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PART 1/7

COMMISSION STAFF WORKING DOCUMENT

'Innovation Union Competitiveness report' 2013 edition

Commission Staff Working Document

European Commission, 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 triad¹. 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 and the United Kingdom 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 private 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

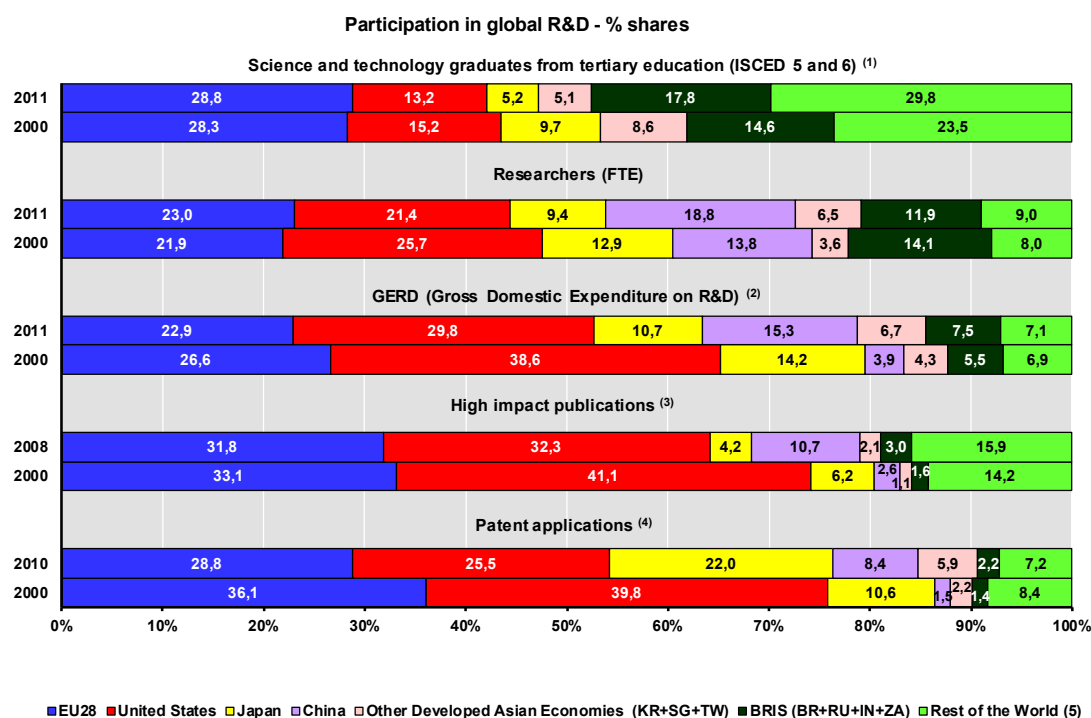
This chapter is an update and further development of the analysis of Europe's competitive position in research and innovation (R&I) published in the 2011 edition of the Innovation Union Competitiveness (IUC) report. Some structural long-term indicators have not been repeated although this edition goes 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 PPSE.

(3) (i) Top 10% 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 of innovation performance, according to the IUS, was 1.6 % in the 5-year period 2008–2012.

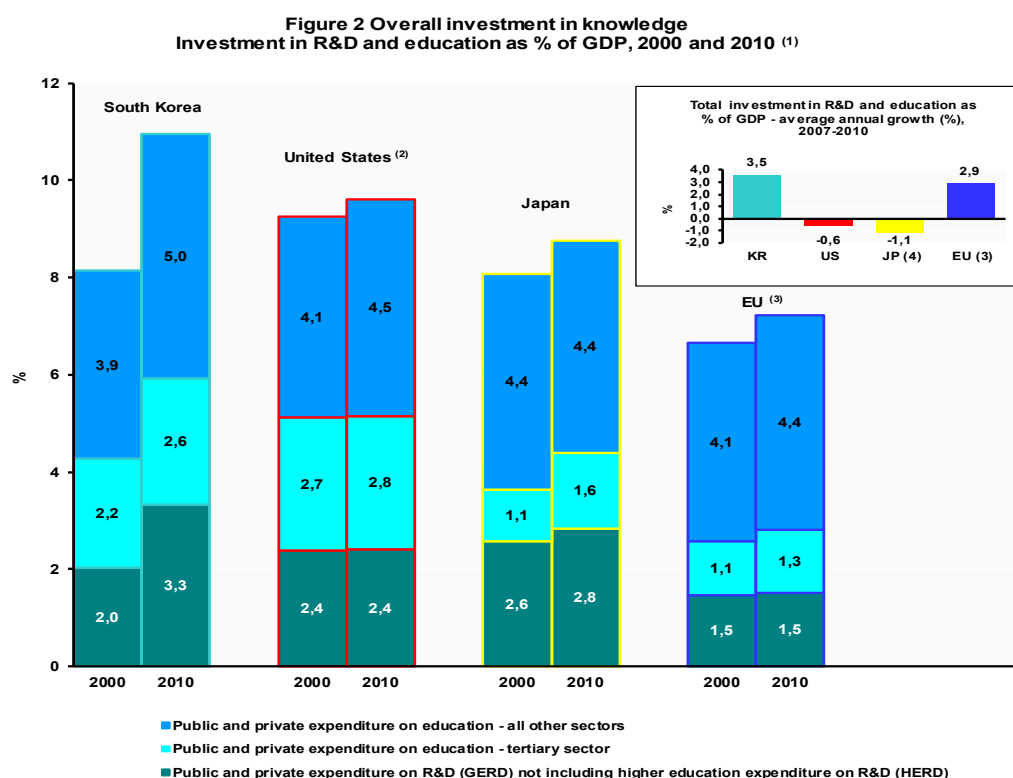
⁵ PCT: Patent Cooperation Treaty. 'International' patent application seeking patent protection for an invention in several countries.

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.

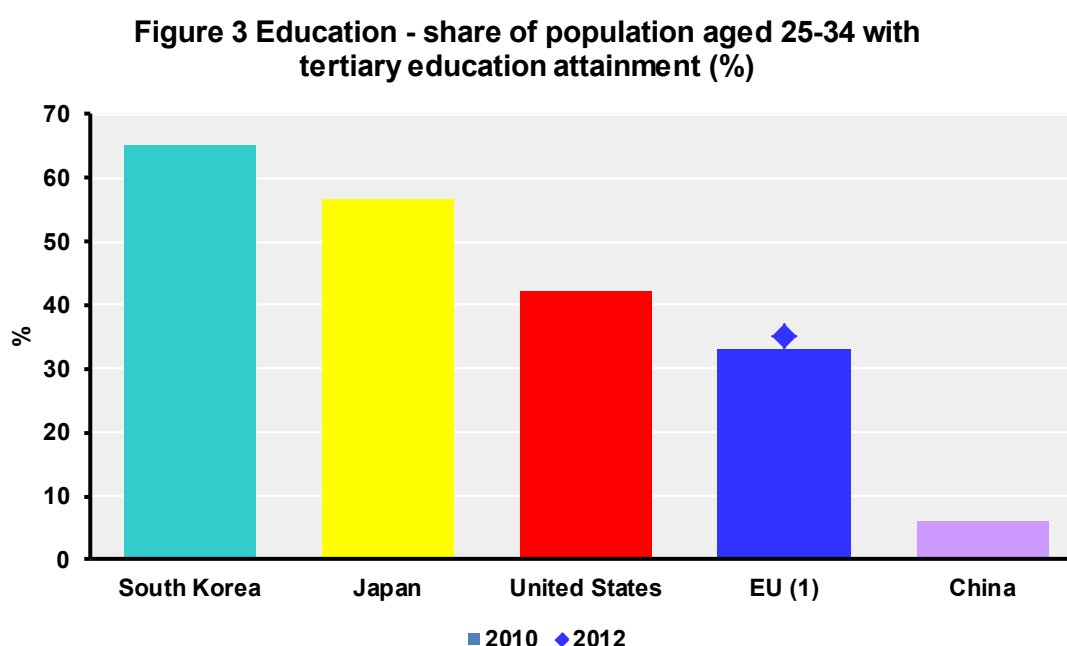
(2) US: GERD not including HERD does not include most or all capital expenditure.

(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.



Innovation Union Competitiveness report 2013

Source: DG Research and Innovation - Economic Analysis Unit

Data: Eurostat, OECD

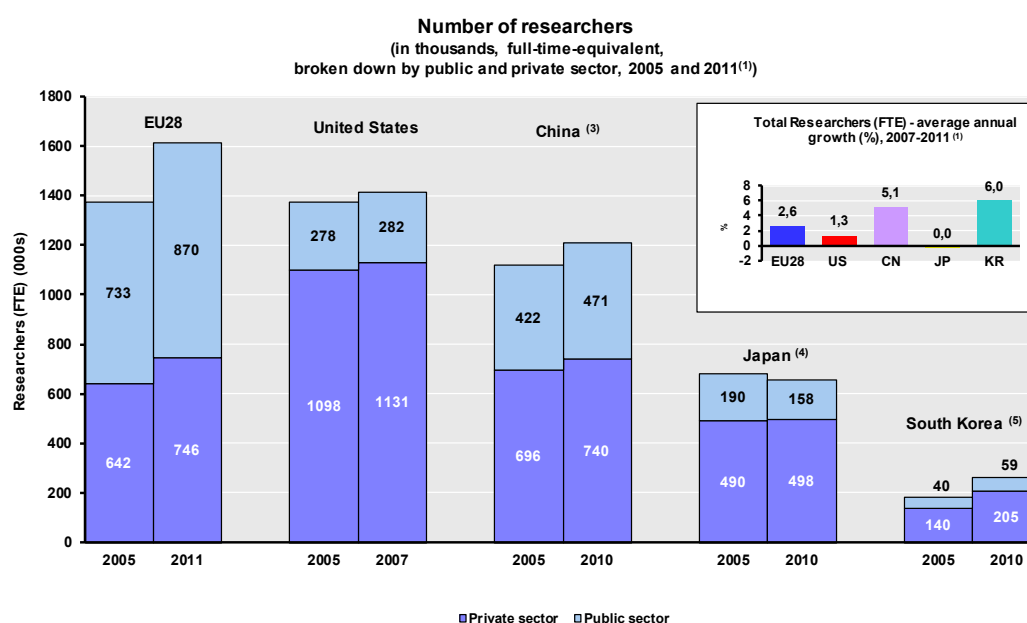
Note: (1) Data for 2012 are available only for the EU.

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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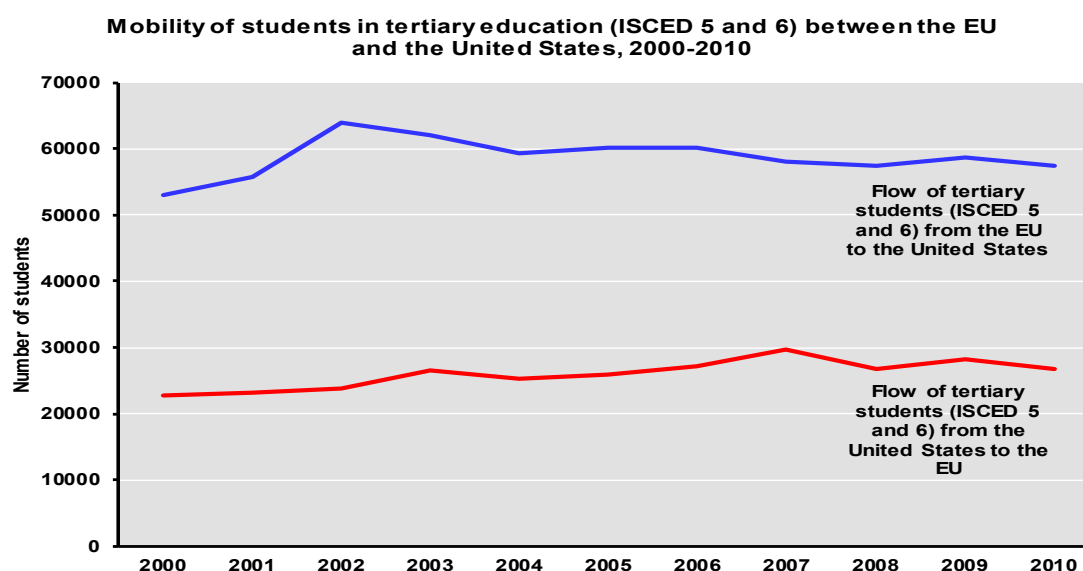
⁷ In the Innovation Union Competitiveness report 2011, based on the previous official statistics of China. China had overtaken both the United States and the EU in number of FTE researchers. Latest Organisation for Economic Co-operation and Development (OECD) data for China show that there is a major 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



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

Innovation Union Competitiveness Report 2013

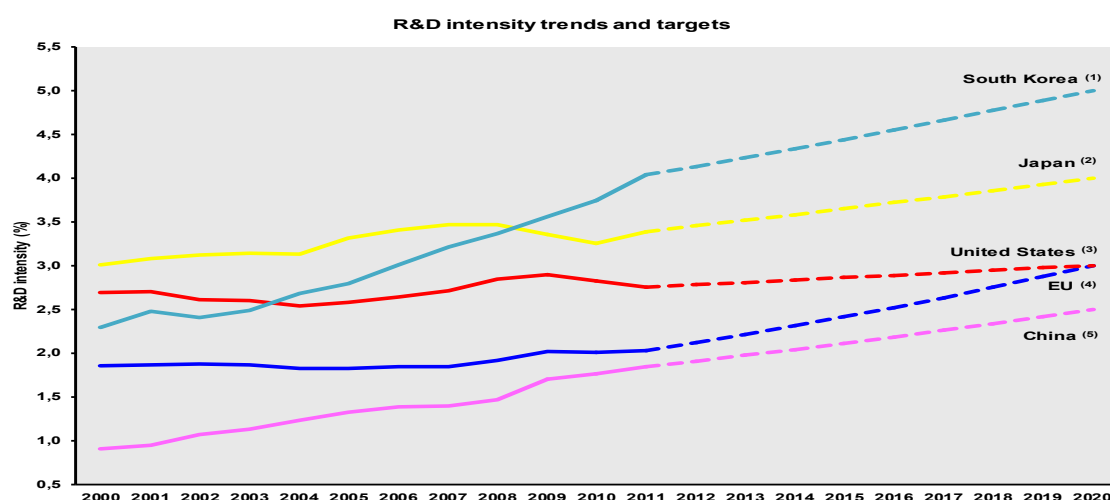
⁸ A more detailed analysis is available in Chapter I.3.

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.

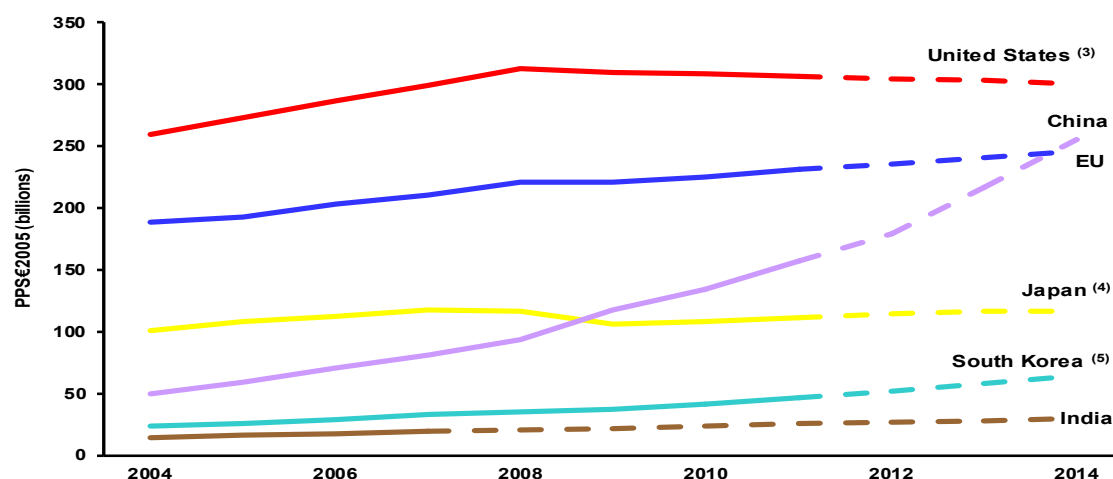
(3) United States: (i) The projection is based on an R&D intensity target of 3.0% for 2020; (ii) R&D expenditure does not include most or all capital expenditure (iii) There is a break in series between 2006 and the previous years.

(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.

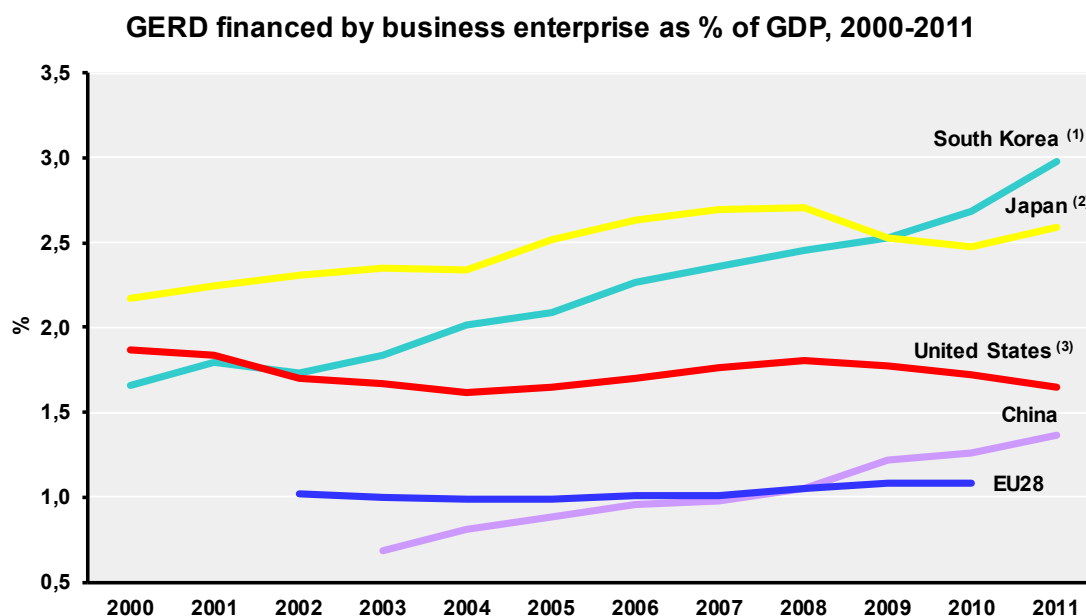
(4) JP: There is a break in series between 2008 and the previous years.

(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

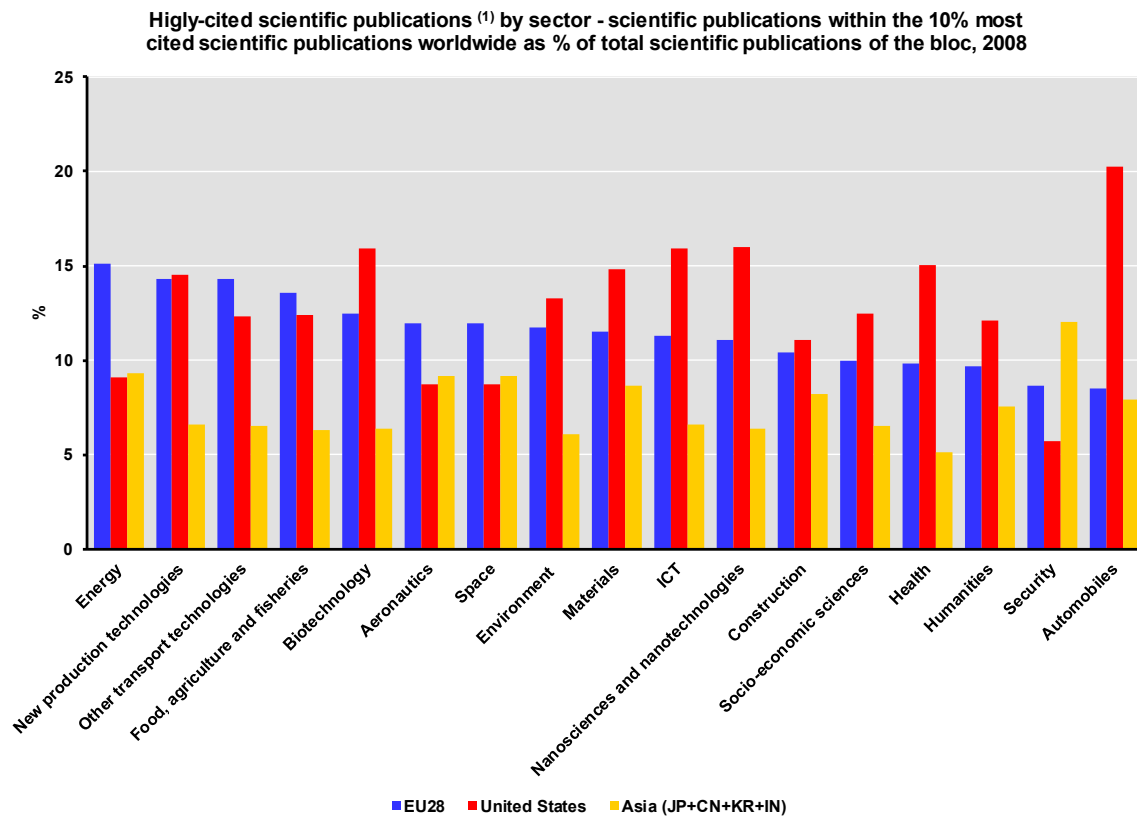
The growing geographic distribution of knowledge creation in the world, coupled with the continuous accumulation of the total knowledge assets available globally, push international competition towards an increasing specialisation. It is more and more difficult to be among the world leaders in a broad 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 technologies » 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

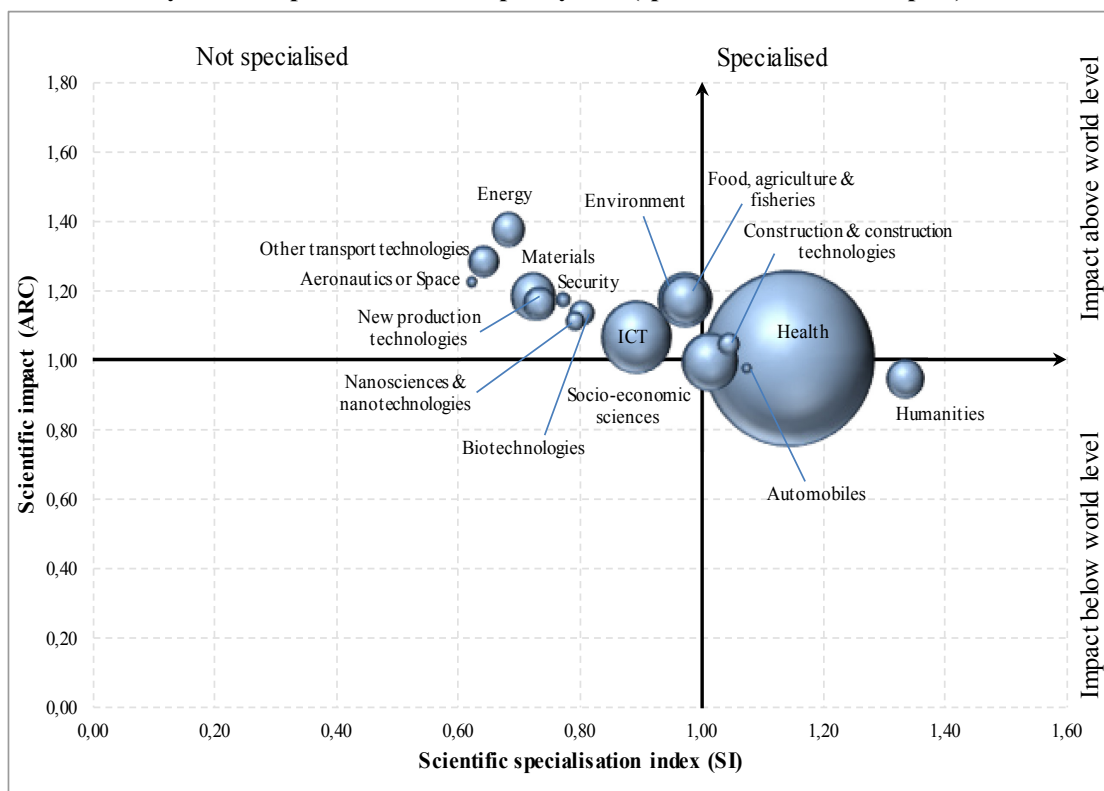
remains in line with the world average and has not significantly improved over the last decade. The EU's other major publication fields are materials, environment and socioeconomic sciences. The trend is an increase up to the economic crisis, since which scientific production in most areas has stagnated.

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

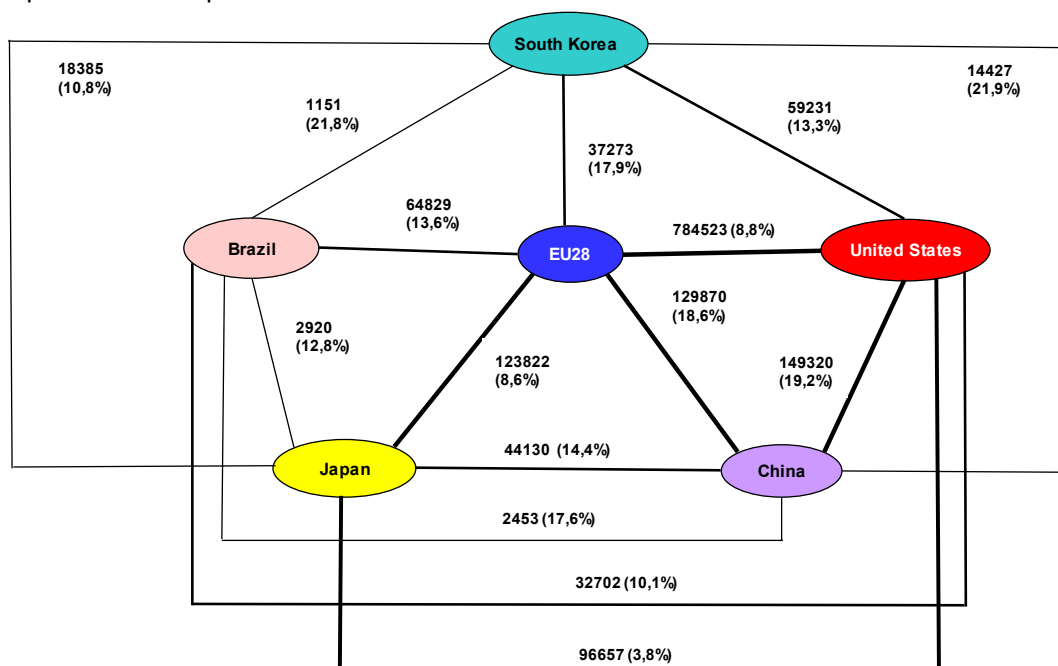
The evolution towards more geographically distributed scientific production, coupled with growing overall production and pressure for reviewed specialisation strategies, goes hand in hand with an increase in international scientific cooperation. Given that today over 70 % of knowledge production takes 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.

Scientific co-publications between the EU, the United States, Japan, South Korea, China and Brazil, 2000-2011
The values refer to total scientific co-publications over the period 2000-2011; in brackets: average annual growth in scientific co-publications over the period 2000-2011.



Source: DG Research and Innovation - Economic Analysis Unit
Data: Science Metrix / Scopus (Elsevier)

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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).

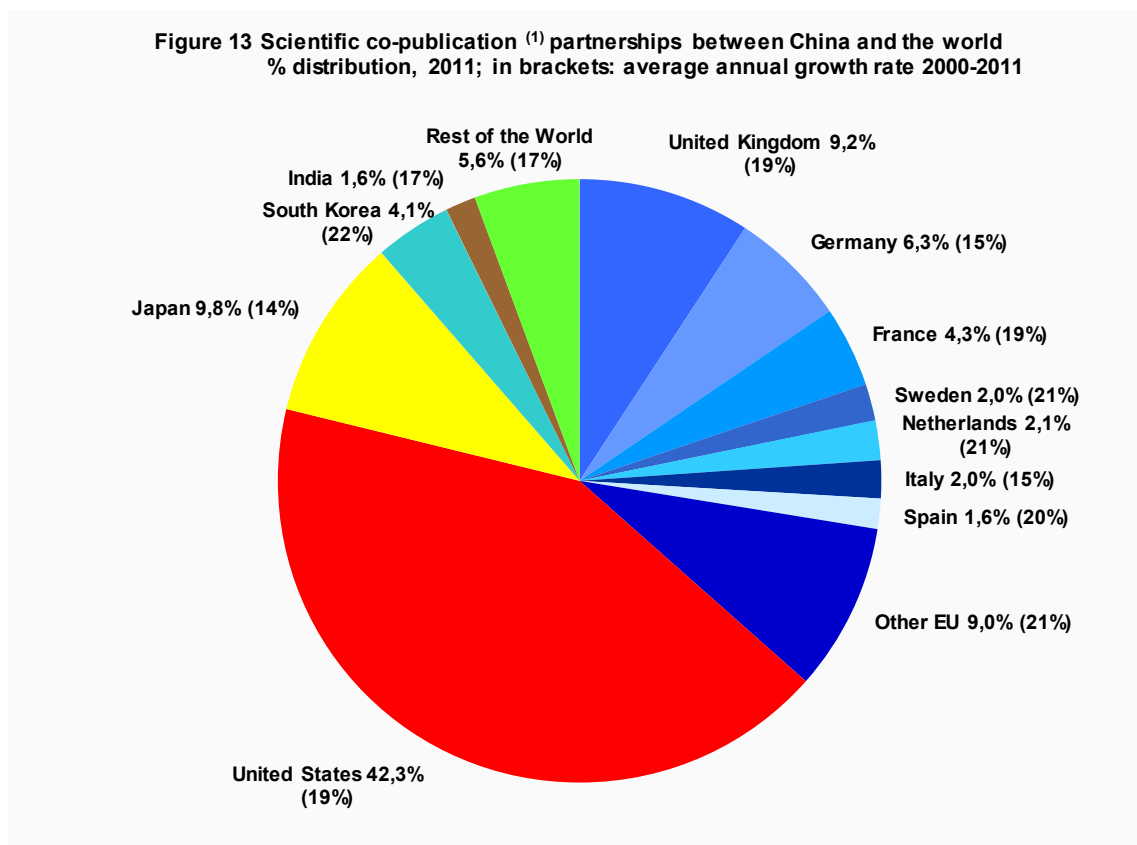
Given the large scale of the international science and technology, individual EU Member States alone have less relative weight

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 % ⁽¹⁴⁾ of Chinese international

¹⁴ Threshold chosen to inclusion in the figure.

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

Data: Science Metrix / Scopus (Elsevier)

Note: (1) Full counting method.

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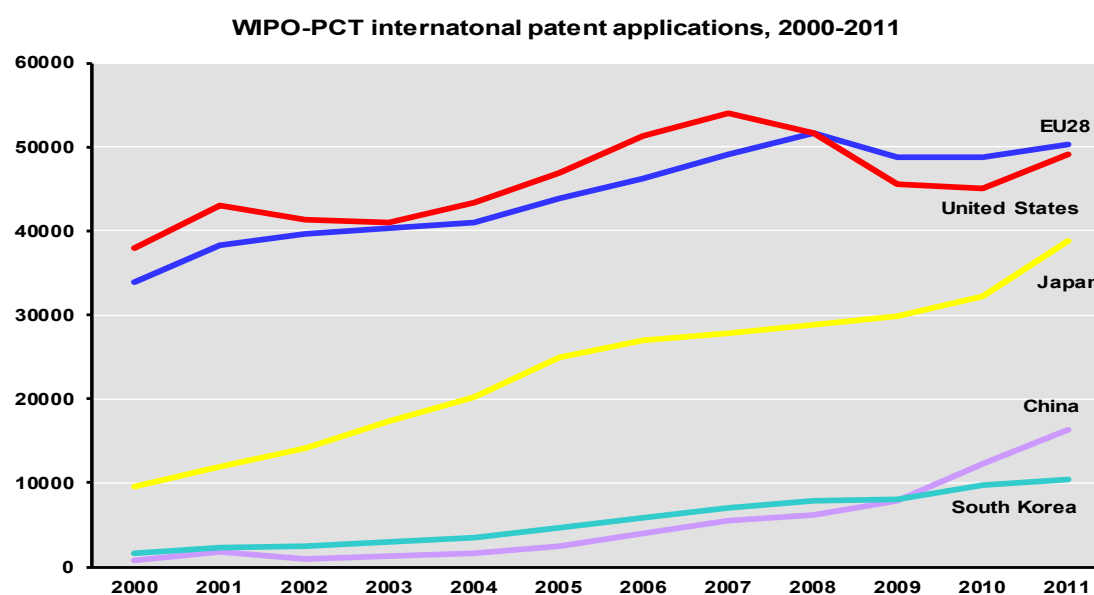
4. The EU's competitive position in technology development

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 ⁽¹⁵⁾.

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



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

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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

¹⁵ 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%	30.9%	49.4%	47.9%	14.5%	17.3%
	6015	7207	9068	11 172	2661	4035
Biotechnology	28.0%	32.0%	49.0%	44.4%	20.7%	20.8%
	2787	2415	4885	3346	2068	1566
ICT	37.7%	25.8%	40.0%	35.0%	20.5%	37.9%
	8354	9960	8864	13 486	4552	14 613
Energy	29.8%	31.6%	48.2%	46.9%	19.7%	19.2%
	1624	1744	2467	2591	1007	1059
Green energy	32.7%	33.3%	43.6%	32.5%	21.2%	31.7%
	3196	3806	4258	3687	2075	3624
Environment	34.7%	34.5%	42.0%	31.8%	20.8%	31.1%
	3970	4839	4815	4456	2386	4363
Nanotechnology	31.5%	34.1%	45.6%	37.0%	19.8%	26.5%
	256	478	371	552	161	389
Materials	41.7%	35.5%	34.4%	29.4%	21.0%	32.1%
	7091	8070	5850	6691	3566	7296
New Prod. techn.	36.0%	36.8%	45.1%	36.33%	15.8%	23.8%
	4978	5664	6236	5596	2185	3670
Security	38.7%	34.8%	45.5%	37.6%	12.6%	24.9%
	2200	2934	2585	3171	717	2098
Automobiles	60.0%	50.2%	24.5%	17.3%	14.3%	31.2%
	1642	2213	670	763	391	1378
Other Transport	58.0%	47.5%	25.6%	22.3%	9.8%	24.2%
	449	625	198	294	76	318
Aeronautics	42.8%	65.7%	50.0%	26.7%	5.0%	6.1%
	112	460	131	187	13	43
Space	27.7%	35.4%	50.5%	34.2%	18.8%	30.4%
	28	28	51	27	19	24
Construction	54.8%	44.2%	28.2%	35.6%	11.0%	15.4%
	1532	2183	787	1757	307	759
Food, Agriculture	43.4%	36.8%	36.0%	37.7%	15.4%	21.1%
Fishery	1641	1902	1362	1949	582	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.

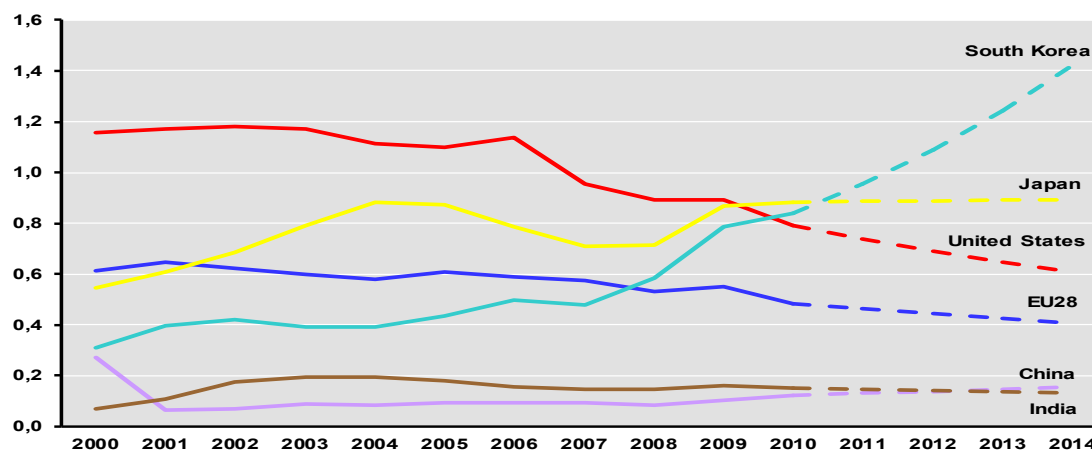
Economic transformation addressing societal challenges may come from Asia

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⁾



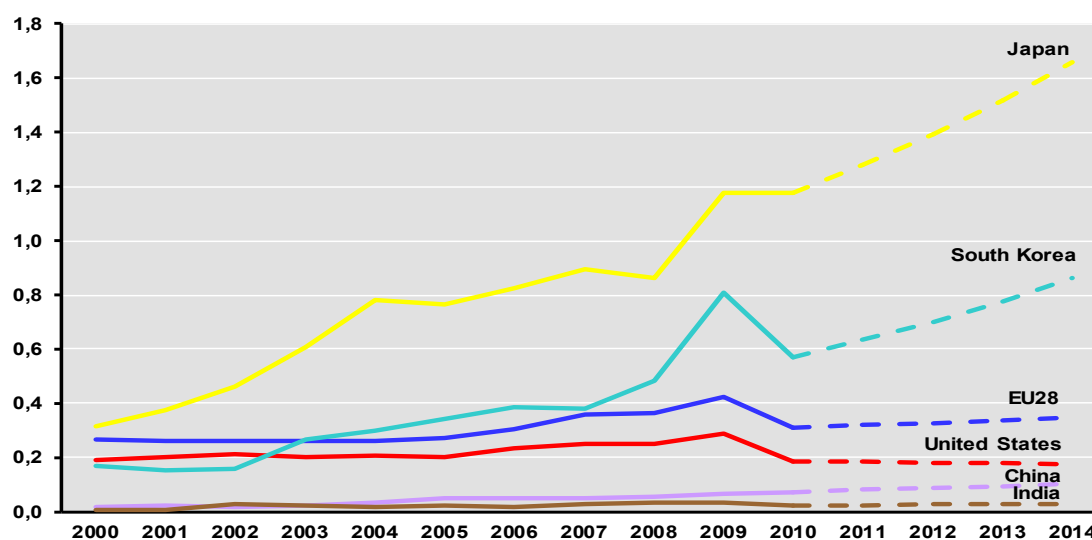
Source: DG Research and Innovation - Economic Analysis Unit Innovation Union Competitiveness Report 2013

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 ⁽¹⁶⁾ to the relative importance of this technological area in worldwide patent production ⁽¹⁷⁾. 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

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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

¹⁶ The EU and Associated Countries.

¹⁷ 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.

industries such as aeronautics, automobiles, other transport technologies and construction 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.

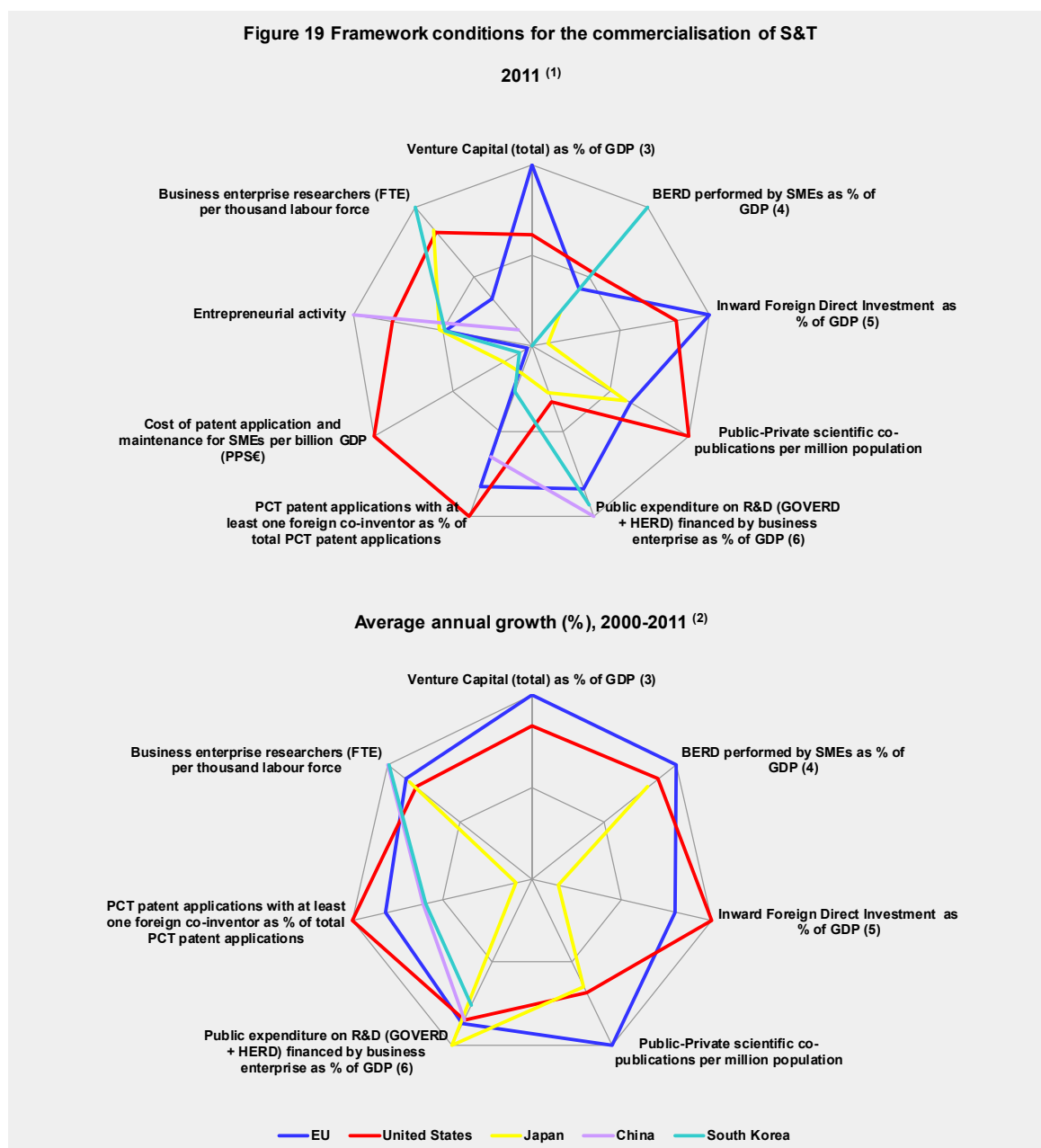
Comparing the EU's technology specialisation profile (Figure 18) with its technology strengths at the world level (Figure 15), a clearer match emerges than during the comparison with the EU's scientific production profile. The specialisation in transport and construction reflects the technology areas 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

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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.

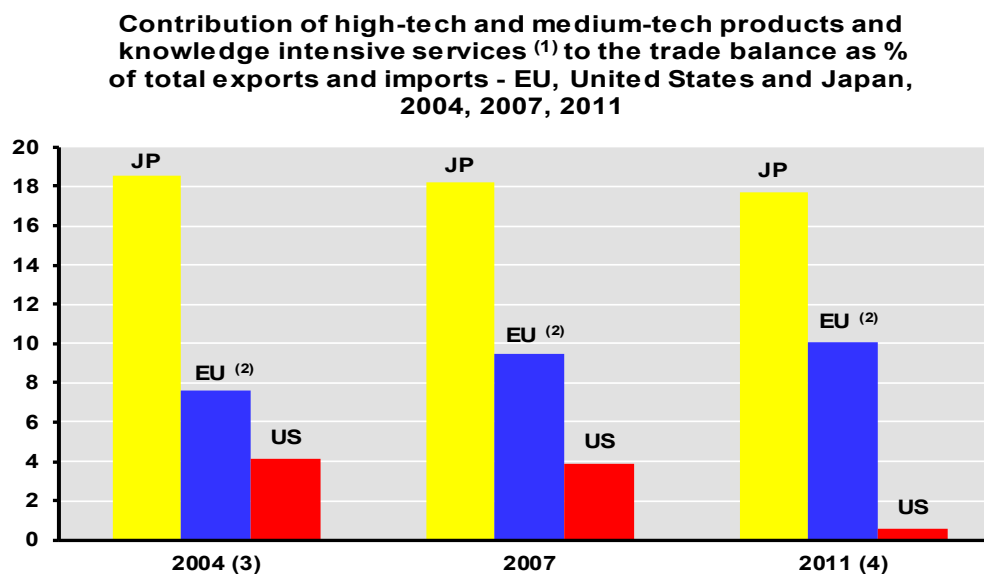
(6) US: (i) GOVERD refers to federal or central government expenditure only; (ii) HERD does not include most or all capital expenditure.

(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 ⁽¹⁸⁾. 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



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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.

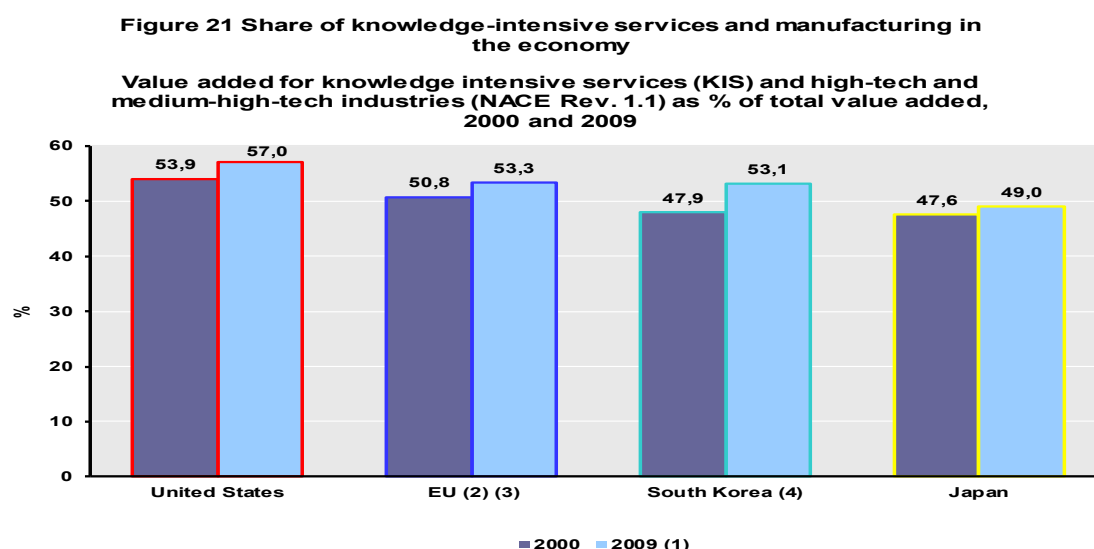
As represented in Figure 20, the EU has increased its contribution of high-tech products, medium-tech products and knowledge-intensive services (KISs) to the overall trade balance (progressing from 7.6 % to 10 % in 2011). It is worth noting that in the same period, both the United States and Japan experienced 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-

¹⁸ 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 KISSs), the slightly reduced contribution in Japan is due exclusively to an inversion of the contribution of knowledge-intensive services (KISSs) 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 KISSs 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
Data: Eurostat, OECD

Innovation Union Competitiveness report 2013

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 ⁽¹⁹⁾. Maintaining this position depends on the capacity of Europe to upgrade and position itself in the knowledge economy of tomorrow.

¹⁹ For a more detailed analysis of structural change in the EU, see Part III of this IUC 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

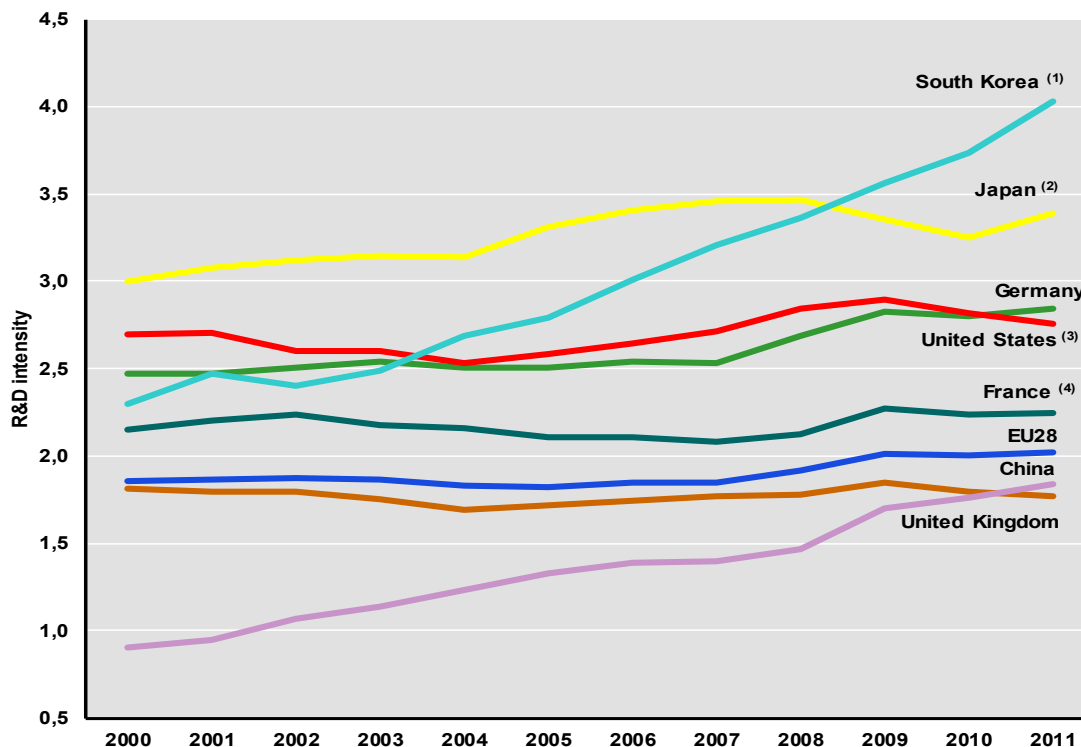
In 2011, the EU represented 22.8% of total R&D expenditure in the world, measured in PPS€ at 2005 prices and exchange rates, down from 26.7% in 2000 (Figure I.1.1). The continuously decreasing share of the EU in world R&D expenditure is mainly due to the rapid rise of China. However, this decrease of 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 2.03 % 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.

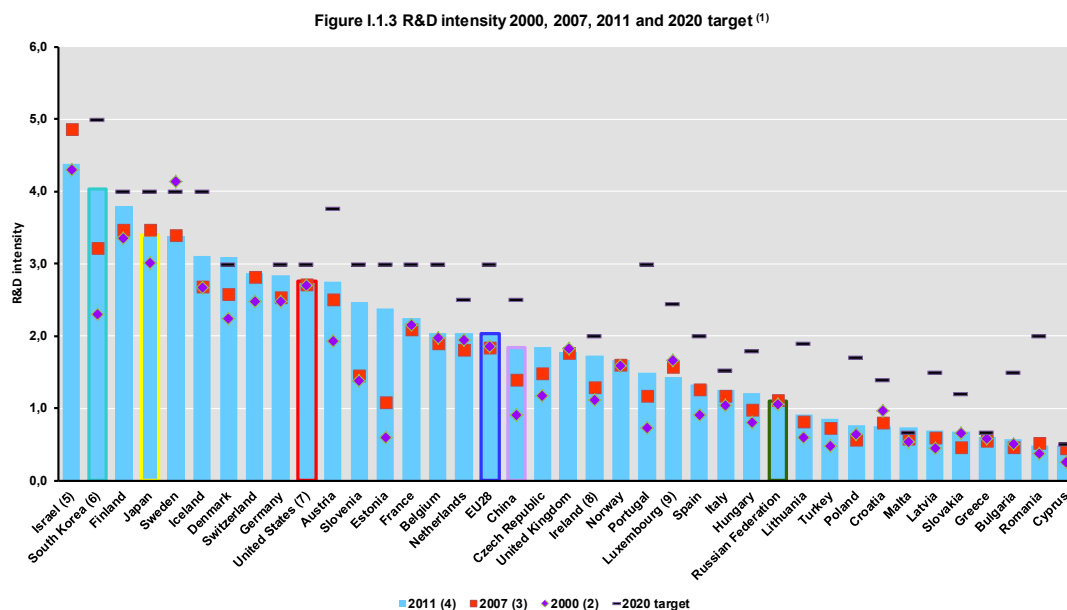
(4) FR: There are a breaks in series between 2004 and the previous years and 2010 and the previous years.

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⁽²⁰⁾. 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⁽²¹⁾.



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.

²⁰ See 'Science, Technology and Competitiveness Key Figures Report 2008/2009', p. 26.

²¹ See 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, 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.

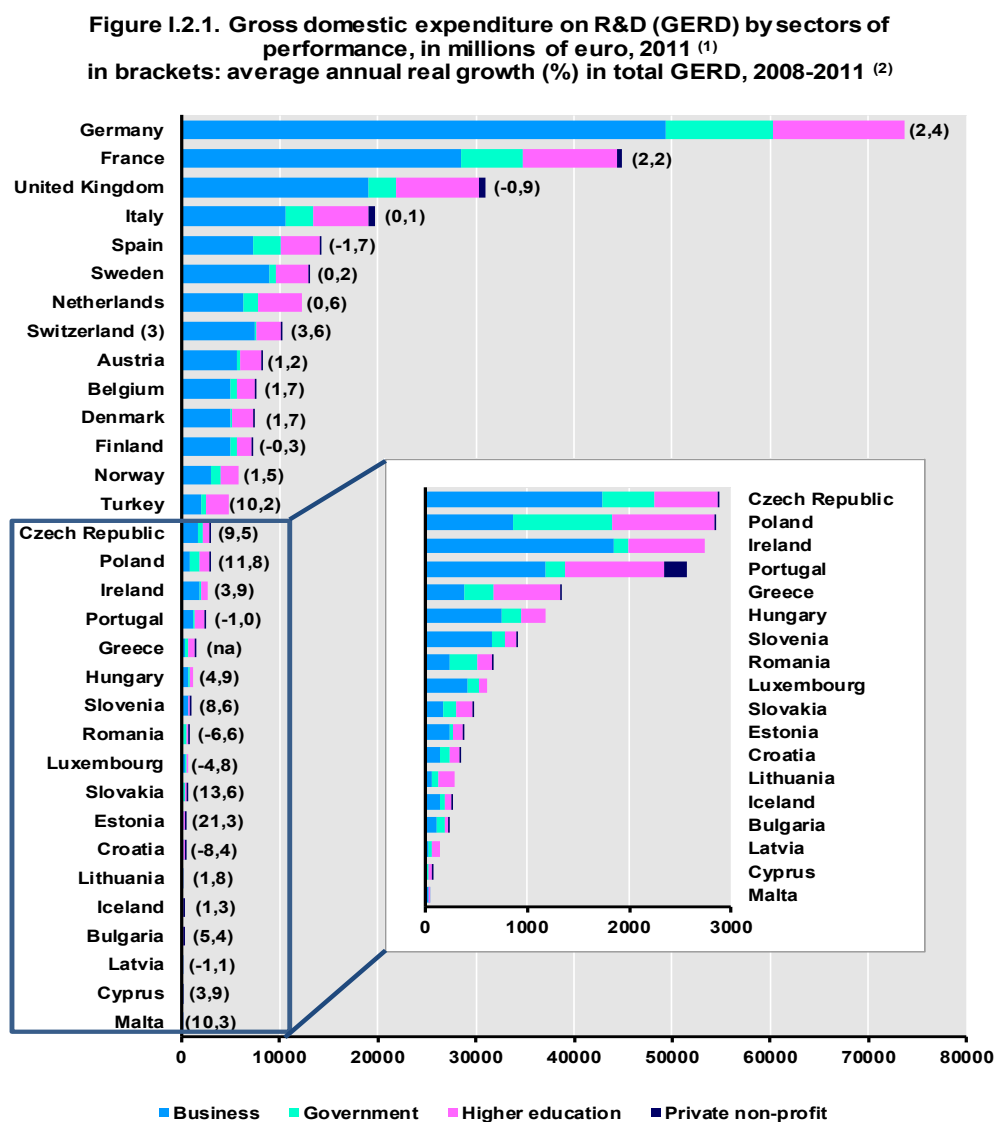
Public budgetary efforts for research and innovation increasingly include tax incentives for business R&D

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, 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.



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.

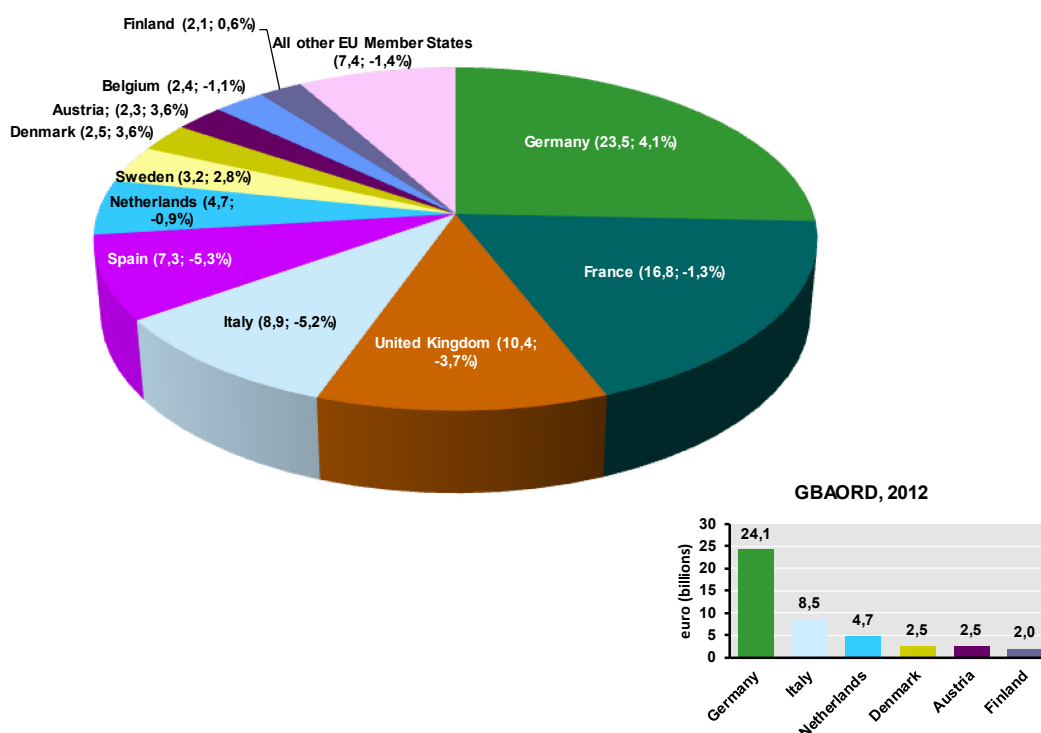
(3) CH: Government refers to federal or central government only.

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 six 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.

Innovation Union Competitiveness report 2013

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

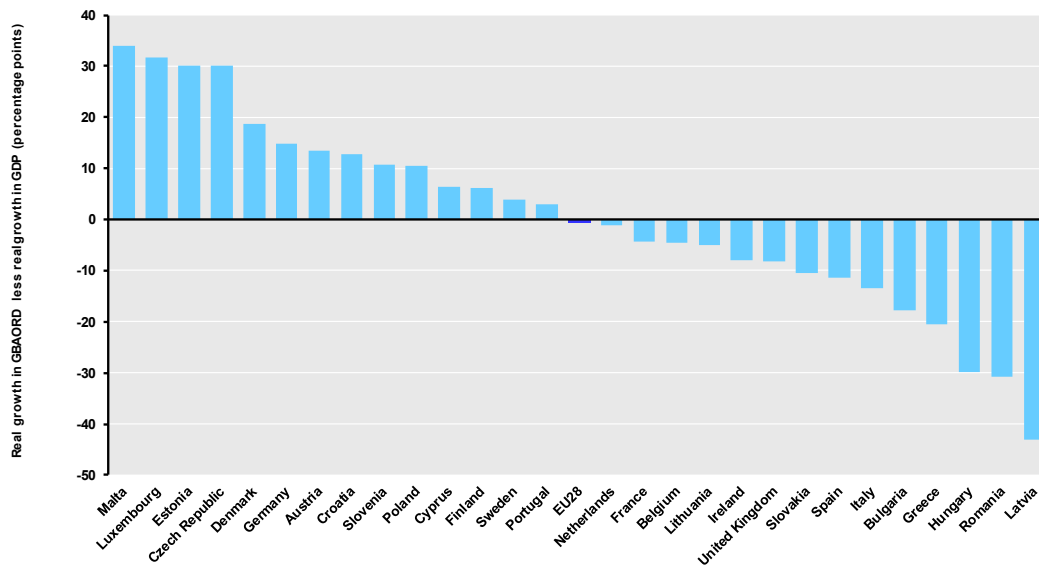
The sovereign debt crisis in Europe has imposed harsh constraints on national government budgets in recent years. How have governments' R&D budgets (GBAORD) evolved in EU Member States in that context?

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.²² 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.

²² Investment in R&D is of course not the only factor improving productivity. A recent IMF study has 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 PPSE at constant 2005 prices and exchange rates.

(2) Foregone tax revenues resulting from R&D tax incentives are not included.

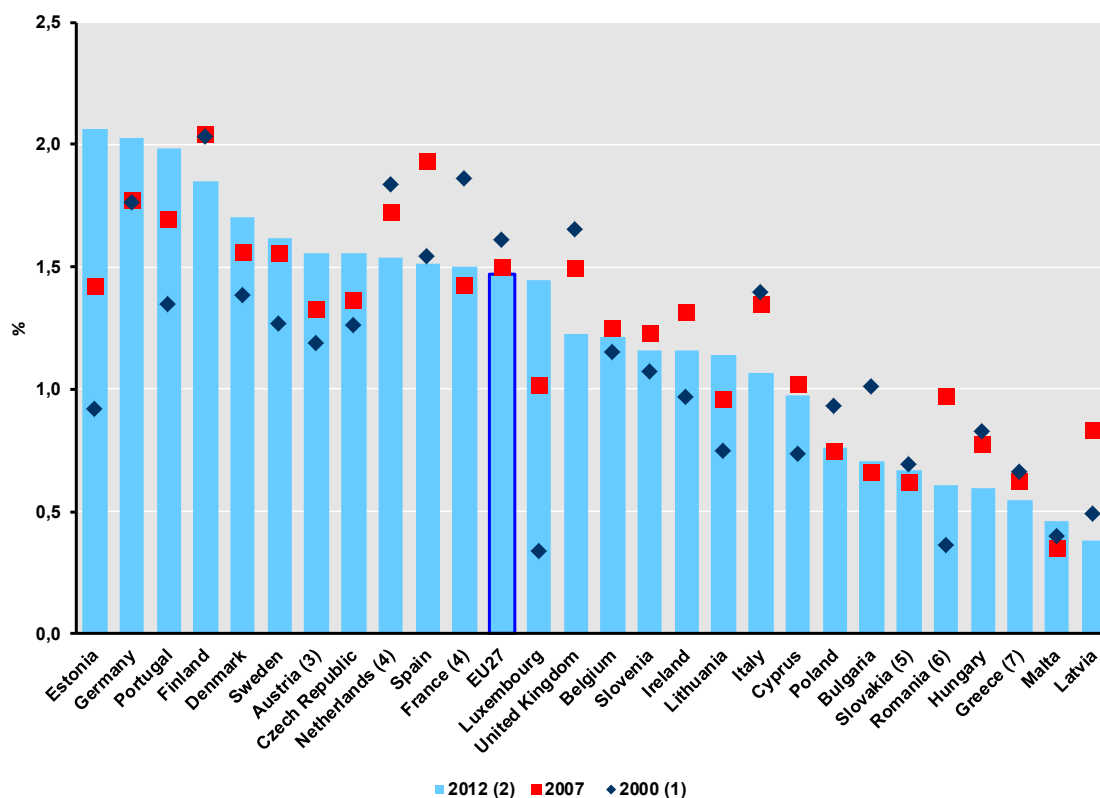
(3) PL: 2008-2009; BE, BG, ES, FR, HR, CY, LV, LT, HU, RO, SE, UK, EU28: 2008-2011.

(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 ⁽²³⁾. 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.

²³ 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

Innovation Union Competitiveness Report 2013

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 (²⁴).

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.

²⁴ 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 allocated and implementation rate and as % of civil GBAORD

	Structural Funds 2007-2013 for RTDI			Civil GBAORD 2007-2011		
	Allocation euro (millions)	Implementation ⁽²⁾ euro (millions)	Implementation rate %	Total euro (millions)	Allocation as % of total	Implementation as % of total
	(1)	(2)	(2) as % of (1)	(3)	(1) as % of (3)	(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

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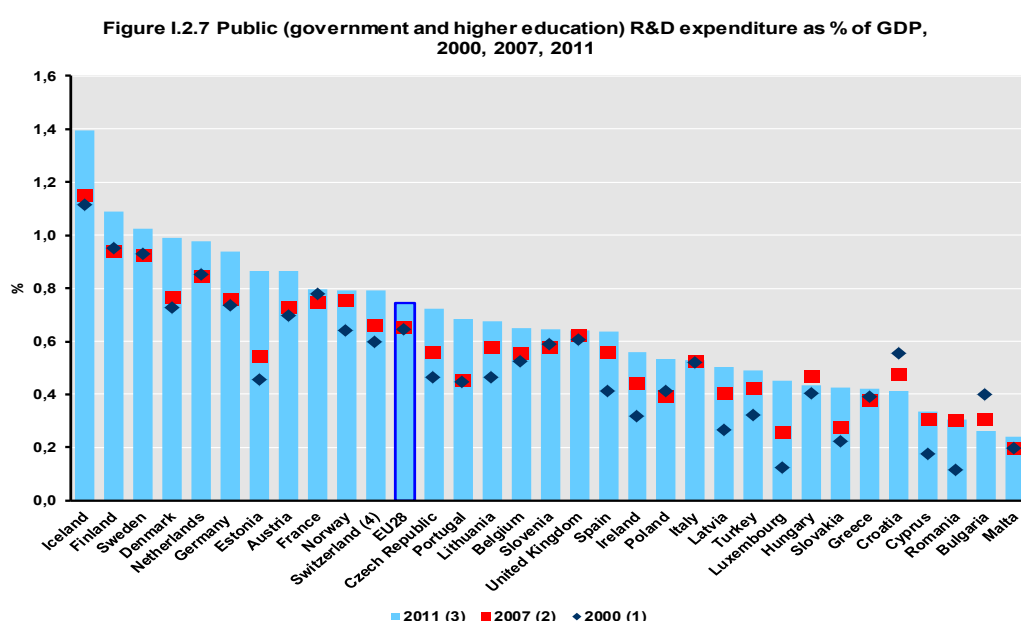
Data: DG Research and Innovation, Eurostat, OECD

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.



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

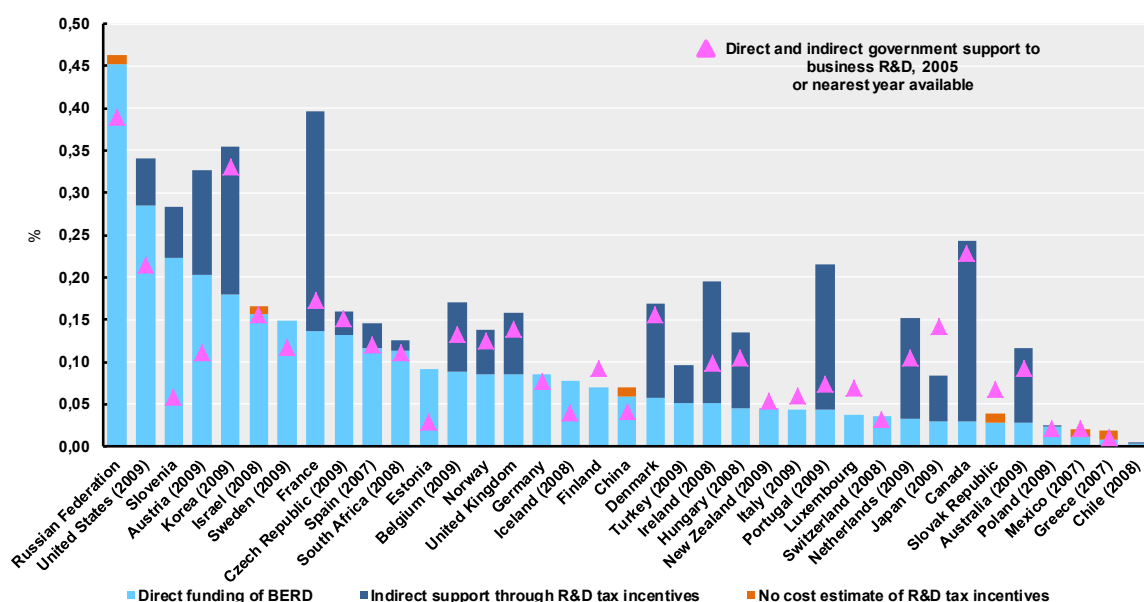
In addition to budgetary efforts for R&D, indirect government support for R&D has significantly increased through R&D tax incentives in a number of Member States since 2007

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 (²⁵) 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 Kingdom²⁶.

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 (²⁷). 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.

²⁵ 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).

²⁶ European Commission, survey of the European Research Area Committee (ERAC), 2012.

²⁷ 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) ⁽²⁸⁾. 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).

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.3.1.

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

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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.

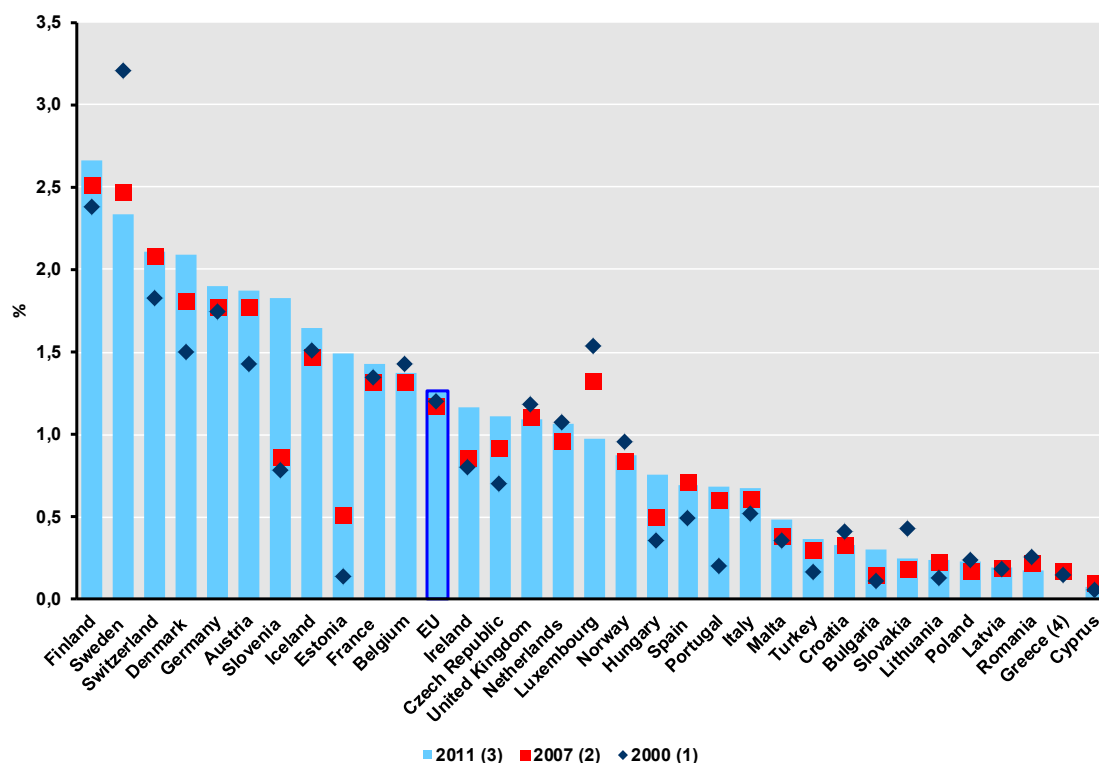
In terms of GDP, business expenditure on R&D in the EU progressed over the period 2007–2011, after a period of stagnation between 2000 and 2007

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) ⁽²⁹⁾. 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 ⁽³⁰⁾, 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

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.

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²⁹ *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.

³⁰ See Chapter I.5.

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

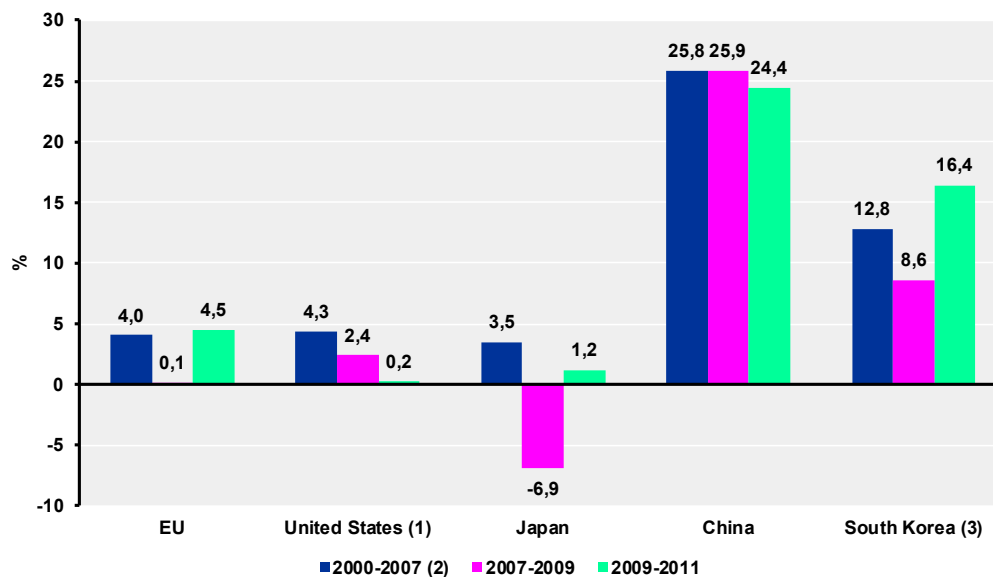
Since 2000, nominal growth in domestic business expenditure on R&D in the EU, the United States and Japan has been largely outpaced by that of South Korea and China (see Figure I.3.3). In China, business expenditure on R&D multiplied by 5 in nominal terms between 2000 and 2007, and further increased 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 (³¹).

³¹ 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

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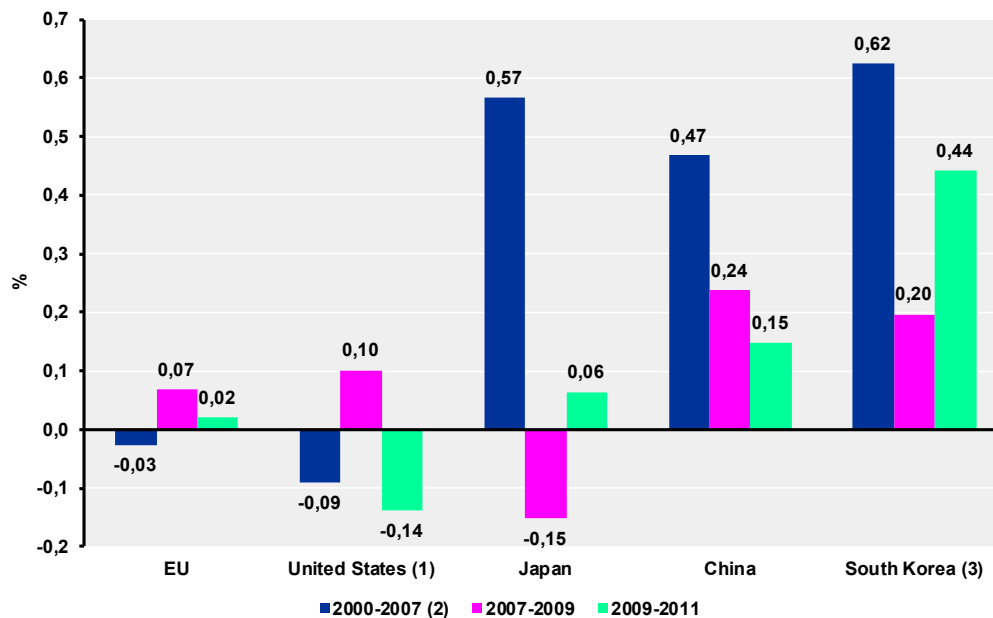
Data: Eurostat, OECD

Notes: (1) US: Most or all capital expenditure is not included.

(2) KR: 2000-2006.

(3) KR: Break in series between 2007 and the previous years.

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



Source: DG Research and Innovation - Economic Analysis Unit

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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 previous years.

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 (³²).

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.

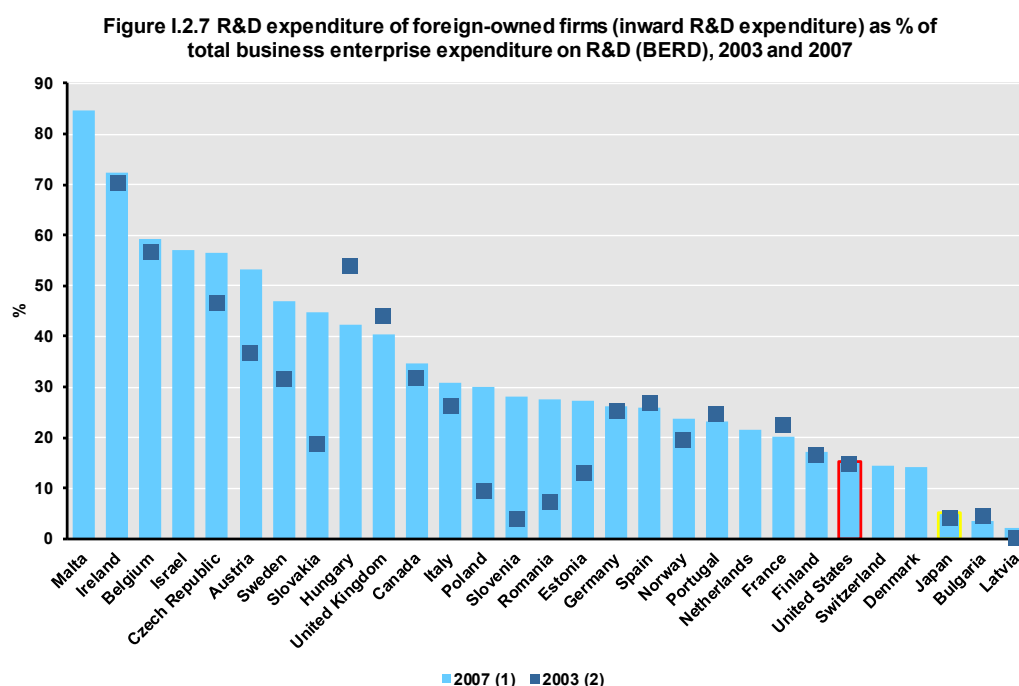
Large countries may have a low degree of internationalisation in relative terms; in absolute terms, however, the United States, Germany, the United Kingdom, Japan and France are by far the most important host countries for the R&D activities of foreign-owned firms. In 2007, foreign-owned firms in the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

³² This section is based on the results of the study 'Internationalisation of business investments in R&D and analysis of their economic impact', Directorate-General for Research and Innovation (DG RTD), 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.

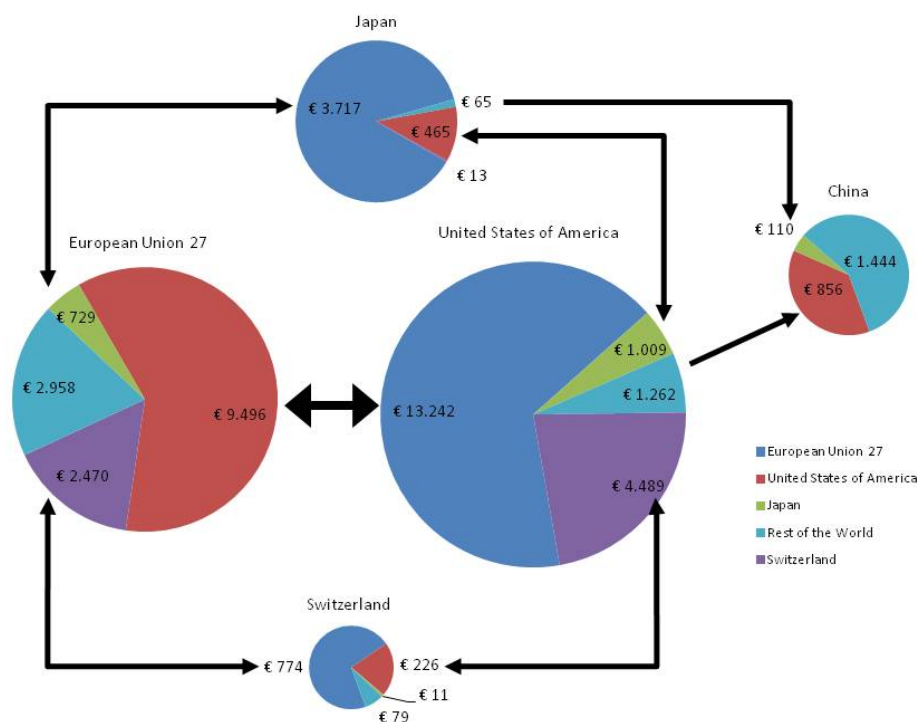
The figure reveals the outstanding importance of the relationship between the US and the EU. R&D expenditure by US firms in the EU and by EU firms in the United States taken together account for two thirds of the R&D expenditure by foreign-owned firms in manufacturing worldwide (³³). The United States 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.

³³ 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.

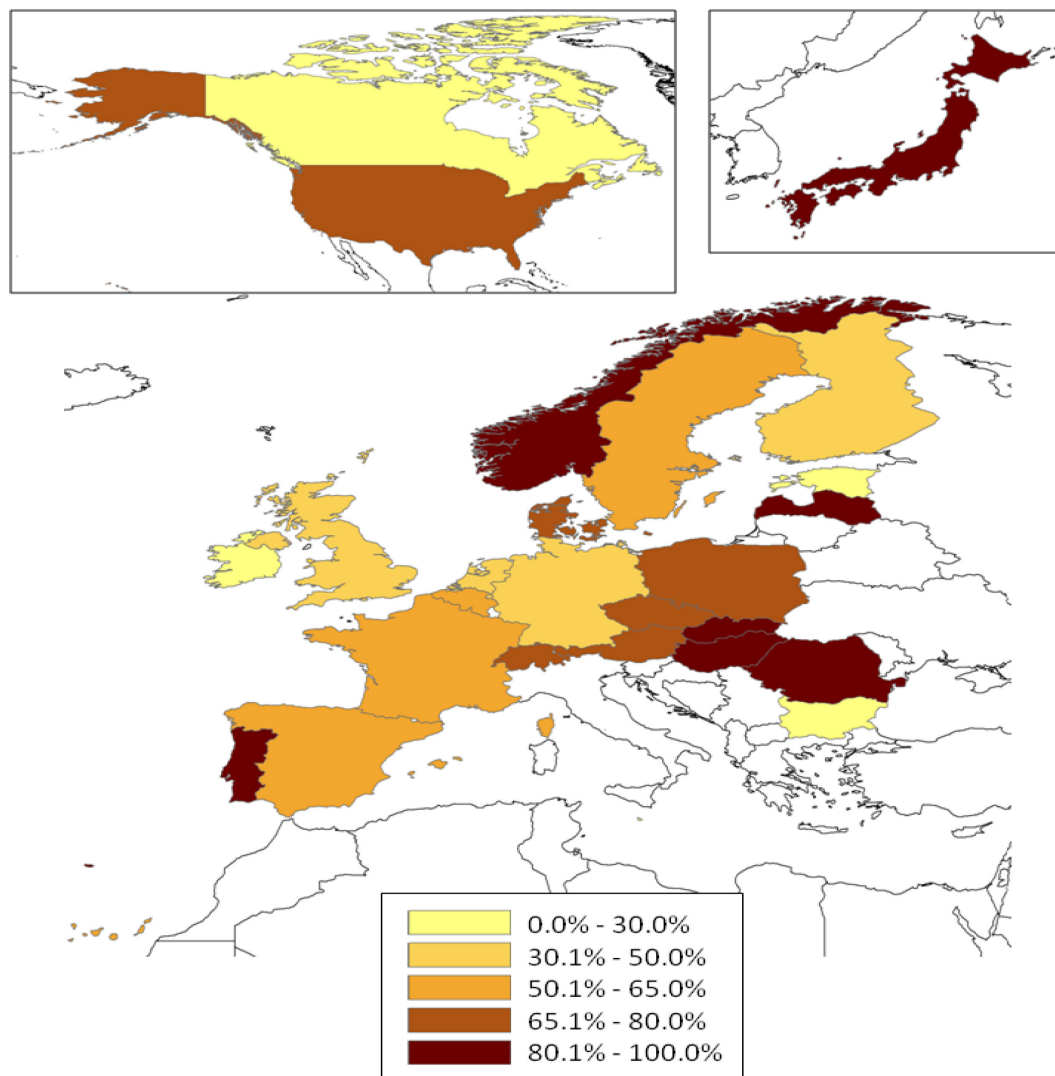
(3) CH: The services sector is included.

(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)⁽³⁴⁾. Despite strong ties between

³⁴ 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 (³⁵).

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.

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

³⁵ A broader analysis of the globalisation of production is presented in Chapter III.4.

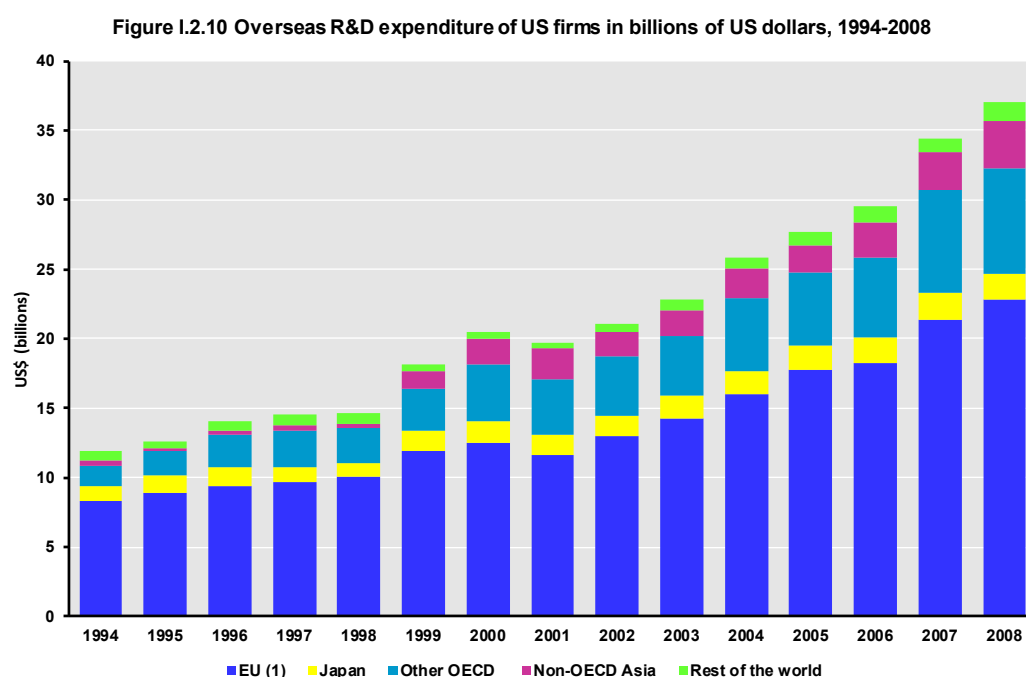
The EU remains an attractive R&D location for firms from outside the EU, but Asian economies are emerging as both host and home countries for international R&D investments

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 (³⁶). 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.

³⁶ 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 (³⁷). 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 (³⁸).

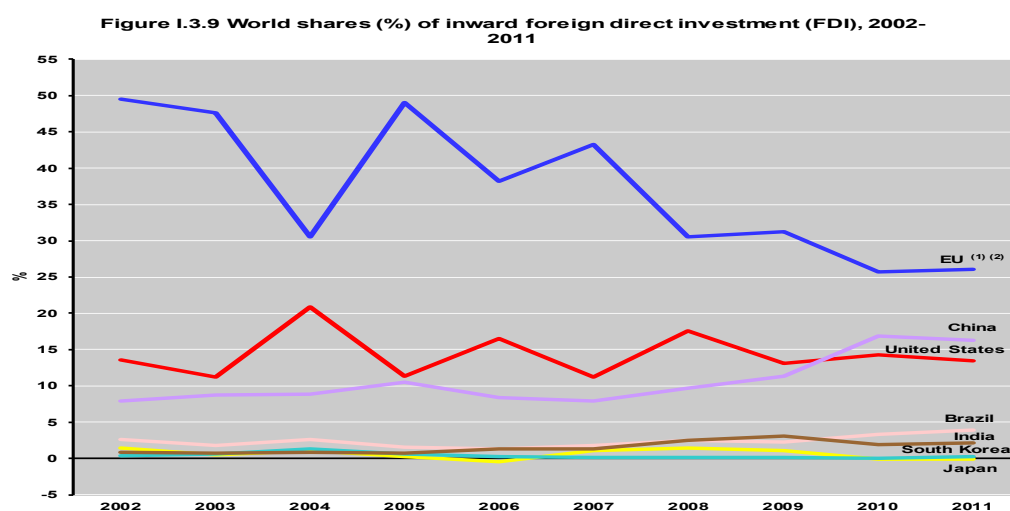
³⁷ Expert group to the European Commission, 2008.

³⁸ 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

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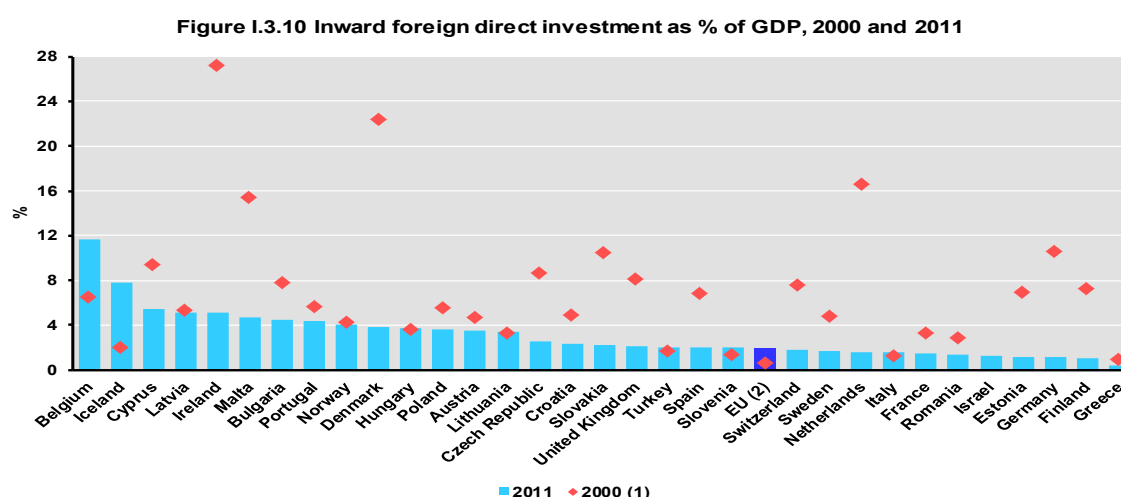
Data: OECD

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

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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.

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) ⁽³⁹⁾. 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

³⁹ 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.

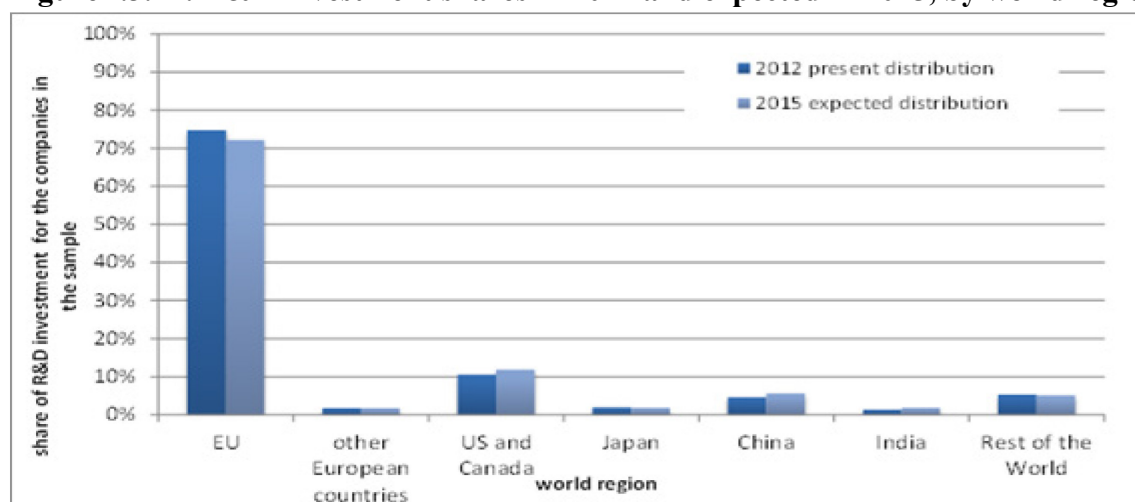
EU firms carry out three quarters of their R&D investments inside the EU. However, business R&D investment outside the EU is growing faster

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 Scoreboard⁴⁰

⁴⁰ <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.

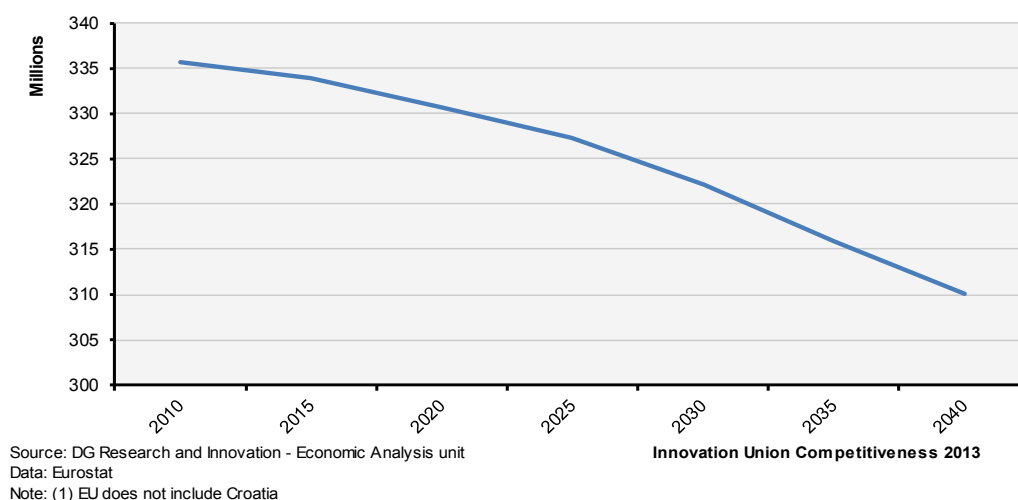
4.1. Are governments and firms investing in skilled labour, researchers and entrepreneurs?

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 (⁴¹). 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.

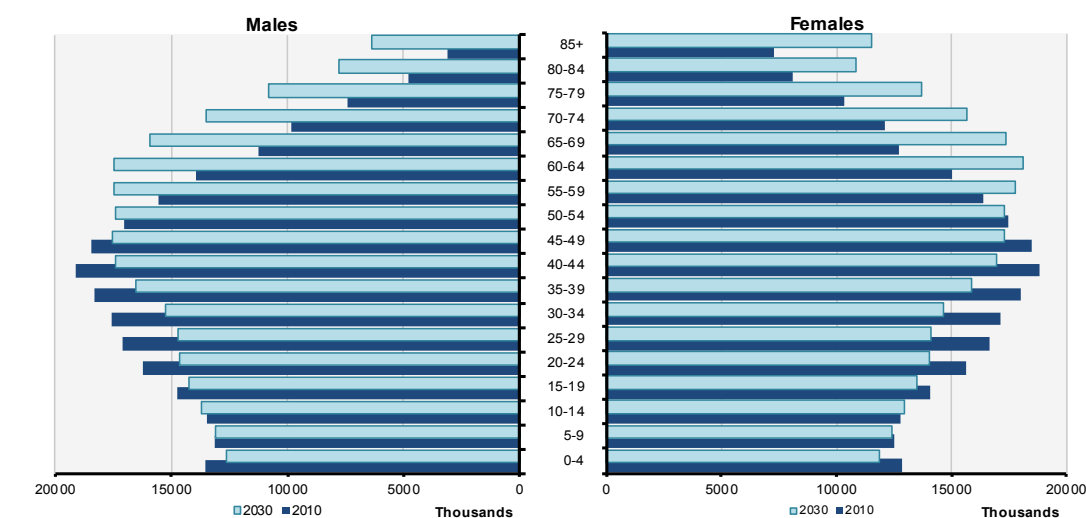
Figure I.4.1 EU ⁽¹⁾ projected working age population (age 15 to 64 years)



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.

⁴¹ 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



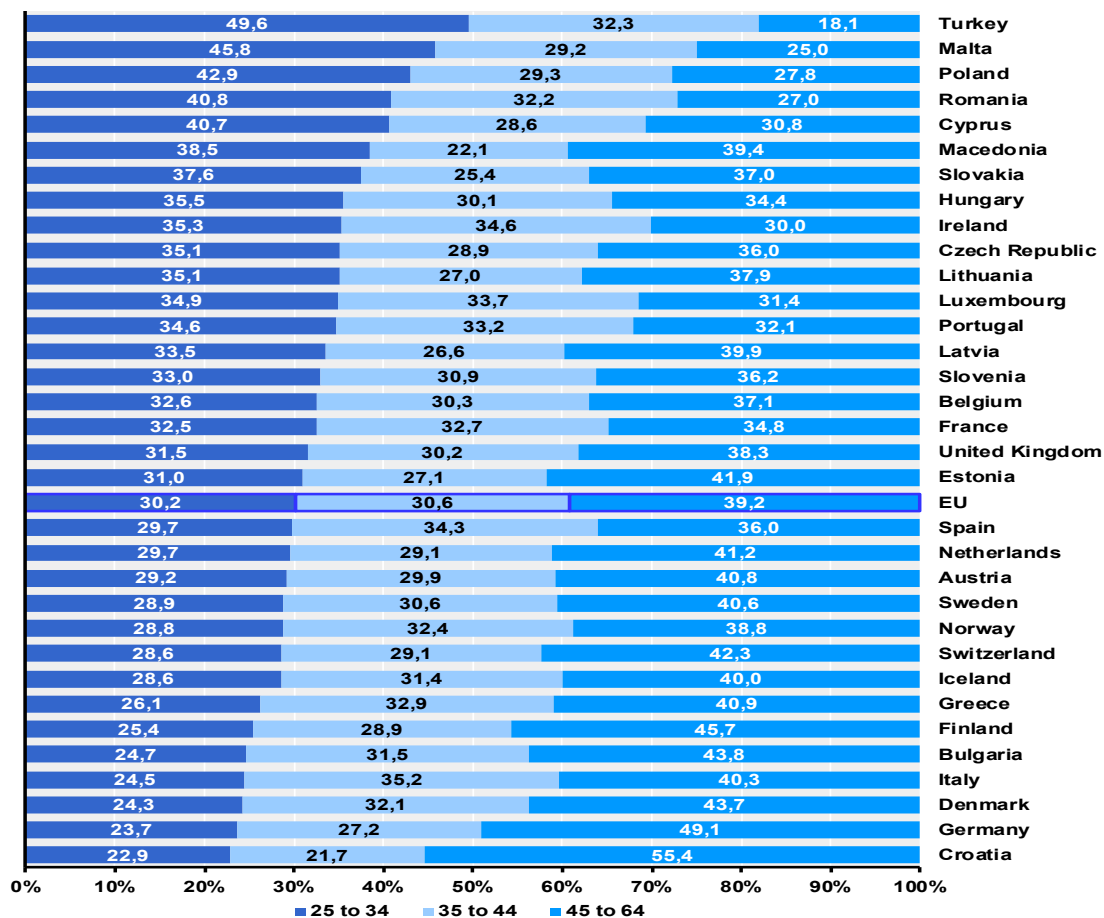
Source: DG Research and Innovation - Economic Analysis unit
Data: Eurostat
Note: (1) EU does not include Croatia

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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
 Data: Eurostat

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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

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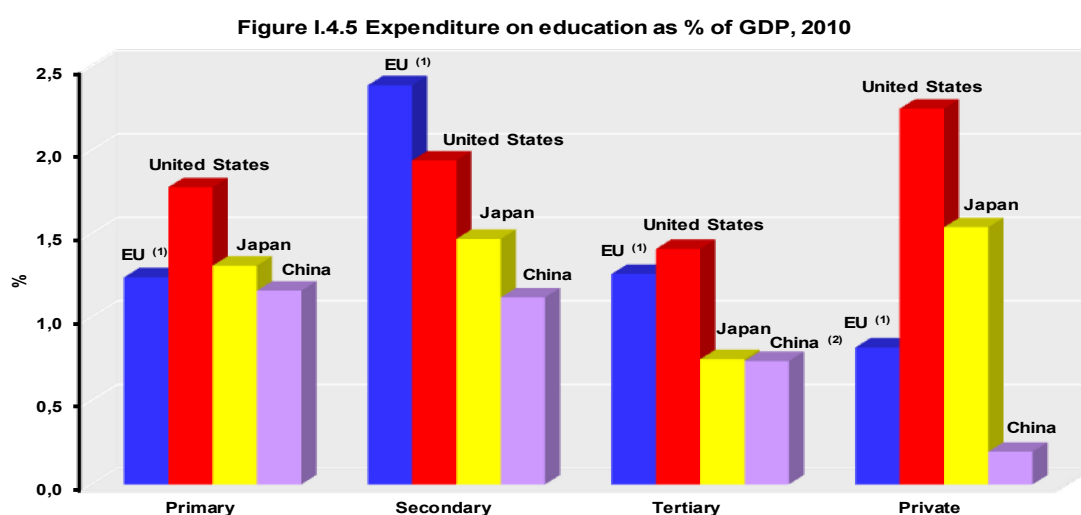
Data: Cedefop - Skills forecast 2012

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 ongoing structural change towards a knowledge based -economy implies, that a further upskilling of the labour force is necessary. 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

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Data: Eurostat, China Statistical Yearbook 2012

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

(2) CN: Tertiary Education includes institutions of higher education for adults.

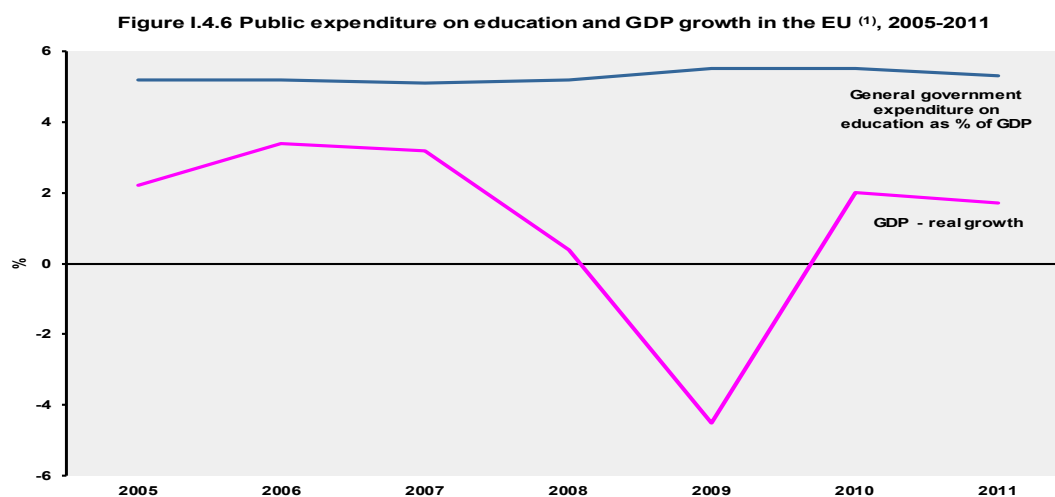
Public spending on education (percentage of GDP) in the EU as a whole is on a similar level as in the United States, but higher than in Japan. The focus in the EU is more on secondary education, including vocational education and training (VET), in which business investment plays a role in some countries. 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⁽⁴²⁾. 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⁾



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

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⁴² 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 (⁴³)) 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.

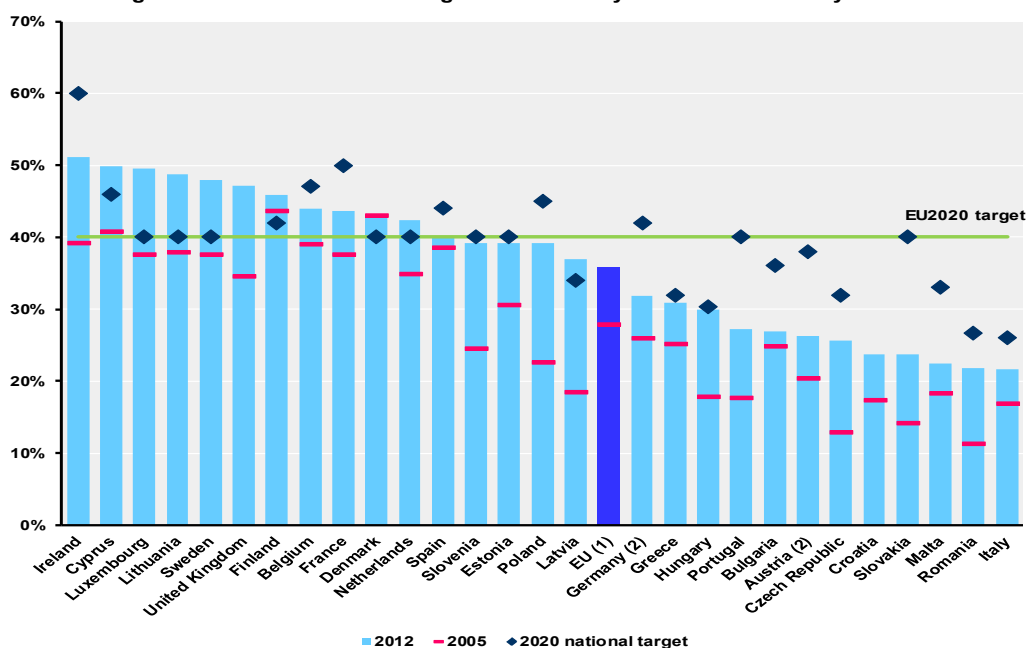
4.2. Tertiary education and training to respond to these challenges

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.

⁴³ Source: 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 still 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⁽⁴⁴⁾) 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/

⁴⁴ An updated classification (ISCED 2011) has been adopted in 2011, but still has 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.

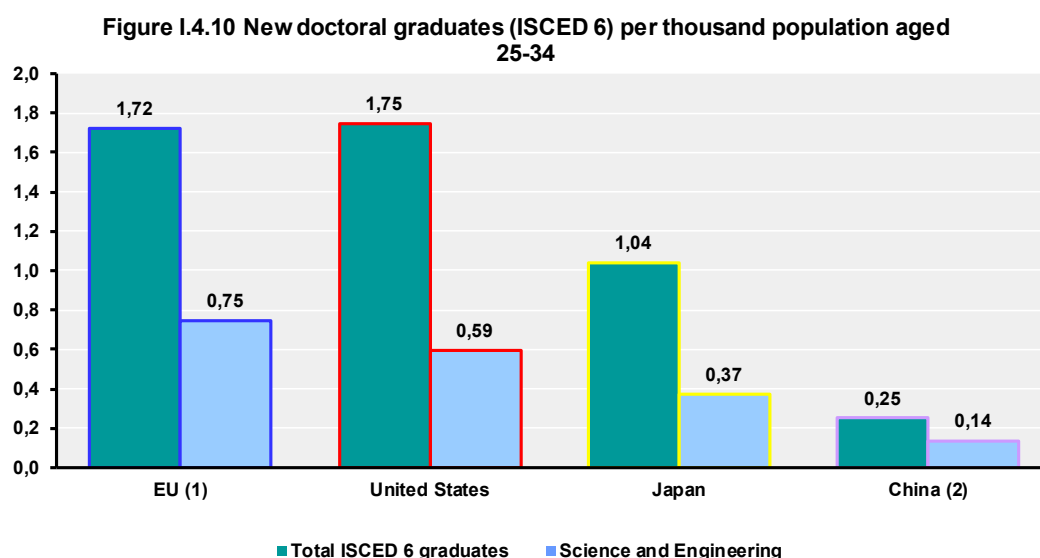
(2) FR: 2005-2009; HR, IS: 2005-2010.

(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.



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.⁴⁵ 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.

⁴⁵ 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

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Data: Eurostat

Notes: (1) Total R&D personnel (Head Count) and Researchers (Head Count) refer to 2009.

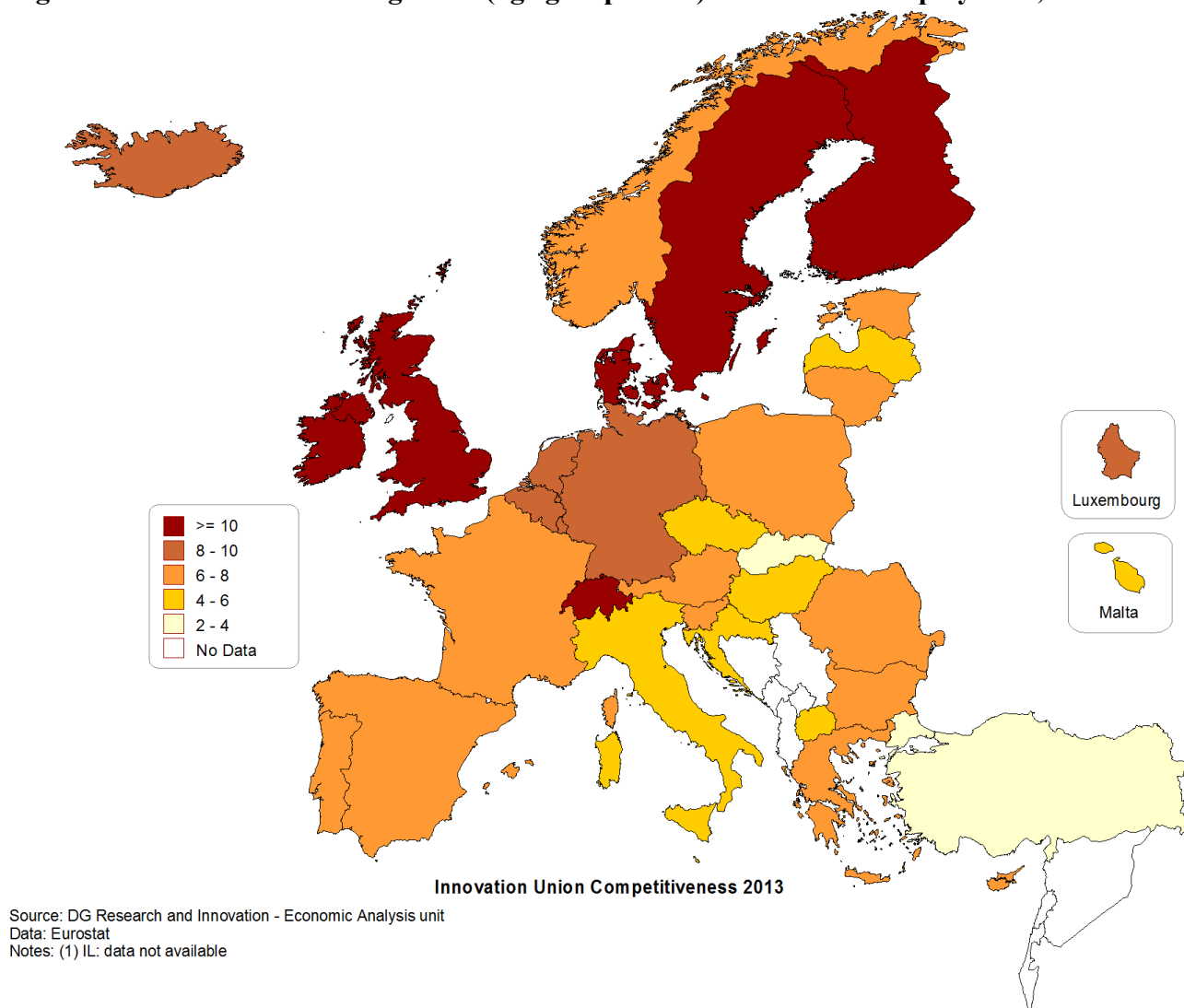
(2) HRST, HRSTE, HRSTO, HRSTC, SE: 2008-2011; Total R&D personnel (Head Count), Researchers (Head Count): 2005-2009.

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



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 ⁽⁴⁶⁾. 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

Innovation Union Competitiveness report 2013

Data: Eurostat

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).

⁴⁶ 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 researchers (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.

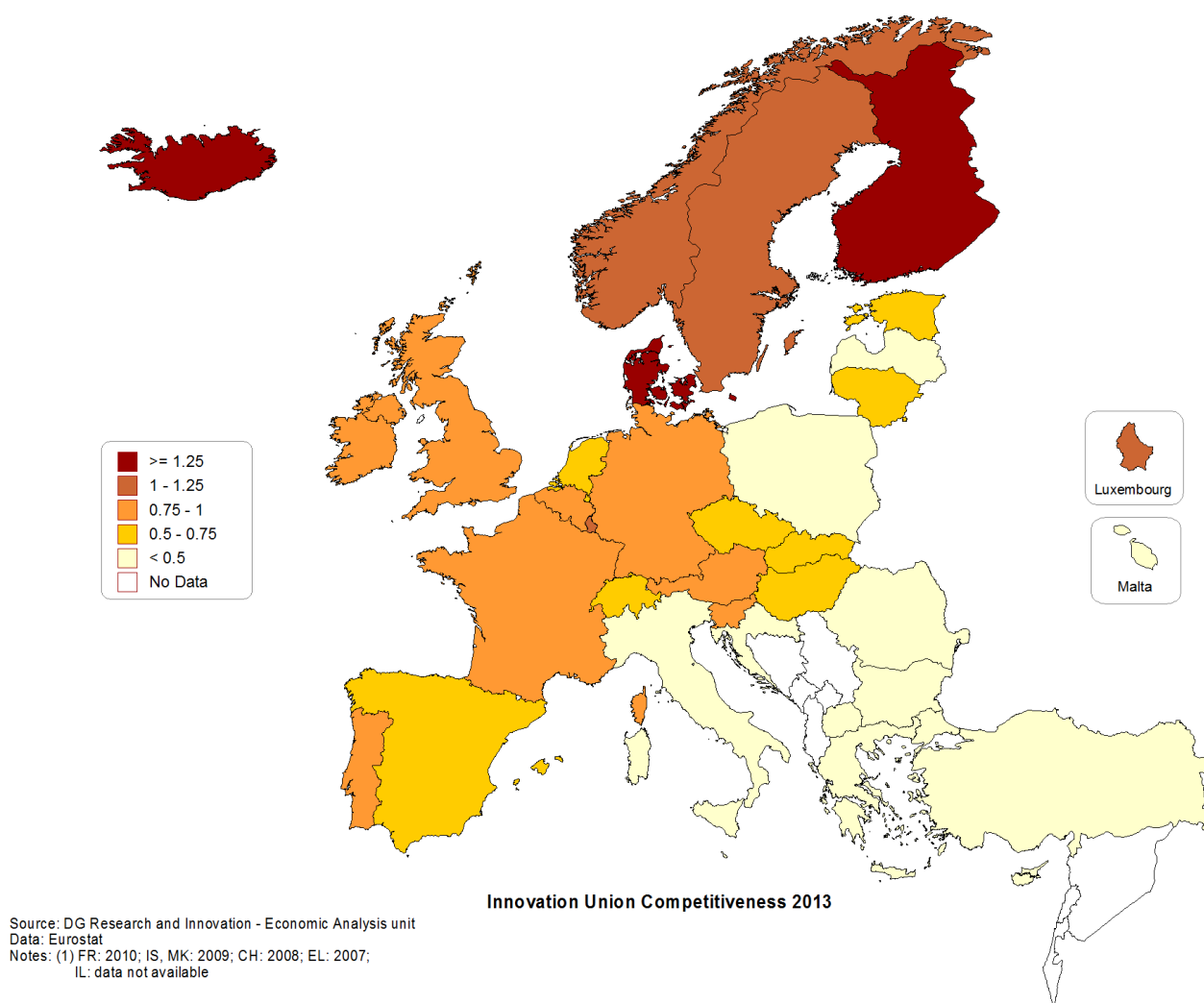
(5) The Former Yugoslav Republic of Macedonia.

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



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 have 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 (⁴⁷).

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);*

⁴⁷ 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 to the 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 (⁴⁸) studies reveal strong differences between countries and thus considerable potential for further improvement in countries performing below average. The results of the PIAAC study⁴⁹ 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.

⁴⁸ 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.

⁴⁹ 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 (⁵⁰).

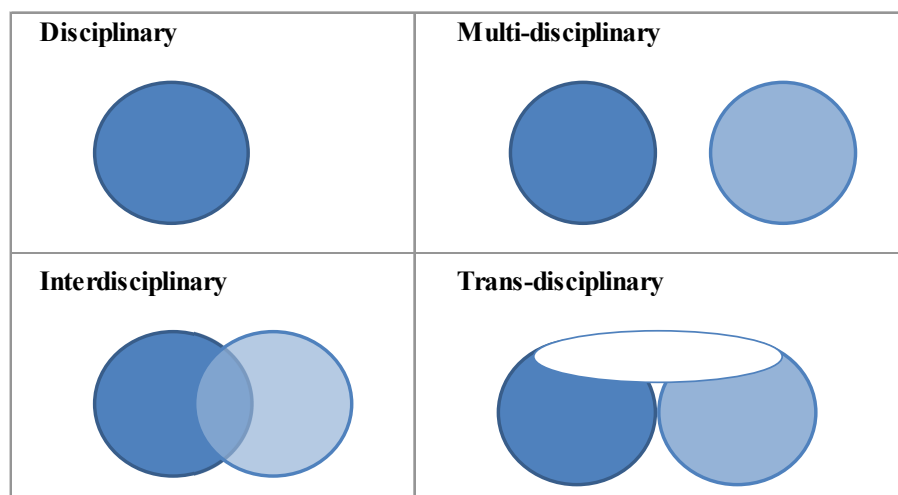
- *Importance of learning to learn and lifelong learning*

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



⁵⁰ 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 (⁵¹).

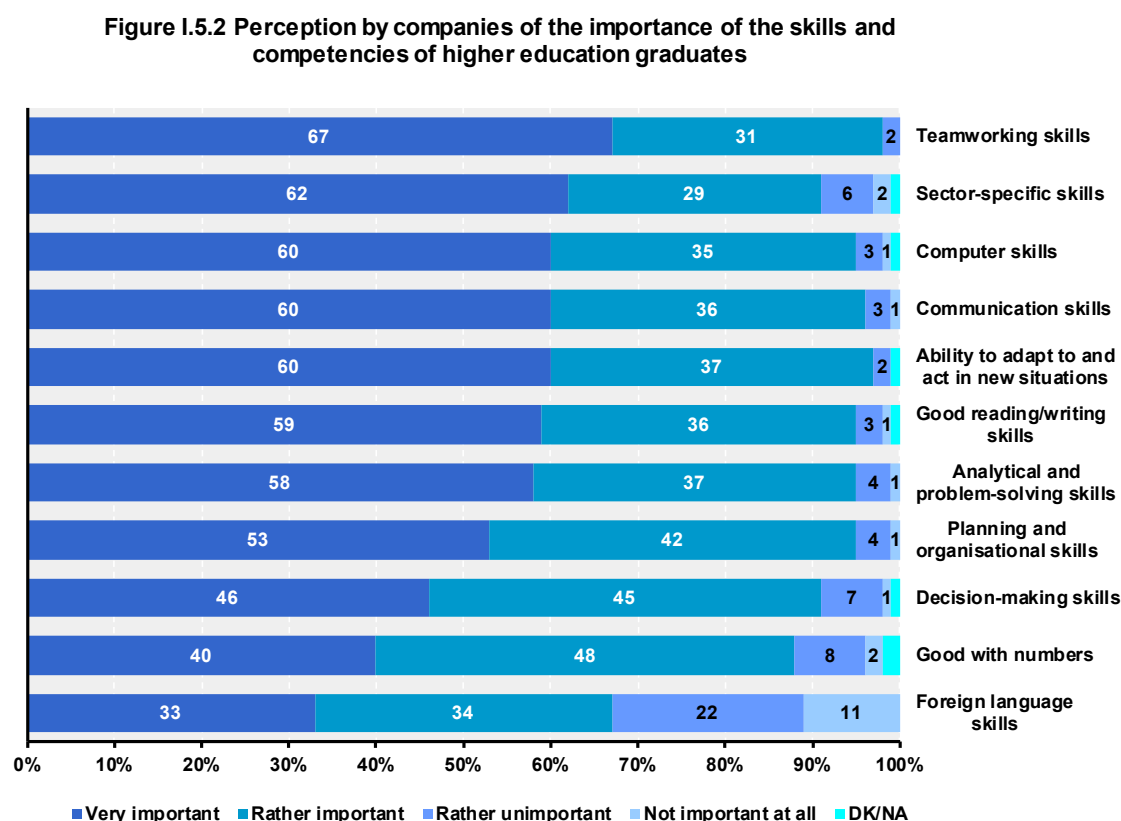
5.2. Findings from recent studies on labour market demand for skills

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.

⁵¹ 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)

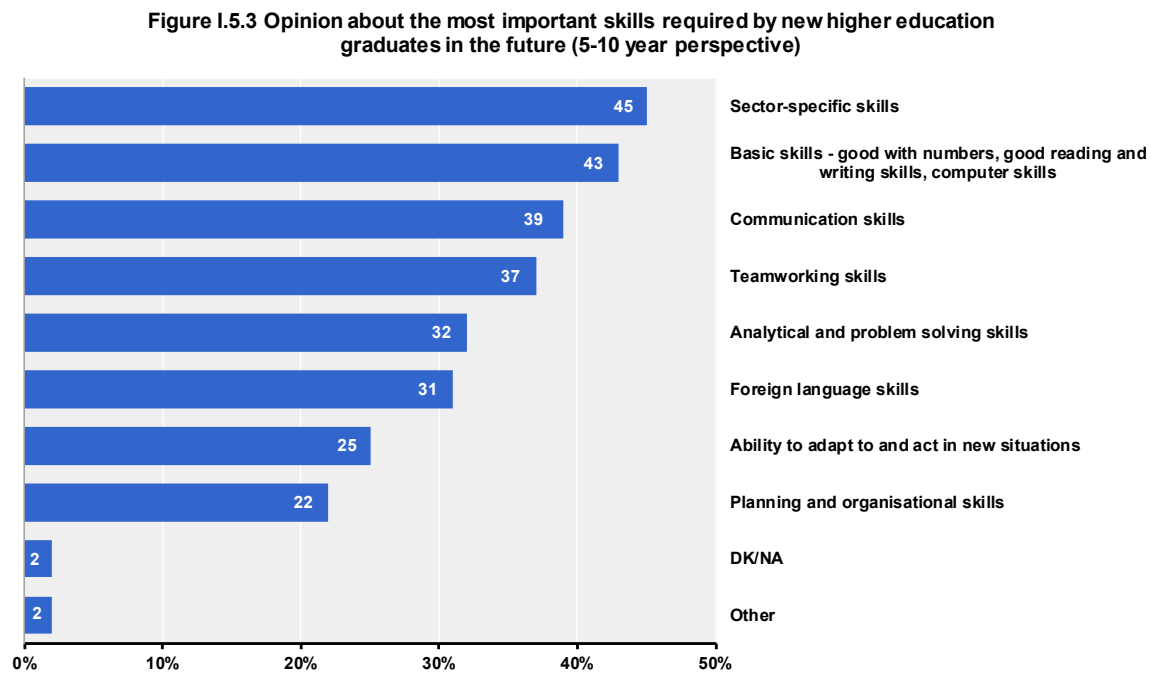
Note: (1) The results are based on all participant companies (% of Total).

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 (⁵²).

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.

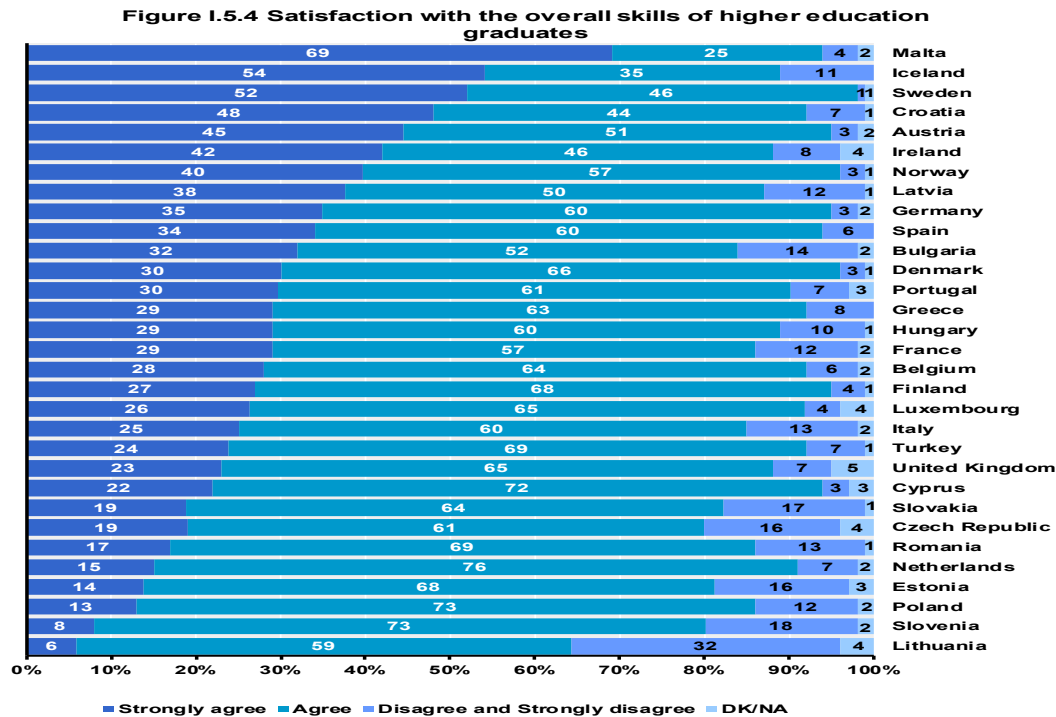
⁵² The Eurostat Adult Education Survey is a source for data on adult language skills. According to this survey, the share of population stating they know at least one foreign language was highest (over 90 % %) in Luxembourg, Lithuania, Latvia, Slovenia and Sweden, while it was lowest (below 40 % %) in Bulgaria and Hungary. No data were available for the United Kingdom and 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)



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

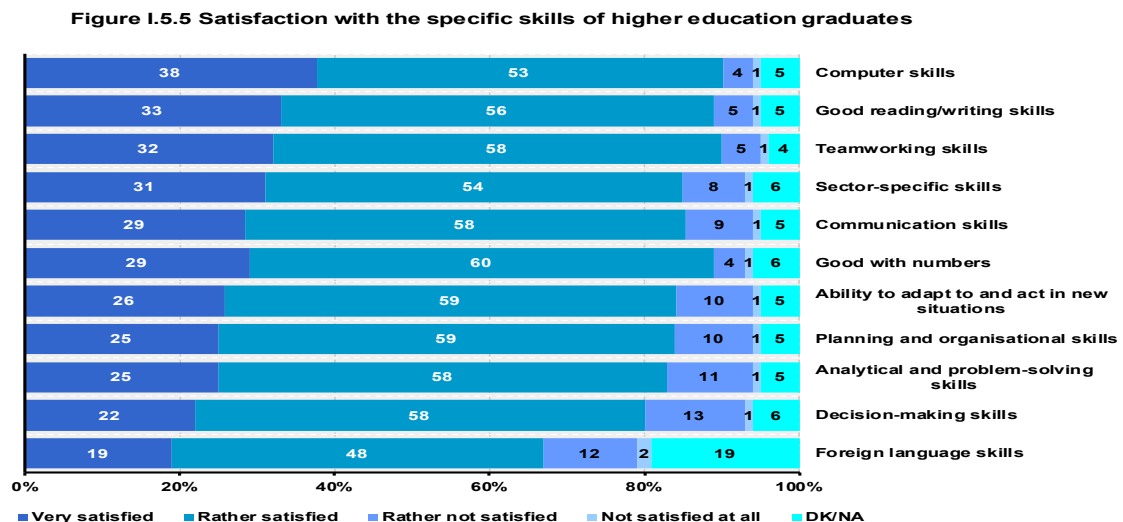
Respondents to the Flash Eurobarometer survey 304 were also asked about their overall satisfaction with graduates recruited in the past three to five years. The responses indicate a relatively high level of satisfaction, which could be seen as surprising given the urgency in the debate about higher education 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.



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 satisfied) 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)



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⁽⁵³⁾. 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

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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 professionals.

⁵³ 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 forecast for future skills demands extends the horizon to 2025 ⁽⁵⁴⁾. 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

⁵⁴ See http://www.cedefop.europa.eu/EN/Files/9081_en.pdf online.

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

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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) ⁽⁵⁵⁾, 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

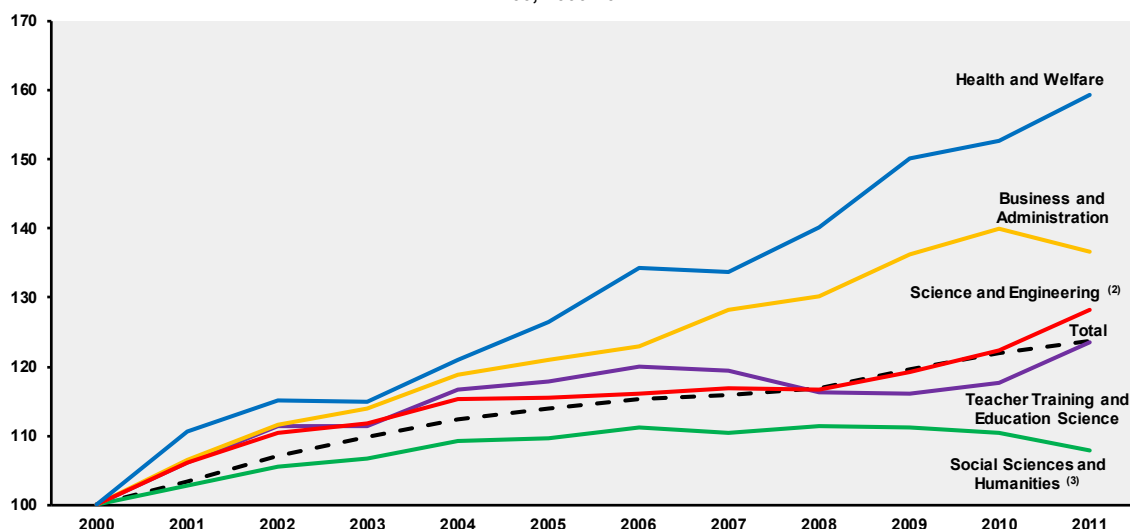
Eurostat data show that the number of tertiary science and engineering (S&E) students is progressing broadly at the same rate as the total number of students. Tertiary student population growth started to decelerate after 2005 as a result of demographic development (smaller cohorts) and because participation 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.

⁵⁵ This study is presented in part 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

Data: Eurostat

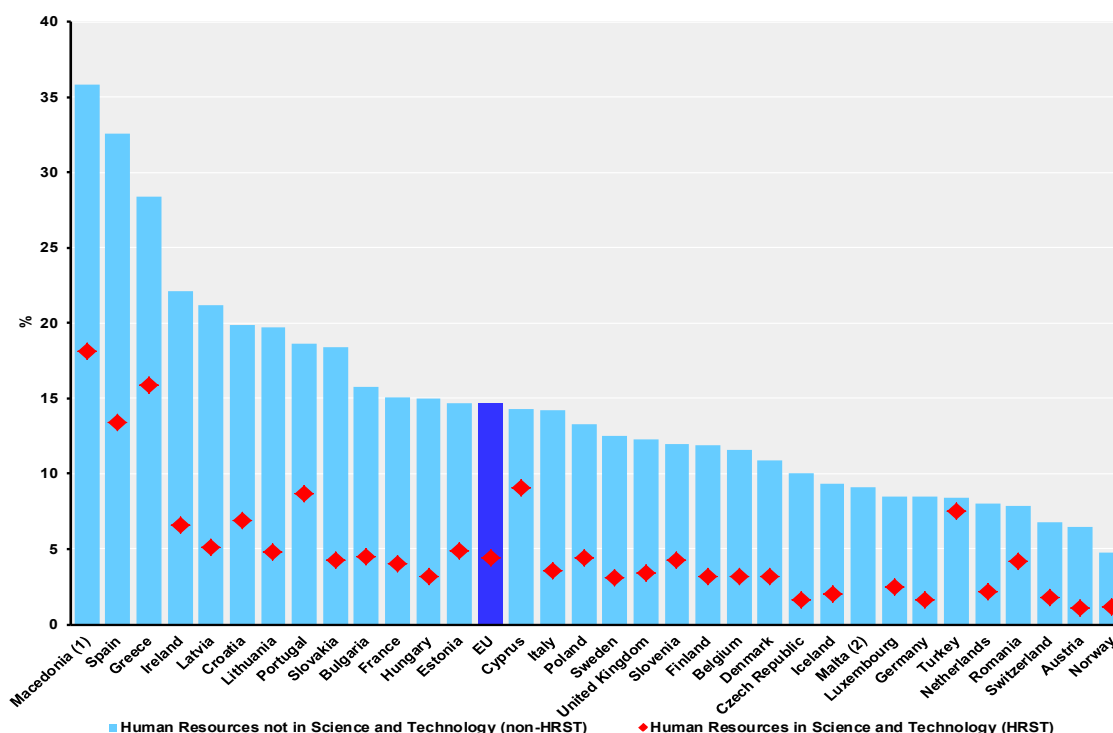
Note: (1) Based on the available data and including estimated values for some Member States.

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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

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Data: Eurostat

Notes: (1) The Former Yugoslav Republic of Macedonia.

(2) MT: Unemployment 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.

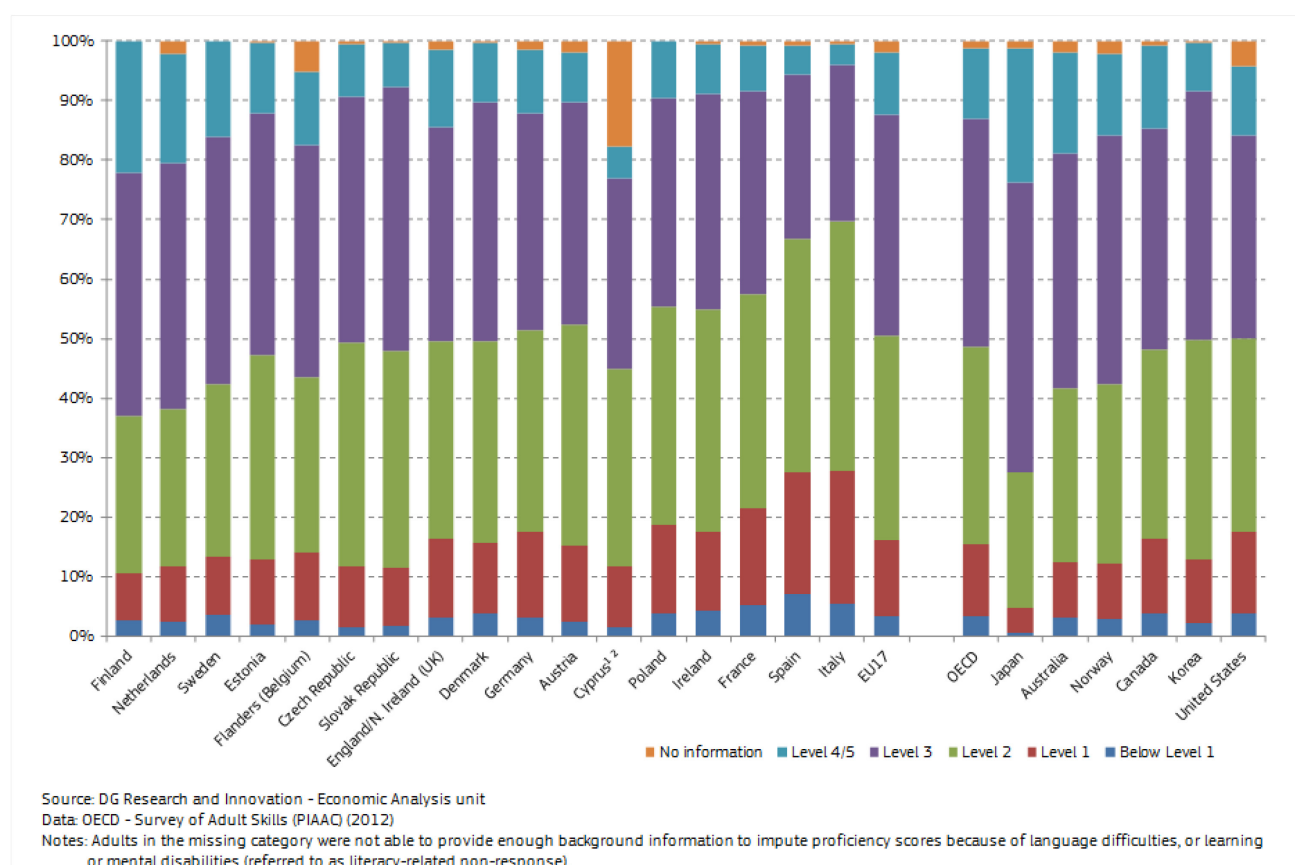
Advanced economies characterised by rapid change can therefore expect to experience skills mismatches and to some extent skills shortages. Part of the answer to a better match between demand and supply of high-level skills therefore rests, apart from on a flexible workforce willing to learn and adapt, 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 PIAAC⁵⁶ 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

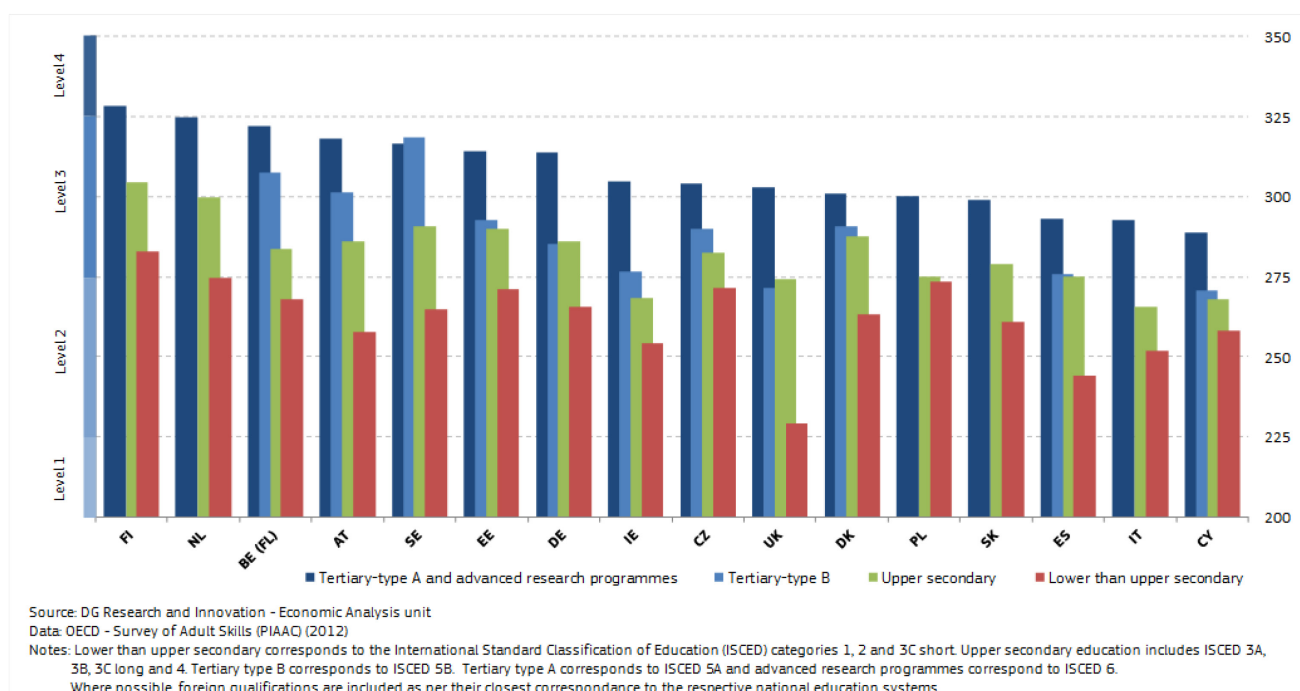


⁵⁶ Programme for International Assessment of Adult Competencies. The results of the first PIAAC study, which covers 17 EU countries, were published on 8 October 2013.

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 skills 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



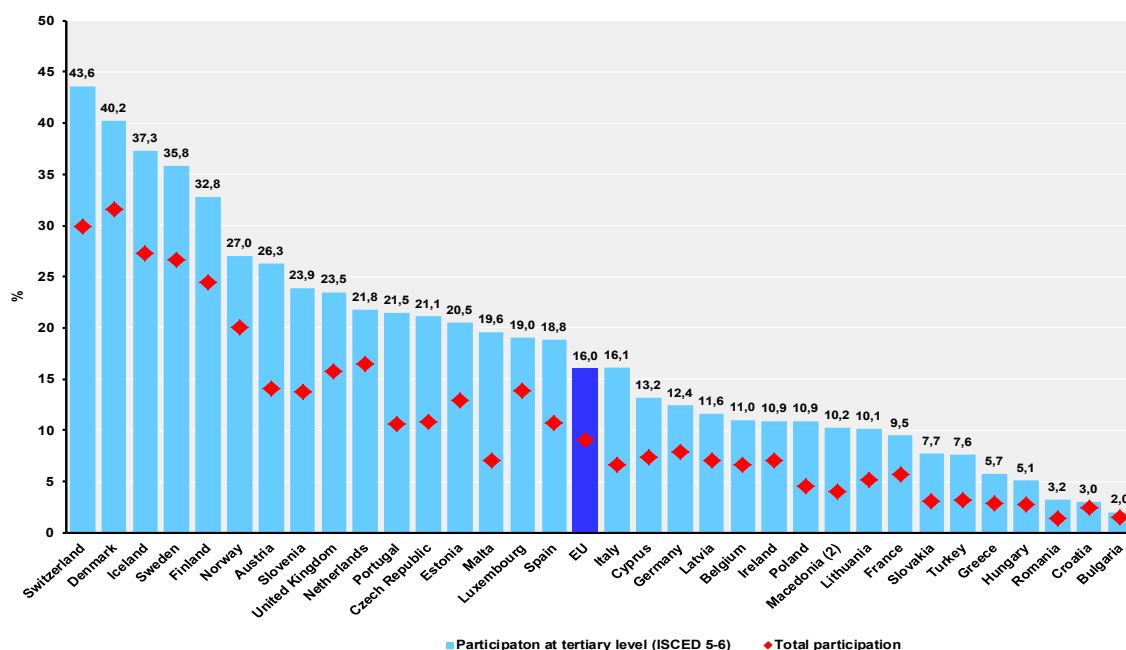
Lifelong learning is associated with innovation and productivity

Eurostat data on adult lifelong learning participation (⁵⁷) 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).

⁵⁷ 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

Data: Eurostat

Notes: (1) The data refer to age-group 25-64.

(2) The Former Yugoslav Republic of Macedonia.

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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 ⁽⁵⁸⁾. 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 ⁽⁵⁹⁾ shows that in 2011 about 4.3 million tertiary students were enrolled outside their country of citizenship. In absolute terms, the

⁵⁸ An analysis of mobility from the perspective of knowledge circulation in the economy is presented in Chapter II.4.

⁵⁹ See [http://www.oecd.org/edu/eag2013%20\(eng\)--FINAL%2020%20June%202013.pdf](http://www.oecd.org/edu/eag2013%20(eng)--FINAL%2020%20June%202013.pdf) online.

largest numbers of foreign students⁽⁶⁰⁾ 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

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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.

⁶⁰ 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 percentage of higher education graduates spending a period of higher education-related study or training (including work placements) abroad to 20 % by 2020⁶¹). 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 are providing 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.

⁶¹ 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⁽⁶²⁾ 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).

⁶² See <http://www.france.fr/en/studying/following-training/long-training-courses/cifre-incentive-scheme-industrial-agreement-training-through-research> online.

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 2020⁶³.

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.

⁶³ 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. 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. 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

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 has to take note that overall the evidence is mixed, as shown for example by Oosterbeek, H. van Praag, M, Ijsselstein, A (2010) 'The impact of entrepreneurship education on entrepreneurship skills and motivation, European Economic Review, 54 (3) : 442-454

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 activities⁶⁵ (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 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.

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 basic 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)

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.

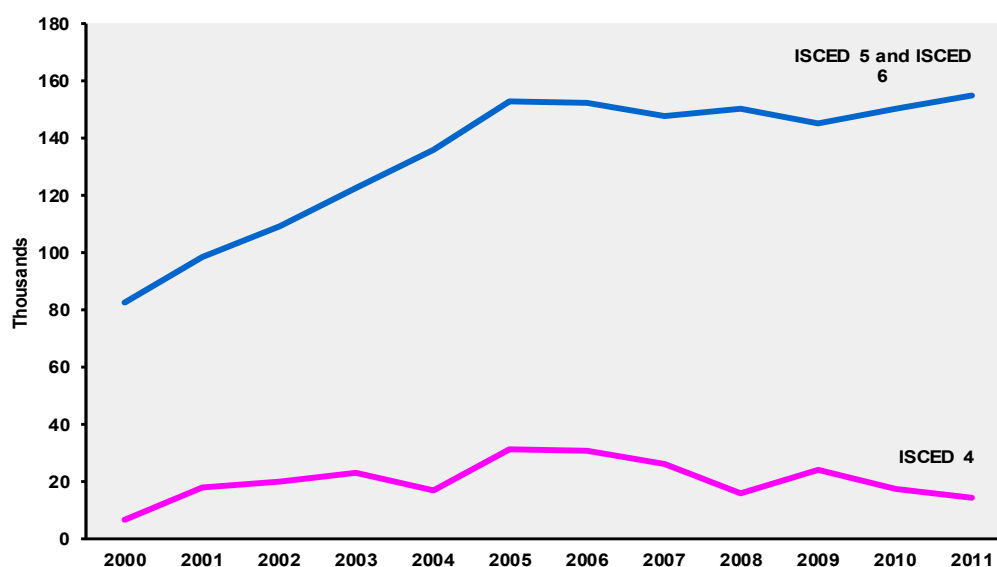
(3) FR: 2005-2009; HR, IS, NO: 2005-2010; BG: 2007-2011; LU: 2010-2011.

(4) Former Yugoslav Republic of Macedonia.

⁶⁷ See http://euskillspace.ec.europa.eu/docs/AnalyticalHighlights/ICT_Sector_en.pdf online.

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