aeronautics (e.g. Aircraft Engineering and Aerospace Technology, Transactions of the Japan Society for Aeronautical and Space Sciences, Canadian Aeronautics and Space Journal). However, it should be noted that this subfield includes many more articles on space science than on aeronautics.

It should also be noted that this solution contains missing links between thematic priorities and scientific papers that are not classified under the suggested matching S&T field/subfield (false negatives), as well as spurious links between thematic priorities and scientific papers that are classified under the suggested match but are not relevant to the theme. Nevertheless, this matching scheme is believed to be highly appropriate for linking the FP7 priorities with scientific output (through bibliometric data).
Source: Science-Metrix/Scopus (Elsevier)

Matching scientific subfields to NACE rev.1.1 fields

The subfields of highest relevance to a given economic sector were selected based on an analysis of the SAI and SI of economic sectors by subfield. Using the product of these two indicators, Science-Matrix sorted the scientific subfields in descending order of likely relevance to a given economic sector. This approach assumes that the subfields of highest relevance to an economic sector are those in which the sector is the most specialised and those in which there is a preferential transfer of knowledge, through citation flows, with the sector. Once scientific subfields were sorted in descending order of likely relevance, Science-Metrix analysts selected those that offered the best matches to a given sector based on an interpretation if the above indicators and on expert judgments taking into account the cognitive relationship between that sector and scientific subfields. Utmost attention was paid to the subject matter of these subfields to obtain, as much as possible, an adequate balance between recall and precision, given the definitions of economic sectors and of scientific subfields. In the cases where the match did not appear specific enough, matching was attempted at the level of scientific journals using the same approach.

The granularity at the level of subfields will allow for an appropriate, rather than perfect match, between the publication indexed in Scopus and the 22 economic sectors based on the NACE rev.1.1 classification for the last ten years (2000-2009). The coverage of the relevant literature provided by these matches is not comprehensive, as there will be many false negatives (i.e., relevant publications not retrieved by the matches), and their importance relative to matched publications varies among economic sectors. Similarly, the coverage provided by the matches are not considered to be highly precise, as there will be many false positives (i.e., irrelevant publications retrieved by the matches), and their importance relative to matched publications varies among economic sectors. Therefore, bibliometric data by

economic sector should be interpreted with care, especially when trying to perform cross-cutting analyses of scientific output versus other STI indicators.
Science-Metrix/Scopus (Elsevier)

Technology Categories
Definition: The four manufacturing industry technology categories are defined as follows (NACE Rev 1.1 codes are given in brackets):
(1) High-tech: office machinery and computers (30), radio, television and communication equipment and apparatus (32), medical, precision and optical instruments, watches and clocks (33), aircraft and spacecraft (35.3), pharmaceuticals, medicinal chemicals and botanical products (24.4).
(2) Medium-high-tech: machinery and equipment (29), electrical machinery and apparatus (31), motor vehicles, trailers and semi-trailers (34), other transport equipment (35) excluding building and repairing of ships and boats (35.1) and excluding aircraft and spacecraft (35.3), chemicals and chemical products (24) excluding pharmaceuticals, medicinal chemicals and botanical products (24.4).
(3) Medium-low-tech: coke, refined petroleum products and nuclear fuel (23), rubber and plastic products (25), non-metallic mineral products (26), basic metals (27), fabricated metal products (28), building and repairing of ships and boats (35.1).
(4) Low-tech: food products and beverages (15), tobacco products (16), textiles (17), wearing apparel; dressing and dyeing of fur (18), tanning and dressing of leather, manufacture of luggage, handbags, saddlery and harness (19), wood and products of wood and cork, except furniture (20), pulp, paper and paper products (21), publishing, printing and reproduction of recorded media (22), furniture and other manufacturing (36), recycling (37).

Technological Specialisation
Definition: The relative technological specialisation index (or RCA) is calculated for 19 technology domains on the basis of PCT patent applications (at the international phase, designating the EPO). The data were classified by earliest priority date and country of residence of the inventor.

The formula used is the hyperbolic tangent function for the ratio of the share of a domain in a country compared to the share of the domain in the total for the world: $RCA_{ki} = 100 \times \tanh \ln \{(A_{ki}/\sum_i A_{ki})/(\sum_k A_{ki}/\sum_{ki} A_{ki})\}$, with A_{ki} indicating the number of PCT patent applications (at international phase, designating the EPO) of country k in the field i. LN centres the data on zero and the hyperbolic tangent multiplied by 100 limits the RCA values to a range of +100 to -100. Scores below -20 are considered a significant under-specialisation in a given scientific domain, scores between -20 and +20 are around domain average and mean no significant (under-)specialisation, and scores above +20 mean a significant specialisation in a given domain. The RCA indicator allows the assessment of the relative position of a field i in a country beyond any size effects. Neither the size of the domain nor the size of the country has an impact on the outcome of this indicator. Therefore, it is possible to directly compare countries and domain.

Source: JRC-IPTS, based on EPO and WIPO data

Revealed Technological Advantage index (RTA)

Definition: The Revealed Technological Advantage (RTA) index provides information about the technological specialisation of areas and countries. The formula used to calculate the RTA index is the following:

$$RTA_{ij} = \left(\frac{X_{ij}}{\sum_j X_{ij}}\right) / \left(\frac{\sum_i X_{ij}}{\sum_i \sum_j X_{ij}}\right)$$

where

X_{ij}	=	The number of patents of area (or country) *i* in technology *j*
$\sum_j X_{ij}$	=	Total number of patents for the area (or country) *i*
$\sum_i X_{ij}$	=	Total number of patents for the technology *j*
$\sum_i \sum_j X_{ij}$	=	Total number of patents worldwide

The numerator of the expression represents the share of technology *j* among all patents of area (or country) *i*. In other words, it represents the relative importance of technology *j* in the patenting activity of area (or country) *i*.

The denominator represents the share of all patents in all areas (countries) accounted for by technology *j*, i.e. it represents the relative importance of technology *j* in the patenting activities worldwide.

A value of zero of the RTA indicates that area *i* has not patented in technology *j* and thus it is fully de-specialised in that technology. The RTA takes value one when the weight of technology *j* in the patenting activities of area *i* is exactly equal to the weight that this technology has on the patenting at the world level. This implies that a value of the RTA greater than one indicates that area *i* is relatively specialised in technology *j*. On the contrary, a value of RTA lower than one indicates that area *i* is relatively de-specialised in that technology. The comparison of the different levels of specialization in the various technological and economic fields allows drawing conclusions about the relative strengths and weaknesses of different areas and countries (but the RTA index has to be interpreted with caution for those areas and countries, which have registered a relatively small number of patents).

Source: University Bocconi (Italy)

Matching patents to NACE rev.1.1 fields matching

The list of 22 economic sectors based on the NACE rev.1.1 classification (NACE rev.1.1 codes in parenthesis) is presented below.

1. Manufacture of food products and beverages and manufacture of machinery for these products (15 + 29.53)

2. Manufacture and sales of textiles and manufacture of machinery for these products (17

+ 29.54 + 51.41/2 + 51.83 + 52.41/2)

3. Reproduction of recorded media and related manufactured goods (22.3 + 24.64/5)

4. Manufacture of basic chemicals and manufacture of paints, varnishes and similar coatings, and glues and gelatins (24.1 + 24.3 + 24.62)

5. Manufacture of pharmaceuticals (24.4)

6. Manufacture of plastic products (25.2)

7. Manufacture of other non -metallic mineral products (26)

8. Manufacture of general purpose machinery and machine tools (29.1 + 29.2 + 29.4)

9. Manufacture of office machinery and computers (30)

10. Manufacture of electrical motors, generators and transformers (31.1)

11. Manufacture of electricity distribution and control apparatus; manufacture of insulated wire and cable; manufacture of accumulators, primary cells and primary batteries; electricity, gas, steam and hot water supply (31.2 +31.3 + 31.4 + 40)

12. Manufacture of electronic valves and tubes and other electronic components (32.1)

13. Manufacture of medical and surgical equipment (33.1)

14. Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, industrial process control equipment and optical instruments and photographic equipment (33.2 + 33.3 + 33.4)

15. Manufacture of motor vehicles, manufacture of parts and accessories for motor vehicles and their engines (34.1 + 34.3)

16. Manufacture of aircraft and spacecraft (35.3)

17. Recycling (37)

18. Collection, purification and distribution of water (41 + 45. 24)

19. Construction (45 except 45.24)

20. Cargo handling and storage (63.1)

21. Telecommunications (64.2)

22. Services for computer and related activities (72 except 72.5)

The patents are classified using the IPC classification scheme. The NACE rev.1.1 codes needed as input for constructing the 22 economic sectors coincide in most cases with the output of the concordance table. For some sectors however input on a more disaggregated level is needed. For example sector 1 “Manufacture of food products and beverages and manufacture of machinery for these products” contains NACE rev.1.1 codes 15 and 29.53. Some of the NACE rev.1.1 codes, as code 15 (“Food, beverages”), can be directly added to the sector. However, there are NACE rev.1.1 codes that are sub-codes of other NACE rev.1.1 codes, as code 29.53 that is part of the NACE rev.1.1 code 29.5 (“Special purpose machinery”). For this fields a more in depth analysis is required in order to allocate the underlying IPC codes to the relevant sectors. The fields for which a more in depth analysis is required are 22, 24.6, 25, 29.5, 34 and 35.

Moreover, several NACE rev.1.1 codes that have to be matched do not refers to the manufacturing sectors and a content analysis will lead to a correct attribution of fields to these sectors.

Relating the 44 industrial sectors with the 22 economic domains mentioned before implies establishing a concordance scheme based on NACE codes. Several issues emerged when developing the concordance table relating the 44 industrial sectors with the 22 economic domains.

First of all, a number of industries have not been included in the 22 NACE list (see table).

Overview of industries not included in the 22 NACE list

NACE description	NACE nr
Manufacture of tobacco products	16
Manufacture of wearing apparel; dressing and dyeing of fur	18
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	20
Manufacture of pulp, paper and paper products	21
Publishing, printing and reproduction of recorded media	22
Manufacture of coke, refined petroleum products and nuclear fuel	23
Manufacture of chemicals and chemical products	24
Manufacture of rubber and plastic products	25
Manufacture of basic metals	27
Manufacture of fabricated metal products, except machinery and equipment	28
Manufacture of machinery and equipment n.e.c.	29
Manufacture of electrical machinery and apparatus n.e.c.	31
Manufacture of radio, television and communication equipment and apparatus	32
Manufacture of motor vehicles, trailers and semi-trailers	34
Manufacture of other transport equipment	35
Manufacture of furniture; manufacturing n.e.c.	36

Secondly, a number of the 22 classes (17, 18, 19, 20 and 21) have no relationship with IPC codes as they are not manufacturing industries.

Thirdly, within the 22 classification, some industries imply the inclusion of machinery (notably, Food and Textiles). A complete break-down – following a 1:1 logic - of machine technology by 'sector of use' is however not feasible based on the content description of IPC's. Moreover, adding an overall figure (reflecting machine construction technology) to these industries might result in a misleading figure. For both industries we have been able to allocate specific machinery technology that is defined (within the IPC classification) as industry specific. However, a considerable amount of machinery technology has not been allocated due to its generic nature.

Finally, one industry in the 22 classification (Manufacture and sales of textiles and manufacture of machinery for these products (17+ 29.54 + 51.41/2 + 51.83 + 52.41/2)), implies a combination of manufacturing activities and service activities. For the service activities, no corresponding IPC codes exist. As such, this observation deserves especially attention when aggregated economic indicators are being related to technical data.

To summarize, translating the proposed industry classification towards technological fields is in a number of cases not straightforward.

Regarding the service industries within the list of the 22 domains, caution is required when interpreting the data, especially when relating patent indicators to economic indicators pertaining to the implied sectors.

Source: University Bocconi (Italy)

Matching patents to FP thematic priorities

Patent data will be aggregated by technology sectors corresponding to the FP7 Thematic Priorities, by building on a systematic content analysis of the thematic priorities in order to relate the different themes to corresponding IPC classes and existing technological classifications. The thematic fields will preferably be related to the ISI-OST-INPI (FhG35) classification. At the same time, at not all thematic themes correspond clearly with one (or more) of the FhG35 classes. For these thematic priorities, additional information in existing studies and approaches that have addressed the demarcation of technological fields will be used (e.g. the recent studies conducted by IDEA in the field of security technologies and environmental technologies; the search keys developed by OECD).

This approach is feasible for a significant number of priorities (e.g. Health, Food, Biotechnology). For two priorities – Socio-Economic Sciences and Humanities – technological indicators are irrelevant and non-existing. Also for New Production Technologies, patent indicators will – at best – provide a partial picture of underlying dynamics. For a number of priorities refinements are required. These refinements imply for a number of themes a breakdown of existing technology classes (e.g. Transport) or a refinement of IPC codes by either adding or removing relevant/less relevant IPC codes (e.g. Food, Construction and Construction Technologies, Space Technology & Weapons, Materials). For Nanotechnology, a relevant classification will be derived from previous studies in the field. For the remainder of the thematic priorities, the main work consists of analysing and addressing the overlap between the different themes: Energy and Environment; Environment and Transport Technologies; Security and ICT, Materials. A number of thematic priorities clearly signal 'topic' overlap.

Source: University Bocconi (Italy)

Economic specialisation index

Definition: The economic specialisation index provides information about the importance, performance and composition of an industrial sector in the economy of a country based on a location quotient. The location quotient is a Balassa index that measures the relative importance of the industrial sector in the country based on value added. The formula used to calculate the economic specialisation index is the following:

$$Economic\ Specialisation_{ij} = \left(\frac{X_{ij}}{\sum_j X_{ij}}\right) / \left(\frac{\sum_i X_{ij}}{\sum_i \sum_j X_{ij}}\right)$$

where

X_{ij}	=	The value added of the sector *j* in the economy of the country *i*
$\sum_j X_{ij}$	=	The total value added of the country *i*
$\sum_i X_{ij}$	=	The total value added of the sector *j* in the economy of the area considered as location quotient (e.g., EU27)
$\sum_i \sum_j X_{ij}$	=	The total value added of the area considered as location quotient (e.g., EU27)

The relative importance in the EU27 is set to one. A location quotient above a one implies specialisation in an economic sector, i.e. the sector is relatively more important for the total economy.

Source: TNO – Industrial Innovation (Sector study project)

III. TRANSFORM: INNOVATION FOR GROWTH AND JOBS

Knowledge-Intensive Activities (KIAs)

Definition: Knowledge-Intensive Activities (KIAs) are defined as economic sectors in which more than 33% of the employed labour force has completed academic-oriented tertiary education (i.e. at ISCED 5 and 6 levels). They cover all sectors in the economy, including manufacturing and services sectors, and can be defined at two and three-digit levels of the statistical classification of economic activities.

Source: Eurostat

Knowledge-Intensive Activities – Business Industry (KIABI)

Definition: The Knowledge-Intensive Activities-Business Industries (KIABI) includes the following economic sectors (NACE rev1.1): Manufacture of coke, refined petroleum products and nuclear fuel (23), Manufacture of chemicals and chemical products (24), Manufacture of office machinery and computers (30), Manufacture of radio, television and communication equipment and apparatus (32), Manufacture of medical, precision and optical instruments, watches and clocks (33), Air transport (62), Financial intermediation, except insurance and pension funding (65), Insurance and pension funding, except compulsory social security (66), Activities auxiliary to financial intermediation (67), Computer and related activities (72), Research and development (73), Other business activities (74) and Recreational, cultural and sporting activities (92).
Source: Eurostat

Knowledge-Intensive Services (KIS)

Definition: Knowledge-intensive services (KIS) includes the following sectors (NACE Rev.1.1 codes are given in brackets): water transport (61), air transport (62), post and telecommunications (64), financial intermediation, except insurance and pension funding (65), insurance and pension funding, except compulsory social security (66), activities auxiliary to financial intermediation (67), real estate activities (70), renting of machinery and equipment without operator and of personal and household goods (71), computer and related activities (72), research and development (73), other business activities (74), education (80), health and social work (85), recreational, cultural and sporting activities (92).

Source: OECD

Knowledge-Intensive Services exports

Definition: Exports of knowledge-intensive services are measured by the sum of credits in EBOPS (Extended Balance of Payments Services Classification) 207, 208, 211, 212, 218, 228, 229, 245, 253, 260, 263, 272, 274, 278, 279, 280, 284.

Source: UN

Contribution of High-Tech and Medium-Tech manufacturing to trade balance

Definition: The "contribution to the trade balance" is the difference between observed industry trade balance and the theoretical trade balance.

By trade balance we understand the difference between the level of exports and the level of imports at a particular industry/sector.

The contribution to the trade balance is given by the formula:

$$\left[(X_i - M_i) - (X - M)\frac{(X_i + M_i)}{(X + M)}\right] / (X + M) * 100$$

where

$(X_i - M_i)$	=	observed industry trade balance
$(X - M)\frac{(X_i + M_i)}{(X + M)}$	=	theoretical trade balance

If there is no comparative advantage or disadvantage for any industry i, *a country's total trade balance (surplus or deficit) should be distributed across industries according to their share in the total trade. A positive value for an industry indicates structural surplus and a negative value a structural deficit.*

The HT & M-HT trade balance include of the following SITC Rev.3 products: 266, 267, 512, 513, 525, 533, 54, 553, 554, 562, 57, 58, 591, 593, 597, 598, 629, 653, 671, 672, 679, 71, 72, 731, 733, 737, 74, 751, 752, 759, 76, 77, 78, 79, 812, 87, 88, 891.

Source: OECD (*Moving Up the Value Chain: Staying Competitive in the Global Economy*, 2007), UN (Comtrade), RTD - Economic Analysis Unit

Knowledge-intensity of the economy (Structural change of economy)

Definition: Compositional structural change indicators measure changes in the actual sectoral composition of the economy in terms of production and employment, business research and development (R&D), high-tech exports and technological specialization and foreign direct investments. Changes may affect the linkages among sectors and technologies, and influence the changes of the international advantages of countries.

Eight compositional structural change indicators have been identified and organized into five dimensions:

- The R&D dimension measures the size of business R&D (as a % of GDP) and the size of the R&D services sector in the economy (in terms of total value added; source: WIIW calculations using OECD, Eurostat, WIOD and national sources)
- The skills dimension measures changing skills and occupation in terms of the share of persons employed in knowledge intensive activities (both in manufacturing and service sectors considered where on average at least a third of the employees have tertiary graduates; source: Eurostat)
- The sectoral specialization dimension captures the relative share of knowledge intensive activities (in terms of value added; source WIIW calculations using OECD, Eurostat, WIOD and national sources)
- The international specialization dimension captures the share of knowledge economy through technological (patents) and export specialization (revealed technological and competitive advantage) and
- The internationalization dimension refers to the changing international competitiveness of a country in terms of attracting and diffusing foreign direct investment (inward and outward foreign direct investments).

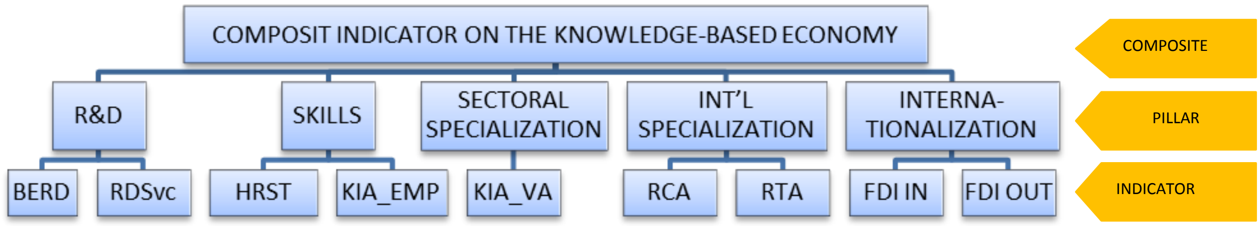
The eight indicators in the five pillars have been normalized between 10 and 100 using the min-max method and taking into consideration three time points simultaneously. The five pillars have also been aggregated to a single composite indicator of structural change using the geometric average to provide an overall measure of country progress in this area.

Source: Group of Research on the impact of the Innovation Union (GRIU), RTD-JRC/IPSC Ispra): Composite Indicators measuring structural change, monitoring the progress towards a more knowledge-intensive economy in Europe, 2011.

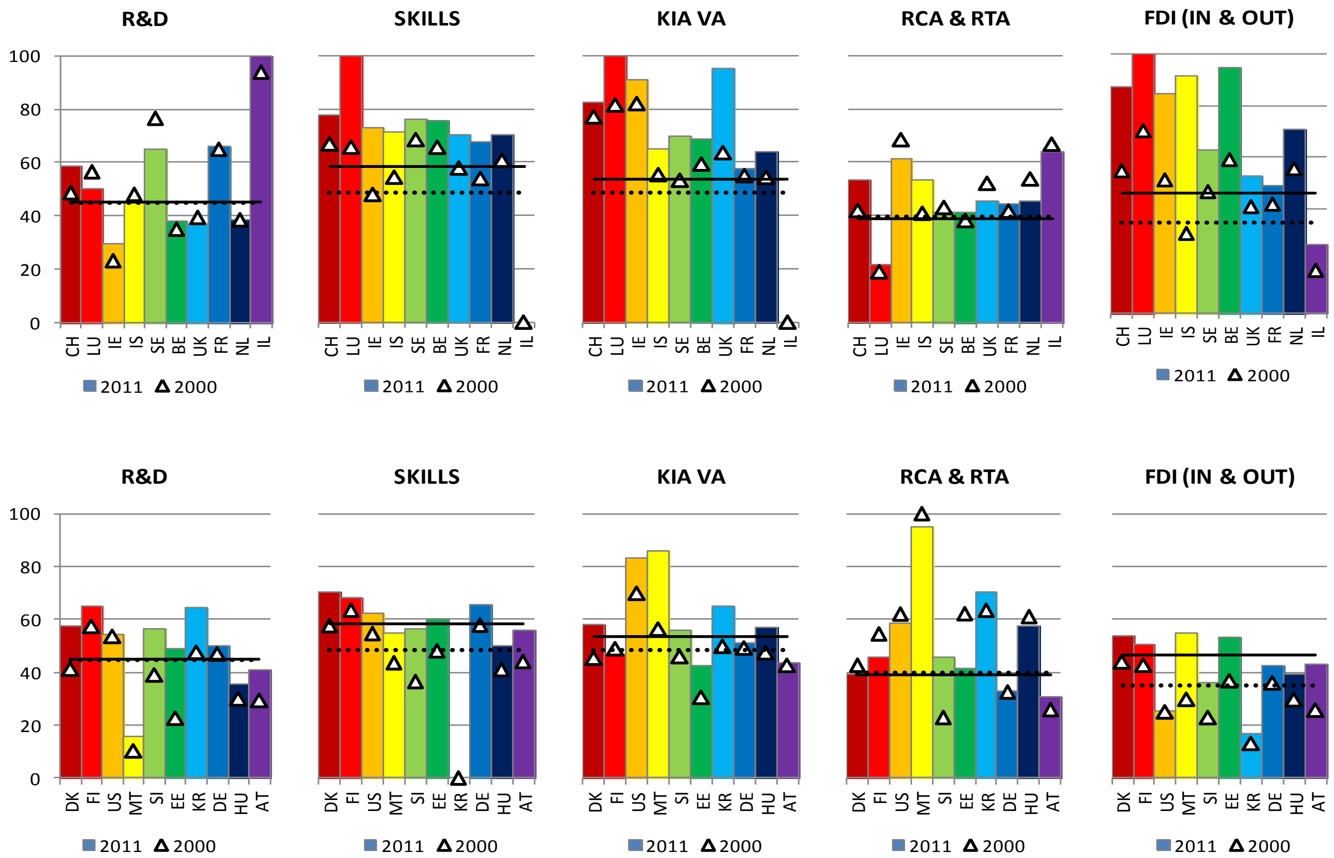
Indicators on the size of the knowledge economy

Indicator	Definition	Source
R&D Indicators		
BERD	Total R&D expenditure as a share of GDP (%)	Eurostat/OECD
RdSvc	The share of R&D services in the economy (the share of sector NACE Rev 1.1 code K73 in the total economy, in terms of value added)	Eurostat/OECD EUKLEMS/WIOD (WIIW)
Skills Indicators		
HRST	Share of Human Resources in Science and Technology (HRST) as a share of active population (15-74) (%)	Eurostat
KIA_EMP	Share of persons employed in knowledge-intensive activities (KiAs) as a percentage of total employment.	Eurostat
Sectoral Specialization Indicator		
KIA_VA	The share of value added in knowledge-intensive activities within the total value added in a country	Eurostat/OECD EUKLEMS/WIOD (WIIW)
International Specialization Indicators		
RTA	Relative specialization in holding PCT patents in selected technology classes (Revealed Technological Advantage – RTA)	OECD
RCA	Relative specialization in the export of medium-high tech and high-tech products (Revealed Competitive Advantage – RCA)	Eurostat
Internationalization Indicators		
FDI_IN	Cumulative inward FDI stock as a share of GDP	Unctad
FDI_OUT	Cumulative outward FDI stock as a share of GDP	Unctad

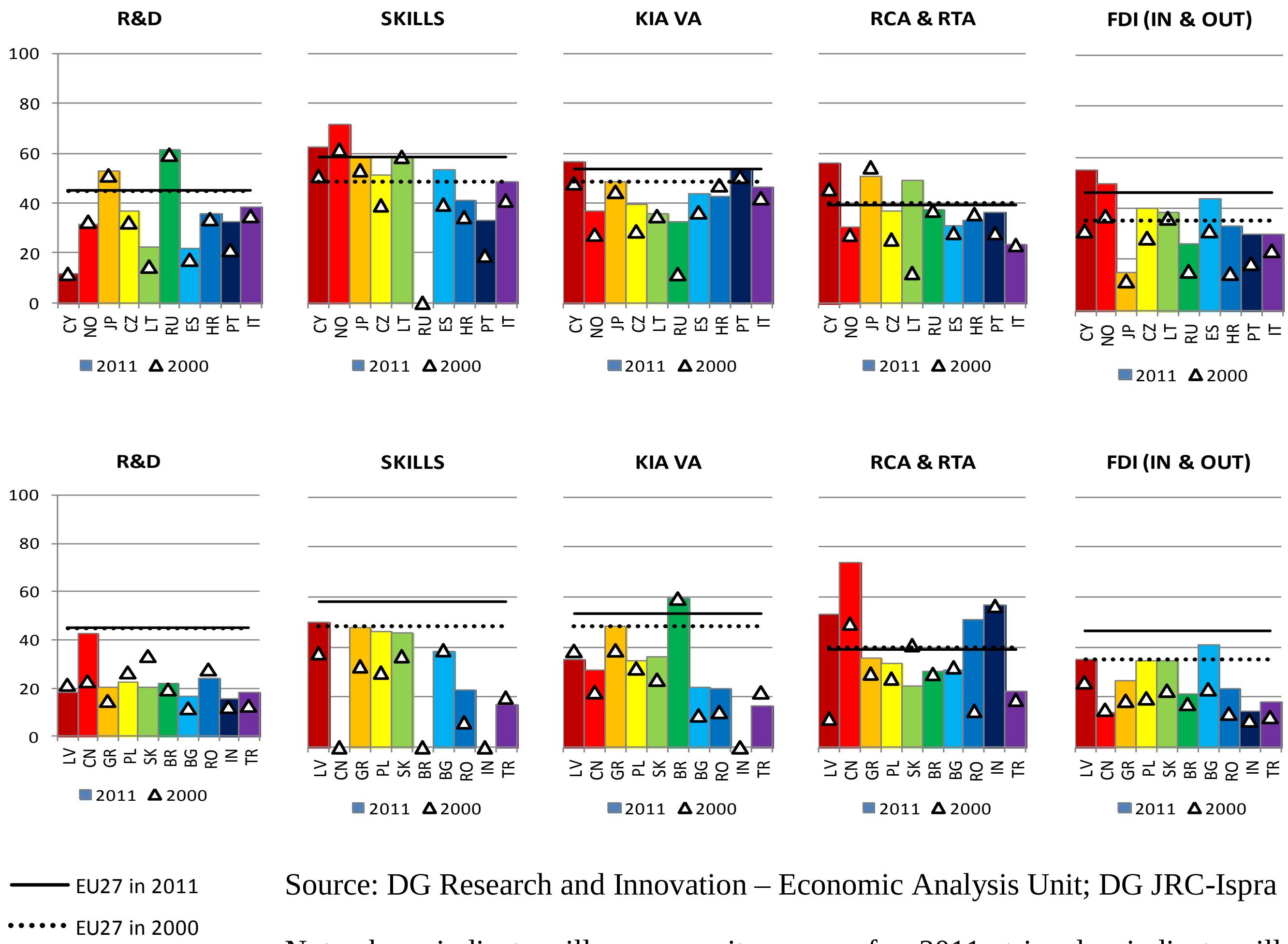
The architecture of the composite indicator on the knowledge-based economy



Comparison of pillar-level structural dynamics for 40 countries, at 2000 and 2011



Comparison of pillar-level structural dynamics for 40 countries, at 2000 and 2011



Source: DG Research and Innovation – Economic Analysis Unit; DG JRC-Ispra

Note: bars indicate pillar composite scores for 2011, triangles indicate pillar scores for 2000.

For reference, EU27 scores are shown with continuous line in 2011 and dotted line in 2000.

Innovation output indicator

$I = w_1 \times PCT + w_2 \times KIA + w_3 \times COMP + w_4 \times DYN$

where

PCT	=	number of patent applications filed under the Patent Cooperation Treaty per billion GDP Patent counts are based on the priority date, the inventor's country of residence and fractional counts. (Eurostat/OECD)
KIA	=	employment in knowledge-intensive activities in business industries (including financial services) as % of total employment. Knowledge-intensive activities are defined, based on EU Labour Force Survey data, as all NACE Rev.2 industries at 2-digit level where at least 33% of employment has a higher education degree (ISCED5 or ISCED6) (Eurostat)
COMP	=	0,5**GOOD*+ 0,5* *SERV*
GOOD	=	contribution of medium and high-tech products exports to the trade balance (see above)
SERV	=	knowledge-intensive services exports as % of total service exports exports of knowledge-intensive services are measured by the sum of credits in EBOPS (Extended Balance of Payments Services Classification) 207, 208, 211, 212, 218, 228, 229, 245, 253, 260, 263, 272, 274, 278, 279, 280 and 284 (UN/Eurostat)
DYN	=	employment in fast-growing firms of innovative business industries, excluding financial services $\sum_s (CIS^{score} \times KIA^{score})_s \frac{E_{sC}^{HG}}{E_C^{HG}}$

where

$(CIS^{score} \times KIA^{score})_s$	=	innovation coefficient of sector *s*, resulting from the product of Community Innovation Survey and Labour Force Survey scores for each sector at EU level
E_{sC}^{HG}	=	the employment in fast-growing firms in sector *s* and country *C*

E_C^{HG}	=	the employment in fast-growing firms in country *C*
w_1, w_2, w_3, w_4	=	the weights of the component indicators, fixed over time, and statistically computed in such a way that the component indicators are equally balanced. The current values are (23, 18, 43, 15).

Source: DG Research and Innovation (*Commission Staff Working Document - Developing an indicator of innovation output*)

Fast-growing enterprises

Definition: The fast-growing enterprises are enterprises with average annualised growth in number of employees of more than 10 % a year, over a three-year period, and with 10 or more employees at the beginning of the observation period (period of growth).

Source: Eurostat, OECD

Hot-spots clusters in key technologies

Based on the total number of patent applications and patents granted by the EPO by NUTS2 regions by inventor's region of residence and by applicant's region, by priority year, period (2001-2010) there were developed clusters for key technologies: 0-25% - low innovative cluster; 26-50% - medium-low innovative cluster; 51-75% - medium-high innovative cluster and 76-100% - high innovative cluster.

Small and medium-size enterprises (SMEs)
Definition: Small and medium-size enterprises (SMEs) are defined as enterprises having fewer than 250 employees.

Sources: Eurostat, OECD

Community Trademark System (CTM)

Definition: The Community trade mark system allows the uniform identification of products and services by enterprises throughout the EU. A unique procedure applied by the Office for Harmonization in the Internal Market (OHIM) allows them to register trademarks which will benefit from unitary protection and be fully applicable in every part of the Community. The CTM system is unitary in character. A CTM registration is enforceable in all member states.

Source: OHIM

EU Industrial R&D Investment Scoreboard

Definition: The EU Industrial R&D Investment Scoreboard presents information on the top 1000 EU companies and the 1000 non-EU companies. The Scoreboard includes data on R&D investment along with other economic and financial data. It is the source for the ICT Scoreboard, which provides data on the ICT companies with the largest R&D budgets globally.

Measuring Global Value Chain (GVC) income

To calculate the income a country generates in this way we follow Timmer et al. (2012) and calculate the income a country earns by contributing to the production of a particular good in the world. Formally, this is calculated as $\mathrm{GVC}_k^r = \mathbf{v}^r \mathbf{L} \mathbf{f}_k$ where $\mathbf{f}_k$ denotes the NCx1 final demand vector at the world level with non-negative entries for industry k and zeros otherwise. Pre-multiplying with the Leontief inverse $\mathbf{L}$ and the value added coefficient vector for country r $\mathbf{v}^r$ (note that this is a vector of dimension $1 \times \mathrm{NC}$ with the value added coefficients for country r and 0's otherwise. This gives the income generated in all sectors of country r needed for global production of final world output of a particular good k. When summing up over all industries yields this country's GDP, i.e. $\mathrm{GDP}^r = \sum_k \mathrm{GVC}_k^r$. This can be expressed as a share of the industry k GVC income indicating to which extent a country over time contributes directly and indirectly to serve world demand. A country's GVC income from a particular industry can be split into the contribution of the various sectors by just considering the selected activities. For example, $\mathrm{GVC}_{i,k}^r = \mathbf{v}_i^k \mathbf{L} \mathbf{f}_k$ would be the value added created in industry i of country r for production of world output of final goods produced in sector k.

Measuring vertical specialisation in final goods production

Based on the simple accounting framework one identifies how much value added is created in the domestic and foreign economy to produce the final output of a particular country in the following way. We denote the $\mathrm{NC} \times 1$ vector of final demand including non-negative values for r 0's for the other countries by $\mathbf{f}^r$ and the vector including value added coefficients of one of the other countries by $\mathbf{v}^s$ which is of dimension $1 \times \mathrm{NC}$ and contains 0's for the other countries. A measure of vertical specialisation is the value added created in the other economies to produce country r's final demand output, i.e. $\mathrm{VS}^r = \sum_{s, s \neq r} \mathbf{v}^s \mathbf{L} \mathbf{f}^r$. We can express this measure of vertical specialisation in per cent of value added to be created in all countries, i.e. also including the domestic country, i.e. $\mathbf{vLf^r}$. The analysis based on these calculations can be refined by considering only particular groups of partner countries from which inputs are sourced by summing up the vertical specialisation measure only over these countries in the formula above or by considering only particular industries rather than final output production of the whole economy. Further, an analogous calculation can be done by considering the vector of a country's exports $\mathbf{e^r}$ instead of final goods production (e.g. Hummels et al., 2001; Koopman et al., 2013; and Foster and Stehrer, 2013).

The foreign value added content of a country's production of final goods is calculated as outlined in Section 3 and aggregated to the level of reporter and partner countries. The foreign value added content in production of a country from another country is modelled as a function of value added in both countries capturing size of the economies, labour productivity and wage rates capturing production costs, employment shares of high and medium educated workers and the capital-output ratio capturing factor endowments and R&D expenditures as a proxy for innovation activities. The model is estimated by taking logs of the variables in levels, i.e. value added, labour productivity, and wages. Variables in shares or ratios are not logged. All regressions include country-pair and year dummies[179]. Data are taken from the WIOD database with only R&D expenditures being collected from the OECD ANBERD database[180].

Results of this exercise are reported in table below for vertical specialisation in final goods production[181] distinguishing between four different samples. In the first sample all countries are included whereas the second sample only includes EU member states as reporter countries only thus capturing the determinants of vertical specialisation of EU countries. The third sample includes EU member states as users of inputs from non-EU member states thus emphasising the determinants of EU countries extra vertical specialisation. Finally, the fourth sample looks at EU intra vertical specialisation by including only countries from the EU as both reporters and partners in vertical integration.

Determinants of vertical specialisation

[179] Results are robust to different specifications. Particularly, when including reporter and partner dummies together with gravity variable one finds the expected effects. Distance is significantly negatively related to offshoring as expected. Thus, the larger is geographical distance the lower is the foreign value added in a country final goods production. The coefficients tend to be rather similar across all specifications. The other gravity variables have the expected signs; particularly common border is positively related to the bilateral degree of vertical specialisation.

[180] As not all countries from the WIOD are included in the OECD data, the number of countries in the regressions is somewhat smaller.

[181] Results for vertical specialisation in exports are qualitatively similar.

	All countries	EU countries vertical specialisation	EU countries extra vertical specialisation	EU countries intra vertical specialisation
	User of foreign value added			
Value added	0.766***	1.092***	1.169***	1.057***
	(0.023)	(0.037)	(0.062)	(0.042)
Labour productivity	0.824***	0.260**	0.680***	-0.001
	(0.080)	(0.108)	(0.182)	(0.127)
Capital-output ratio	-0.326***	-0.454***	-0.848***	-0.197***
	(0.036)	(0.057)	(0.093)	(0.065)
Share high skilled	-1.087***	-0.916***	-1.658***	-0.410
	(0.202)	(0.271)	(0.431)	(0.324)
Share medium skilled	-0.158	-0.233	-0.538*	-0.074
	(0.159)	(0.177)	(0.283)	(0.212)
Wage rate high skilled	-0.240***	-0.258***	-0.341***	-0.221***
	(0.051)	(0.061)	(0.096)	(0.072)
Wage rate medium skilled	-0.090	-0.123	-0.217	-0.061
	(0.068)	(0.084)	(0.139)	(0.097)
Wage rate low skilled	-0.067*	0.078*	0.023	0.107*
	(0.037)	(0.047)	(0.083)	(0.055)
R&D	-0.030**	-0.101***	-0.137***	-0.081***
	(0.012)	(0.015)	(0.025)	(0.016)
	Supplier of value added			
Value added	0.598***	0.557***	0.293***	0.910***
	(0.023)	(0.027)	(0.038)	(0.041)
Labour productivity	0.976***	1.011***	0.653***	0.634***
	(0.078)	(0.094)	(0.156)	(0.120)

	All countries	EU countries vertical specialisation	EU countries extra vertical specialisation	EU countries intra vertical specialisation
Capital-output ratio	-0.078**	-0.108**	-0.271***	0.150**
	(0.036)	(0.043)	(0.079)	(0.065)
Share high skilled	-0.136	0.395	0.022	0.665**
	(0.199)	(0.245)	(0.544)	(0.308)
Share medium skilled	-0.015	0.469**	-0.037	0.115
	(0.167)	(0.201)	(0.564)	(0.223)
Wage rate high skilled	-0.343***	-0.342***	0.105	-0.608***
	(0.053)	(0.065)	(0.154)	(0.077)
Wage rate medium skilled	-0.068	-0.031	-0.113	0.196**
	(0.070)	(0.085)	(0.222)	(0.099)
Wage rate low skilled	-0.076**	-0.130***	-0.313**	-0.067
	(0.038)	(0.043)	(0.137)	(0.054)
R&D	0.094***	0.112***	0.324***	-0.004
	(0.013)	(0.015)	(0.037)	(0.017)
Observations	9602	6127	2287	3840
R squ.	0.990	0.990	0.988	0.993

Source: World Input-Output Database (WIOD)

Literature references

Ackers (2012), “Mobilities and Knowledge: Understanding the dynamics of knowledge transfer and translation processes in North-South Healthcare Partnerships?” *International Migration,* vol 50 issue 5.

Archibugi, D. and J. Michie (1995), "The globalization of technology: a new taxonomy." *Cambridge Journal of Economics,* 19 (1): 121.

Asheim, B. and A. Isaksen (2002), "Regional innovation system: the integration of local 'sticky' and global 'ubiquitous' knowledge." *Journal of Technology Transfer,* 27: 77-86.

Audretsch, D.B. and A. R. Thurik (2000), ‘Capitalism and Democracy in the 21st Century: From the Managed to the Entrepreneurial economy’, Journal of Evolutionary Economics, 10: 17-34.

Baptista, R. and J. Mendonca (2010), Proximity to knowledge sources and the location of knowledge based start-ups, Annals of Regional Science, 45(1): 5-29.

Breschi, S. and F. Lissoni (2001), "Knowledge spillovers and local innovation systems: a critical survey." *Industrial and Corporate Change* 10 (4): 975-1005.

Brocker, J and R. Soltwedel (2010), "Agglomeration and growth in knowledge-based societies: an introduction to this special issue", *Annals of Regional Science*, 45(1): 1-4.

Boschma, R. (2004), Competitiveness of Regions from an Evolutionary Perspective. Regional Studies, 38 : 1001-1014.

Callaert, J.; Vervenne, JA; Looy; Magerman, T.; Song, X.; Jeuris, W. (2012), Patterns of Science-Technology Linkage. Measurement and analysis of Knowledge and R&D exploitation flows assessed by patent and licensing data. Incentim, Bocconi University.

Castellacci, F. & Archibugi, D. (2008), The technology clubs: The distribution of knowledge across nations*. Research Policy*, 37: 1659-1673.

Castellani, D. and Pieri, F. (Forthcoming), R&D Offshoring and the productivity growth of European regions, *Research Policy.*

Chaminade, C. & Plechero, M. (2012), "Do regions make a difference? Exploring the role of different regional innovation systems in global innovation networks in the ICT industry". *CIRCLE Electronic Working Papers*. CIRCLE, LUnd University, Sweden.

Chesbrough, H. (2003), Open Innovation: The New Imperative for Creating and Profiting from Technology. Boston, MA: Harvard Business School Press.

Chesnais, F. (1988), Multinational enterprises and the international diffusion of technology. In: DOSI, G. (ed.) Technical Change and Economic Theory.

Cohen, W. and D. Levinthal (1990), "Absorptive capacity: a new perspective on learning and innovation." *Administrative Science Quarterly* 35: 128-152.

David, P. and D. Foray (1995), "Interactions in Knowledge systems : foundations, policy implications and empirical methods." *STI Review* (16): 14-68.

Delgado, M., Porter, M.E. and Stern, S. (2010), Clusters and entrepreneurship, *Journal of Economic Geography*, 10: 495-518.

Dietzenbacher, E., B. Los, R. Stehrer, M. Timmer and G. de Vries (2013), "The Construction of World Input-Output Database in the WIOD Project", *Economic Systems Research*, 25(1): 71-98.

Di Minin and Zhang (2010) “An exploratory study on international R&D strategies of Chinese companies in Europe”, *Review of Policy Research*, 27(4): 433-455.

Dolfsma, W., C. Chaminade, et al. (2008), "Knowledge dynamics out of balance- knowledge biased, skewed and unmatched." *Research Policy* 37(10): 1657-1658.

Ebersberger, B., Herstad, S., Iversen, E., Kirner, E. & Soom, O. (2011). Open innovation in Europe: effects, determinants and policy. In: COMMISSION, E. (ed.). Oslo. www.proinno-europe.eu/innogrips2

European Commission (2012a), Delivery of the single market act: state of play. Commission staff working document. SWD (2012) 21 Final.

European Commission (2012 b) Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions. Single Market Act II. Together for new growth. COM (2012) 573 final.

European Commission (2012c) Internationalization of business investments in R&D. Luxemburg: Publications Office of the European Union.

European Commission (2012d) Europe 2020 key areas. Chapter 12. R&D and innovation target. http://ec.europa.eu/europe2020/pdf/themes/12_research__development.pdf. Accessed on 23 March 2013.

Foster, N. and R. Stehrer (2013), "Value Added in Trade: A Comprehensive Approach", *Economics Letters*, forthcoming.

Frenz, M. and G. Ietto-Gillies (2009), "The impact on innovation performance of different sources of knowledge: Evidence from the UK Community Innovation Survey." *Research Policy* 38(7): 1125-1135.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P. & Trow, M. (1994) The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies, SAGE Publications.

Giovannoni (2010), Final report of PatVal-EU II survey methods and results. Deliverable D_2_5.pdf. www.innost.unibocconi.it. Accessed on 17 June 2013.

Giuliani, E. (2007), "The selective nature of knowledge networks in clusters: evidence from the wine industry." *Journal of Economic Geography* 7(2): 139-168.

Giuliani, E. (2011), "Networks of innovation." Handbook of Regional Innovation and Growth: 155.

Grimpe, C. and W. Sofka (2009), "Search patterns and absorptive capacity: Low-and high-technology sectors in European countries." *Research Policy* 38(3): 495-506.

Gutiérrez Gracia, A., I. Fernández De Lucio, et al. (2008), "The effects of knowledge sourcing strategies on science-based firms? Innovative performance: evidence from the Spanish manufacturing industry." *INGENIO working paper*. www.ingenio.es

Hassink, R. and d.H. Shin (2005) The restructuring of old industrial areas in Europe and Asia, *Environment and Planning* A, 37: 571-580.

Hummels, D., J. Ishii, and K.M. Yi (2A001), "The Nature and Growth of Vertical Specialization in World Trade", *Journal of International Economics*, 54(1).

Ingstrup, M.B. and Damgaard, T. (2012), " Cluster Facilitation from a Cluster Life Cycle Perspective", *European Planning Studies*, 2012: 1-19.

INSEAD & WIPO (2012). The Global Innovation Index 2012: Stronger Innovation Linkages for Global Growth, INSEAD.

Jensen, M. B., B. Johnson, et al. (2007). "Forms of knowledge and modes of innovation." *Research Policy* 36(5): 680-693.

Karlsson, C. (ed.) (2008), Handbook of Research on Cluster Theory, Cheltenham: Edward

Elgar, 316 pages.

Kitson, M., Martin, R. & Tyler, P. (2004) "Regional Competitiveness: An Elusive yet Key Concept?" Regional Studies, 38: 991-999.

Klepper, S. (2007), The evolution of geographic structures in new industries, in K. Frenken (Ed.) Applied Evolutionary Economics and Economic Geography, Cheltenham: Edward Elgar.

Klink, Van A. and De Langen P. (2001), "Cycles in industrial clusters: the case of the shipbuilding industry in the Northern Netherlands", *Tijdschrift voor Economische en Sociale Geografie*, 92: 449.

Knop, L. and Olko, S. (2011), Crises in the cluster life-cycle, Management Knowledge and Learning, International Conference, Silesian University of Technology, Gliwice, Poland.

Koopman, R., W. Powers, Z.Wang, and S.-J.Wei (2013), "Give Credit Where Credit is Due: Tracing Value Added in Global Production Chains", *American Economic Review*, forthcoming.

Laursen, K. and A. Salter (2006). "Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms." *Strategic Management Journal* 27(2): 131-150.

Leiponen, A. and C. E. Helfat (2010). "Innovation objectives, knowledge sources, and the benefits of breadth." Strategic Management Journal 31 (2): 224-236.

Lorenzen, M. (2005), 'Why do clusters change?' European Urban and Regional Studies, 12(3): 203-208.

Marcel P. Timmer, Bart Los, Robert Stehrer, Gaaitzen de Vries (2012), Fragmentation, Incomes and Jobs. An analysis of European competitiveness, WIOD Working Paper, No. 9.
Maliranta, M., Mohnen, P. & Rouvinen, P. (2009). "Is inter-firm labor mobility a channel of knowledge spillovers? Evidence from a linked employer–employee panel". *Industrial and corporate change*, 18: 1161-1191.

Martin and Sunley (2011), "Conceptualising Cluster Evolution: Beyond the Life-Cycle Model?" *Papers in Evolutionary Economic Geography*, Utrech University http://econ.geo.uu.nl/peeg/peeg.html

Marx, M. (2011), The Firm Strikes Back Non-compete Agreements and the Mobility of Technical Professionals, *American Sociological Review*, 76: 695-712.

Menzel, P.E. and Fornahl, D. (2009), "Cluster life cycles: dimensions and rationales of cluster development" *Jena Economic Research Papers* no. 2007-076, Jena: Germany: Max Plank Institute in Economics.

Narula, R. & Hagedoorn, J. (1999), Innovating through strategic alliances: Moving towards international partnerships and contractual agreements, *Technovation*, 19, 283-294.

Nooteboom, B., W. Van Haverbeke, et al. (2007), "Optimal cognitive distance and absorptive capacity." *Research Policy* 36(7): 1016–1034.

Nowotny, H., Scott, P. & Gibbons, M. (2001), Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty, Wiley.

OECD (2012c), Draft final report on financing, transferring and commercializing knowledge. DSTI/STP/TIP(2012)20.

OECD (2012a), Knowledge networks and markets. Final report. DSTI/EAS/STP/NESTI/ TIP (2013)1/FINAL

OECD (2012b),Knowledge flows and the mobility of skilled employees: an international perspective on the role of non-compete agreements and their legal enforcement. DSTI/EAS/STP/NESTI/TIP (2012)10.

OECD (2012d), Knowledge flows in the innovation system: selected indicators and key trends. DSTI/EAS/STP/NESTI/TIP (2012) 6/CHAP1.

OECD (2011), Science, Technology and Industry Scoreboard 2011. Paris: OECD.

Pavitt, K. (1984). Sectoral patterns of technical change: towards a taxonomy and a theory. *Research Policy*, 13: 343-373.

Porter, M.E. (1990), The Competitive Advantage of Nations, New York, Free Press.

Porter, M.E. (1998), Clusters and the New Economics of Competition, Harvard Business Review, November-December: 77-90.

Power, D. & Malmberg, A. (2008), The contribution of universities to innovation and economic development: in what sense a regional problem? Cambridge Journal of Regions, Economy and Society, 1: 233-245.

PRO INNO sEurope: INNO-Grips II report, Brussels: European Commission, DG Enterprise and Industry.

Reinstaller A. (coord.), Hölzl, W., Janger J., Stadler, I., Unterlass F., Daimer S., Stehnken, T. (2010), Barriers to internationalisation and growth of EU's innovative companies.

Reynolds, P., D. Storey and P. Westhead (1994), 'Cross –National Comparisons of the Variation in New Firm Formation Rates – An Editorial Overview', Regional Studies, 28: 343-346.

Reynolds, P.D., S.M.Campus, W.D. Bygrave, E. Autio and M. Hay (2001), Global Entrepreneurship Monitor – 2001 Executive Report, Kauffman Center for Entrepreneurial Leadership, Kansas City: Kauffman Foundation.

Rocha, H.O. (2004), "Entrepreneurship and Development: The Role of Clusters, Small Business Economics", 23: 363-400.

Rocha, H.O. and R. Sternberg (2005), "Entrepreneurship: The Role of Clusters Theoretical Perspectives and Empirical Evidence from Germany", *Small Business Economics*, 24: 267-292.

Silva, M. J. M., J. Simões, et al. (2012). "Investment and Expenditure on Innovation Activities and Innovative Capability: Empirical Evidence from Portuguese Services Firms and KIBS." *International Business Research* 5(2): 114.

Stephan, P. (2012), How economics shapes science. Boston, MA: Harvard University Press

Sonderegger, R. and Taube, F (2010) , "Cluster life cycle and diaspora effects: Evidence from the Indian IT Cluster in Bangalore", *Journal of International Management*, 16: 383-397.

Stough, R.R. (2013 in press) Agglomeration, Clusters and Entrepreneurship in in Karlsson, C. R. Johansson and R.R. Stough, Regional Economic Development: Agglomerations, Clusters and Entrepreneurship, Edward Elgar: Cheltenham, United Kingdom.

Stöllinger, R. (2012). International spillovers in a world of technology clubs. WIIW Working paper. Viena**:** 25.

Swann, G.M.P. (2002), "Towards a model of clustering in high-technology industries", in

Swan, M., G.M.P. Prevezer and D. Stout (eds), The Dynamics of Industrial Clustering, Oxford, Oxford

Thurow, L. (1992) Head to head: The coming battle among Japan, Europe, and America. New York: Morrow.

Tidd, J., J. Bessant, et al., Eds. (2002 (2nd edition)), Managing innovation: integrating technological, market and organizational change. New York, Wiley.

Tijssen, R. (2003), "Scoreboards of research excellence", *Research Evaluation*, 12(2): 91-103

Timmer, M., B. Los, R. Stehrer, and G. de Vries (2012), Fragmentation, Incomes and Jobs: WIOD Working Paper 9.

Boschma, R. (2005), "Proximity and Innovation: A Critical Assessment." *Regional Studies* 39(1): 61-74.

Trippl, M. (2011), "Scientific Mobility and Knowledge Transfer at the Interregional and Intraregional Level". First published on: 11 March 2011 (iFirst), *Regional Studies*: 1-15.

Utterback, J.M. and W.J. Abernathy (1975), A dynamic model of process and product innovation, Omega, 3(6): 639-656.

Vervenne, JB; Zhang, L.; Yan, X.; Song, X.; Van Looy, B. (2012), Measurement and analysis of knowledge and R&D exploitation flows, assessed by patent and licensing data.

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