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Innovation Union Competitiveness report 2011

<u>Analysis:</u>

Part I. Investment and performance in R&D - Investing for the future

This is the first part of the more analytical section of the IUC report. It reviews a large range of indicators and data on investment and performance in Research and Innovation in Europe. From the perspective of progress towards a higher knowledge capacity in Europe, findings are presented on progress towards the EU and national R&D targets in the context of the Europe 2020 strategy, on the effect of the economic crisis on R&D investment using the most recent data, on public investment in research as well as education, on the dynamics of human resources for R&D, and on business-sector investment in R&I. In contrast with this public and private input, the section ends with evidence concerning scientific and technological output in Europe, including reflections on the efficiency of the relationship between investment and output performance.

Part I: Investment and performance in R&D — Investing for the future

1. Progress towards the EU and national R&D intensity targets

Highlights

Over the last ten years, the European Union has only slightly progressed towards the objective of investing 3% of GDP in research and development, which contrasts with the remarkable R&D intensity growth in the major Asian research-intensive countries. In real terms, total R&D investment in the EU has increased by 50% between 1995 and 2008, but this is a much lower growth rate than that in other parts of the world: 75% in developed Asian economies (Japan, South Korea, Singapore, Taiwan), 855% in China, 145% in BRIS countries (Brazil, Russia, India, South-Africa) and almost 100% in the rest of the world. As a result, the EU share of world R&D expenditures has shrunk from 29% in 1995 to about 24% in 2008.

There has been progress in R&D intensity in 24 Member States, and in a majority of Member States, R&D intensity grew at a faster pace in 2006–2009 than in 2000–2006. Despite this progress, in 2009 most Member States remained far from the national 2010 targets they set for themselves in 2005. The overall EU aggregate R&D intensity is largely determined by the four largest member states.

Investment in research and development is highly concentrated in some parts of the European Union. Half of the total EU–27 R&D expenditure is located in approximately 60 NUTS 2 regions, i.e. one fifth of the regions in the EU. Conversely, half of all the regions contribute to only 6% of the total EU R&D expenditure. The regional concentration of R&D expenditures is larger than that of GDP in the EU.

The EU 3% target and further national targets have mobilised increasing resources for R&D. The national 2020 R&D targets set up by member states in 2010 are ambitious but achievable and would bring the EU R&D intensity to 2.7–2.8% of GDP in 2020, close to 3% in 2020.

1. Progress towards EU and national R&D intensity targets

In the 2002 Lisbon Strategy, the EU set the objective of devoting 3% of its GDP to R&D activities by 2010. In 2005, with the re-launch of the Lisbon Strategy, Member States set their own national R&D intensity targets to be met in 2010. In the Europe 2020 Strategy adopted in 2010, the EU maintained the 3% objective for 2020 and in the following months, Member States adopted their 2020 national R&D intensity targets.

This chapter analyses the progress made by the EU and individual Member States towards their respective R&D objectives. It therefore focuses on the evolution of total R&D expenditure in countries.

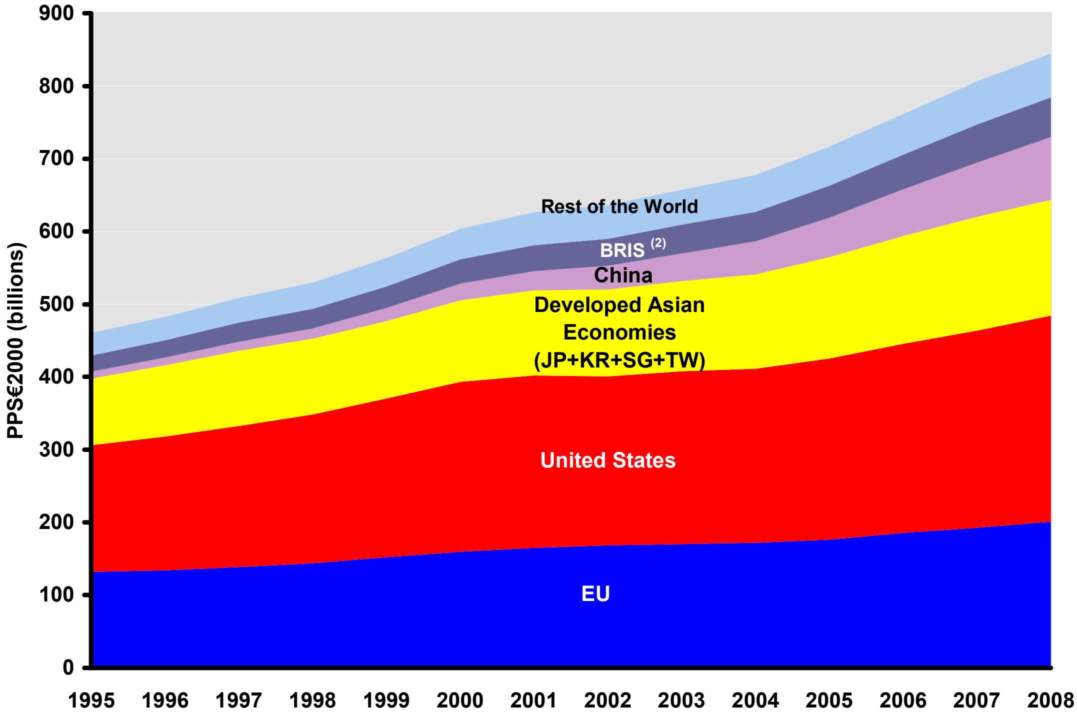
1.1. Has the EU made progress since the year 2000 to meet the R&D intensity target?

Overall research investment in the EU has increased in recent years, although at a lower growth rate than in other parts of the world

Between 1995 and 2008 the world's gross domestic expenditure on R&D (GERD) has almost doubled in real terms (Figure I.1.1). Over this period real GERD has increased by about 50% in the EU, 60% in the United States, 75% in developed Asian economies, 855% in China, 145% in BRIS countries (Brazil, Russia, India, South-Africa) and almost 100% in the rest of the world. As a result, less than 24% of R&D expenditure in the world was located in the EU in 2008, compared to almost 29% in 1995. The share of the United States and Japan also decreased substantially from almost 38% to 33% in the United States and from 16% to 13% in Japan. Moreover this global trend has been accelerating since 2004, which marked the beginning of a steeper increase in R&D expenditure in China and developed Asian economies.

This evolution is expected since rapid economic growth in China and a number of other countries in the world allows for rapid increases in R&D expenditures in these countries. Also, high growth rates are more easily reached when the initial level is relatively low. In that context, the share of the EU and other advanced economies is bound to shrink and the figure below quantifies this shrinkage. This re-balancing in knowledge production has important consequences for the EU in terms of international scientific and technological cooperation and knowledge flows in the world.

Figure I.1.1 Evolution of World GERD in real terms (PPS€ at 2000 prices and exchange rates), 1995-2008



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat, OECD, UNESCO
Notes: (1) Elements of estimation were involved in the compilation of the data.
(2) BR+RU+IN+ZA.

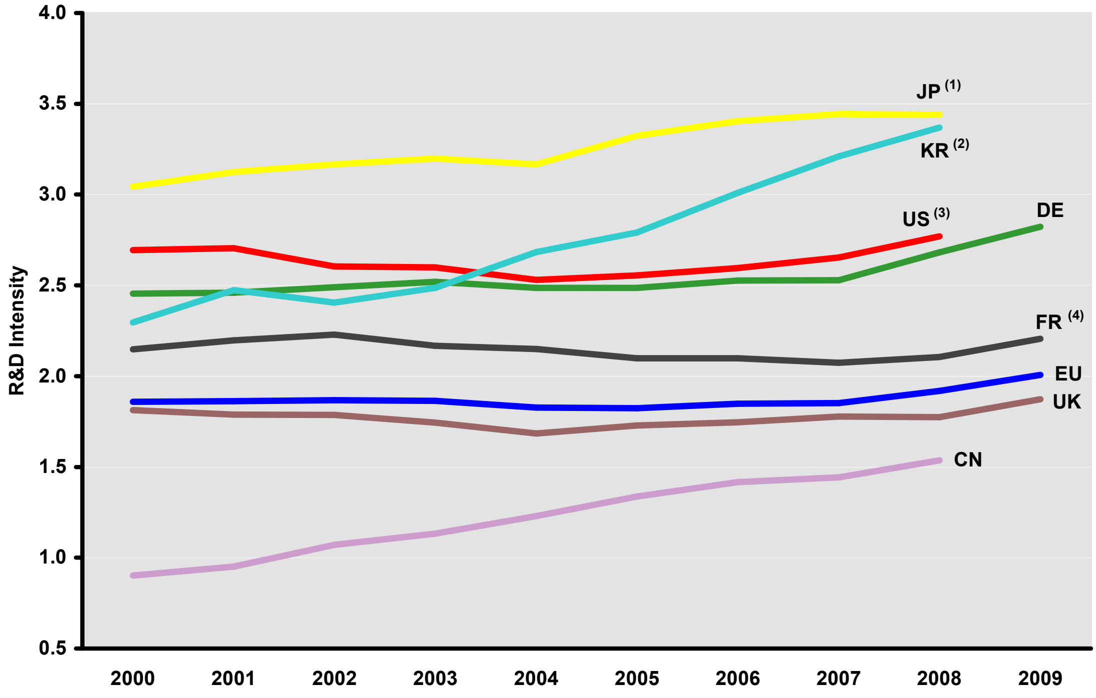
Research intensity in the EU has increased only marginally since 2000, which contrasts with the remarkable growth in the major Asian research-intensive countries

Despite a 25 % real-terms increase in research expenditure over the period 2000–2008, R&D intensity in the EU has stagnated at around 1.85 % of GDP between 2000 and 2007 with a slight increase in 2008 and 2009 to 2.01 % of GDP. This late increase in R&D intensity is, however, due to a more rapid decrease in GDP than in R&D expenditure.

In the United States, after a continuous decline during the first half of the decade, R&D intensity has started to increase since 2005 to 2.77 % of GDP in 2008, slightly above its 2000 value (2.69 % of GDP). This quasi-stagnation of R&D intensity in the EU and the United States contrasts with the strong increases observed in Japan, South Korea and China during this period, up to 3.44 %, 3.37 % and 1.54 % of GDP respectively. Part of the very high R&D intensity growth observed in China is due to its low initial position. It is to be noted that this increase slowed down in 2007–2008 in Japan.

Of the largest contributors to R&D expenditure in the EU, France and the United Kingdom have followed a similar path to the EU average, while Germany is closer to the US level.

Figure I.1.2 Evolution of R&D Intensity, 2000-2009



Source: DG Research and Innovation

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Data: Eurostat, OECD

Notes: (1) JP: There is a break in series between 2008 and the previous years.

(2) 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.

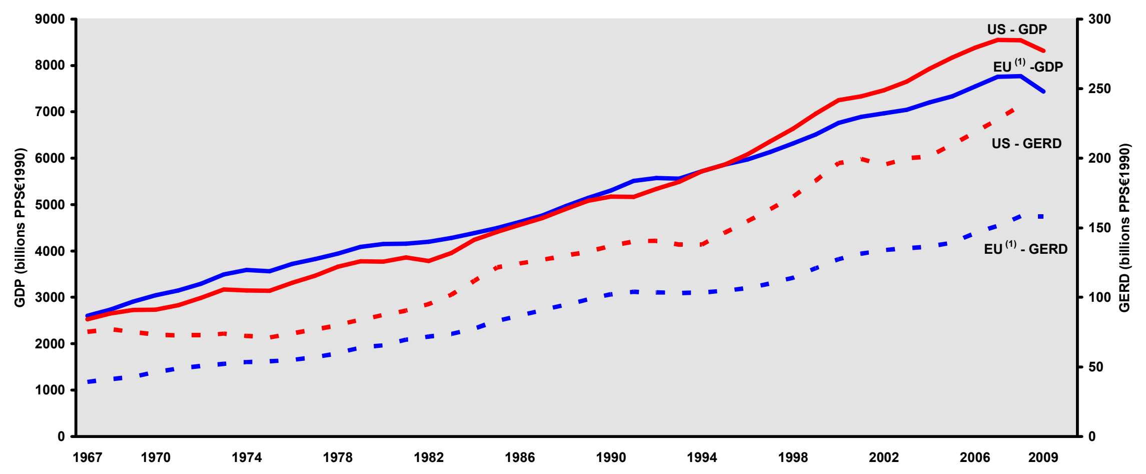
(3) US: GERD does not include most or all capital expenditure.

(4) FR: There is a break in series between 2004 and the previous years.

Box I.1.1 – A persistent, historical R&D intensity gap

The R&D intensity gap between the EU and the US has always existed since one started to measure it (Figure I.1.3). It therefore reflects a deep structural difference between both countries that is relatively robust throughout time.

Figure I.1.3 EU [(1)] and the United States - Evolution (in real terms [(2)]) of GDP and Gross Domestic Expenditure on R&D (GERD), 1967-2009



Source: DG Research and Innovation
Data: Eurostat, DG ECFIN,OECD
Notes: (1) EU: BE, DK, DE, ES, FR, IE, IT, NL, AT, PT, FI, SE, UK.
(2) PPS€ at constant 1990 prices and exchange rates.

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R&D intensity progressed in 24 Member States over the period 2000–2009[1]

The pace of progress in R&D intensity has been very different across Member States:

- Two Member States (Estonia and Portugal, representing about 1.5 % of EU-27 GDP[2]) have increased their R&D intensities by more than **100 %**.
- Three Member States (Cyprus, Ireland and Spain, representing about 10.4 % of EU-27 GDP[3]) have had R&D intensity increases of between **50 % and 100 %.** Of the Associated Countries, Turkey has experienced a comparable increase in R&D intensity.
- Ten Member States (Hungary, Austria, Lithuania, Denmark, Slovenia, Romania, Czech Republic, Italy, Finland and Germany, representing about 42.4 % of EU-27 GDP[4]) have had R&D intensity increases of between **15 % and 50 %.** Of the Associated Countries, Switzerland has experienced a comparable increase in R&D intensity.
- Nine Member States (Malta, Bulgaria, Latvia, Luxembourg, the United Kingdom, the Netherlands, France, Sweden and Poland representing about 40.2 % of EU-27 GDP[5]) have increased their R&D intensity by **less than 15 %.** Of the Associated Countries, Norway has experienced a comparable increase in R&D intensity.

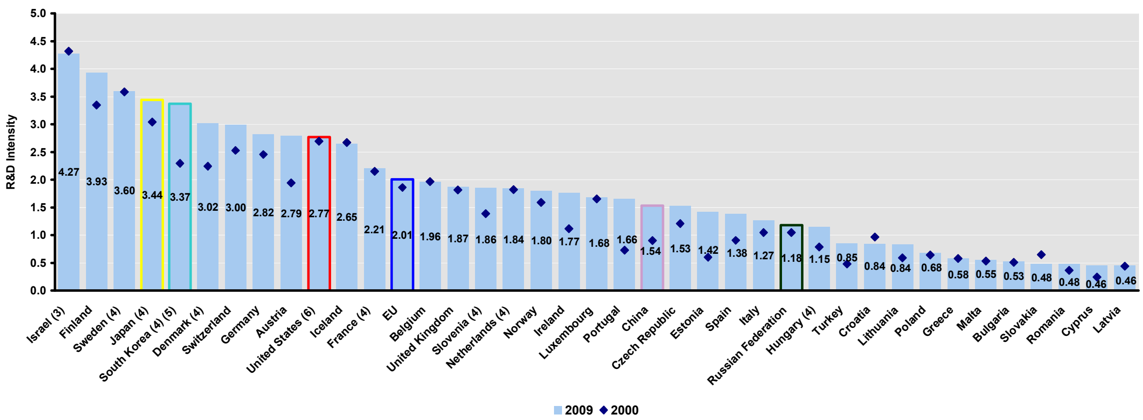
In contrast, three Member States (Greece, Belgium and Slovakia, representing about 5.4 % of EU-27 GDP[6]) have seen their R&D intensity remain at the same level or decrease over the period 2000–2009. With the exception of Belgium, these are Member States with low R&D

[1] For data availability reasons, the actual period covered differs across countries, see footnote to Figure I.1.4.
[2] In 2009.
[3] In 2009.
[4] In 2009.
[5] In 2009.
[6] In 2009.

intensity, which therefore have fallen further behind. Among the Associated Countries, R&D intensity also decreased in Israel and Croatia.

The GDP fall of 2009 is responsible for part of the progress in R&D intensity in all countries. However, a good part of this progress is still due to an increase in R&D expenditure, in particular in countries of the first three groups with the highest R&D intensity growth (over 15%). A particular focus on the evolution of R&D expenditure in 2009 during the economic crisis is to be found in Chapter 2 of this Part.

Figure I.1.4 R&D Intensity 2000 (1) and 2009 (2)



Source: DG Research and Innovation
Data: Eurostat, OECD
Notes: (1) SE: 1999; EL, NO: 2001; HR: 2002; MT: 2004.
(2) EL: 2007; IS, CH, US, JP, CN, KR: 2008; AT, FI: 2010.
(3) IL: GERD does not include defence.
(4) DK, FR, HU, NL, SI; SE, JP, KR: Breaks in series occur between 2000 and 2009.
(5) KR: GERD for 2000-2006 (inclusive) does not include R&D in the social sciences and humanities.
(6) US: GERD does not include most or all capital expenditure.

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Please note that Figure I.1.4. is slightly changed due to change of value for Poland. I will send you this revised figure as the one you have may have a different value for Poland

In a majority of Member States, R&D intensity grew at a faster pace in 2006–2009 than in 2000–2006[7]

In 2005, the Lisbon Strategy was re-launched and Member States set national R&D intensity targets to be reached in 2010.

In a majority of Member States, progress in R&D intensity occurred at a faster pace (on an annual average) in the period 2006–2009 than in the period 2000–2006 (highlighted in green in Table I.1.1 below). This observation is also valid when comparing 2006–2008 to 2000–2006 to exclude the effect due to that fall in GDP in 2009.

However, several Member States (Czech Republic, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Austria and Romania) that experienced a rapid increase in R&D intensity over 2000–2006 saw their pace of progress slow down or even reverse after 2006.

[7] For data availability reasons, the actual periods covered differ across countries, see footnote to Table I.1.1.

Table I.1.1 R&D Intensity - average annual growth (%), 2000-2006 (1) and 2006-2009 (2)
(A green background indicates a higher rate of growth in 2006-2009 (2) than in 2000-2006 (1))

	Average annual growth (%)	
	2000-2006 (1)	2006-2009 (2)
Belgium	-0.91	*1.74*
Bulgaria	-1.73	*4.80*
Czech Republic	4.20	-0.48
Denmark	1.68	*8.84*
Germany	0.48	*3.76*
Estonia	11.05	*8.08*
Ireland	1.85	*12.20*
Greece	*0.03*	*-0.17*
Spain	4.77	4.85
France	-1.21	*1.69*
Italy	1.34	*3.80*
Cyprus	9.75	*2.65*
Latvia	7.97	-13.19
Lithuania	5.08	1.70
Luxembourg	0.07	*0.37*
Hungary	7.25	4.62
Malta	6.95	-3.20
Netherlands	-0.60	*-0.72*
Austria	*4.02*	3.22
Poland	-2.43	6.69
Portugal	*5.22*	*18.81*
Romania	3.68	1.83
Slovenia	1.95	12.25
Slovakia	-4.68	-0.37
Finland	0.64	*3.12*
Sweden	*-4.70*	*-0.76*
United Kingdom	-0.63	*2.34*
EU	*-0.10*	*2.78*

Source: DG Research and Innovation   Innovation Union Competitiveness Report 2011
Data: Eurostat
Notes: (1) SE: 2001-2004; EL: 2001-2006; NL: 2003-2006; FR, HU, MT: 2004-2006.
(2) EL: 2006-2007; AT, FI: 2006-2010; DK: 2007-2009; SI: 2008-2009.
(3) Values in italics are estimated or provisional or forecasts.

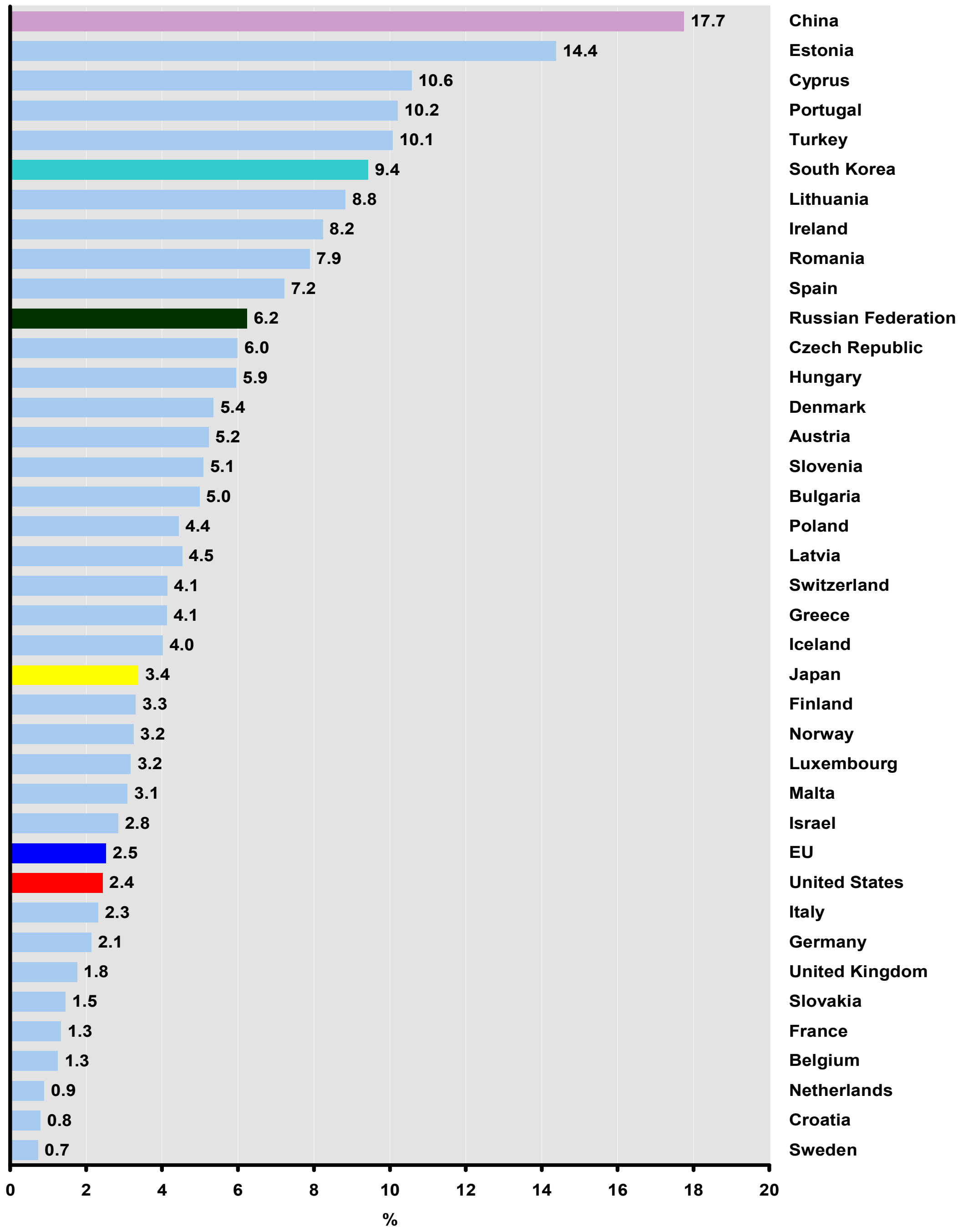
Please note that Table I.1.1. is slightly changed due to change of value for Poland. I will send you this revised table as the one you have may have a different value for Poland

***In real terms, R&D expenditure grew in all Member States between 2000 and 2009*[8]**

In real terms, R&D expenditure grew in all 27 Member States, candidate countries and Associated Countries over the period 2000–2009 (Figure I.1.5). In some cases the growth has been considerable: real growth of R&D expenditure over the period 2000–2009 exceeded 100 % in Estonia (236 % over 2000–2009), Cyprus, Portugal, Lithuania and Ireland; it exceeded 60 % in Romania, Spain, Czech Republic and Austria. On average for the EU, the total real growth of R&D expenditure between 2000 and 2009 reached 25 %.

[8] For data availability reasons, the actual period covered differs across countries, see footnote to Figure I.1.5.

Figure I.1.5 Gross Domestic Expenditure on R&D (GERD) - average annual real growth (%), 2000-2009 [(1)]



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat, OECD
Notes: (1) KR: 2000-2006; SI, JP: 2000-2007; IS, CH, US, JP, CN: 2000-2008; AT, FI: 2000-2010; EL: 2001-2007; NO: 2001-2009; HR: 2002-2009; NL: 2003-2009; FR, HU, MT: 2004-2009; SE: 2005-2009; DK: 2007-2009.
(2) KR: R&D in the social sciences and humanities is not included.
(3) IL: Defence is not included.
(4) US: Most or all capital expenditure is not included.

Please note that Figure I.1.5. is slightly changed due to change of value for Poland. I will send you this revised figure as the one you have may have a different value for Poland

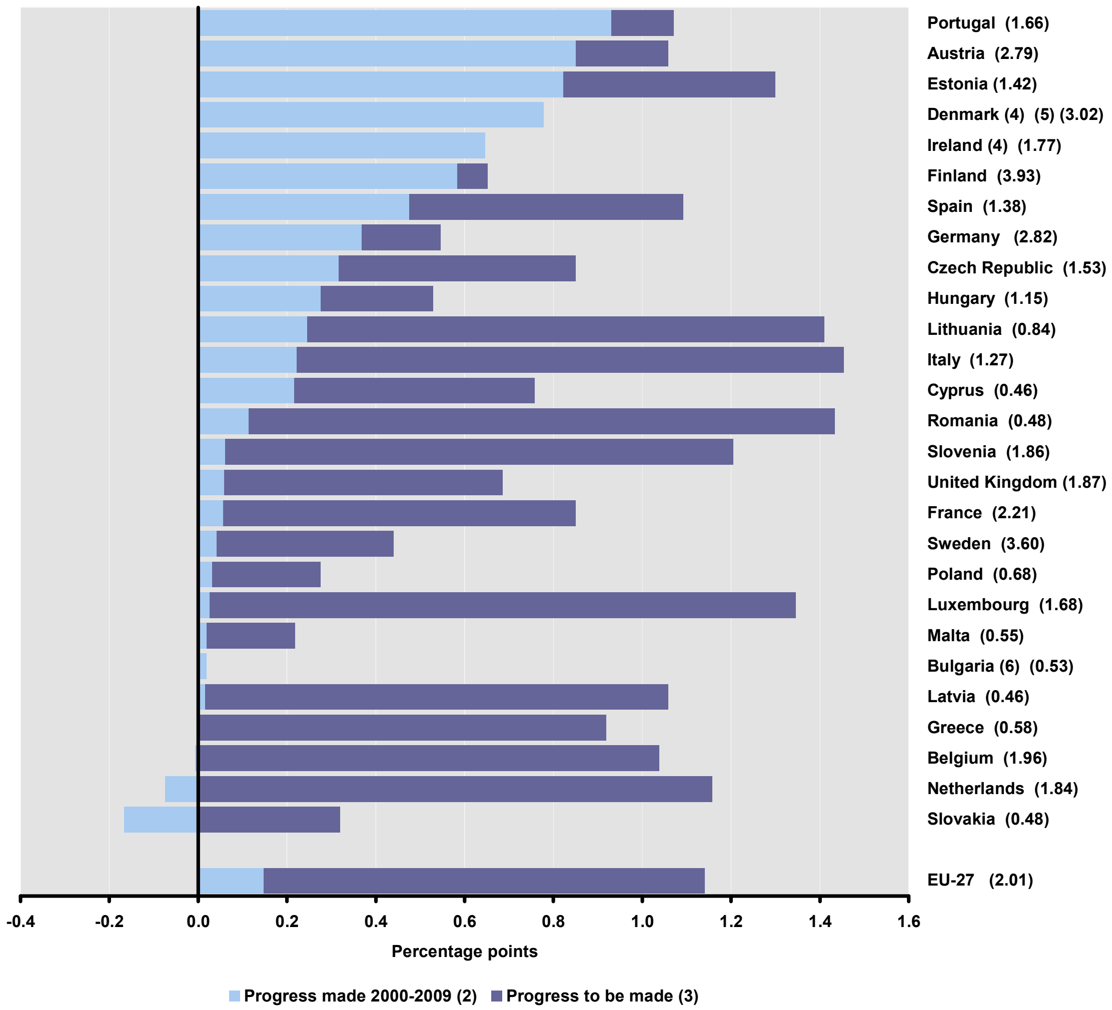
Despite clear progress in real R&D expenditure and R&D intensity, in 2008 most Member States remained far from their national 2010 targets

Figure I.1.6 shows the difference between R&D intensity for the latest available year[9] and R&D intensity in 2000 for each Member State in blue. For instance, R&D intensity in Portugal was 0.93 percentage points higher in 2009 (at 1.66 % of GDP, shown in brackets on the graph) than in 2000 (at 0.73 %). The blue bars show for each Member State the distance separating its latest[10] R&D intensity value and its R&D intensity target for 2010. Portugal's R&D intensity target for 2010 of 1.8 % of GDP is 0.14 percentage points higher than its 2009 R&D intensity of 1.66 %. In other words, in the period 2000–2009, Portugal has made about 87 % of its way towards its 2010 target. The distance between the right end of the blue bar and the y-axis, measures the distance in percentage points of GDP from the initial value of R&D intensity in 2000 to the 2010 target fixed by the Member State. For some countries, this distance between the initial position and the target was greater (even two or three times greater in some cases) than the initial position, which made the target very difficult to reach.

Denmark and Ireland have reached their 2010 targets. Portugal, Austria, Finland and Germany have achieved substantial progress towards their respective targets. Estonia and Spain have made good progress as well but remain far from their targets. In 15 other Member States, progress made is only a fraction of what was required to meet their respective targets[11]. In three Member States, R&D intensity was higher in 2000 than in 2009 (negative grey bars). These Member States are therefore further away from their national R&D intensity targets in 2009 than in 2000.

[9] 2009 or 2010 according to the latest data available for each country, see footnote to Figure I.1.6 (2007 for Greece).
[10] Idem previous footnote.
[11] Bulgaria had no target for 2010.

Figure I.1.6 R&D Intensity - progress towards the 2010 targets (in percentage points); in brackets: R&D Intensity, 2009 (1)



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat, Member States
Notes: (1) EL: 2007; AT, FI: 2010.
(2) SI: 2000-2007; AT, FI: 2000-2010; EL: 2001-2007; NL: 2003-2009; HU, MT: 2004-2009; FR: 2004-2009; SE: 2005-2009.
(3) EL : 2007-2015; FI: 2010-2011; FR: 2009-2012; UK: 2009-2014.
(4) DK, IE: The R&D Intensity targets for 2010 were achieved in 2009.
(5) DK: There is a break in series between 2007 and the previous years.
(6) BG has not set an R&D intensity target.

Please note that Figure I.1.6. is slightly changed due to change of value for Poland. I will send you this revised figure as the one you have may have a different value for Poland

Box I.1.2 — Austria: R&D intensity increased by 44 % between 2000 and 2009, advancing towards the national R&D target

Austria, together with Portugal, is the Member State that has achieved the most substantial progress towards its R&D intensity target of 3 % of GDP by 2010.

Sources of funds responsible for the R&D intensity growth
In terms of financing, 47 % of the increase in R&D intensity in Austria is due to the business sector, 48 % to the government sector and 5 % to investors from abroad. A very large part of business R&D in Austria is financed by business abroad (0.42 % of GDP, i.e. 15 % of total R&D investment).

Table I.1.2 Austria: R&D Intensities for the four sources of funds

Source of funds	2000	2010
Business enterprise	*0.81*	*1.21*
Government	*0.74*	*1.15*
Other national sources	*0.01*	*0.01*
Abroad	*0.39*	*0.42*
Total	*1.94*	*2.79*

Innovation Union Competitiveness Report 2011
Source: DG Research and Innovation
Data: Eurostat
Note: (1) Values in italics are estimated or provisional or forecasts.

Economic sectors responsible for business R&D growth
Four economic sectors account for almost 50 % of total BERD in Austria over the period 2001–2006:
- Radio, TV and communication equipment (22 %)
- Machinery and equipment (11 %)
- R&D services (10 %)
- Motor vehicles (9 %)

Seven additional economic sectors account for more than 30 % of total Business Expenditure on R&D (BERD) in Austria. These eleven main economic sectors performing R&D in Austria have seen their **R&D intensity grow between 1998 and 2006**, with the exception of 'Chemicals less Pharmaceuticals' which very slightly diminished. In addition, these sectors all **grew in terms of their share in total value added** in Austria, except 'Radio, TV and communication equipment', which hardly diminished, and 'Wholesale and Retail trade'. The increase in business R&D intensity in Austria is therefore due both to increased research intensity in the R&D performing sectors in Austria and to a gain in weight of these sectors in the economy. 'R&D services', 'computer services' and 'machinery and equipment' are the three sectors which made the largest contributions to the increase of business R&D.

Research policy
Since the mid-1990s, Austria has considerably increased public funding for R&D. R&D has become and remained a policy priority supported by all political parties in Austria. During the last decade, the Austrian research and innovation system has gone through a catching-up phase and many recurring weaknesses have been overcome, e.g. mobilisation of resources for R&D, science–industry cooperation, international R&D collaboration, institutional funding and governance. In December 2007, the Federal Budget Act ('*Bundeshaushaltsgesetz*') has been changed fundamentally, providing the basis for long-term planning in any field of government spending including R&D. The federal government has also launched a number of initiatives in the field of research and technology which have received additional funding (*Sondermittel*) on top of the regular budget. The R&D funding agencies have undergone structural reforms which provided an institutional basis for an efficient implementation of funding measures in the context of increased public funding.
Indirect research funding through R&D tax incentives has been largely expanded; in 2007, indirect research support represented almost half of total government support to business R&D (see Figure I.3.4).

The governance of Austrian universities has undergone a drastic change following the University Act of 2002. Universities have been given both a new organisational structure and full decision-making power and responsibility. Performance contracts between each university and the Ministry of Science and Research were signed in 2007 in order to define the services that are to be provided by each university. These include: teaching, research, mobility of researchers and students, cooperation, strategy, specialisation etc. Institutional funding is provided through three-year global budgets: 80 % are allocated as a basic budget and 20 % depend on the achievement of performance indicators (‘formula-based budget’). Of particular importance in this context, evaluations of research and teaching have become compulsory, and intellectual capital reports will be used as the main tool for monitoring each university’s performance and the achievement of their goals.

The strong commitment by the government which resulted in increased public funding also stimulated private R&D investment. A large number of measures are aimed at stimulating private R&D spending. The more recent ones are: JITU[12] (a programme promoting the creation and development of innovative and technology-oriented companies), ProTRANS (supporting SMEs to better use their innovation potential) or ‘*Innovationsscheck*’ (supporting SMEs to establish research and innovation activities). Over the past 15 years external evaluations which analyse the impact of different funding measures have become an integral part of Austrian R&I policies, and action is taken accordingly. In addition to the continuous efforts of the federal government, the *Bundesländer* have contributed with their own activities in R&I.

The Austrian National Reform Programme 2008–2010 has emphasised strengthening and fostering knowledge and innovation. R&D policy is seen as crucial to safeguarding the location of businesses and jobs and a comprehensive policy is in place. The country will be positioned as a dynamic partner and an attractive business location within the European Research Area.

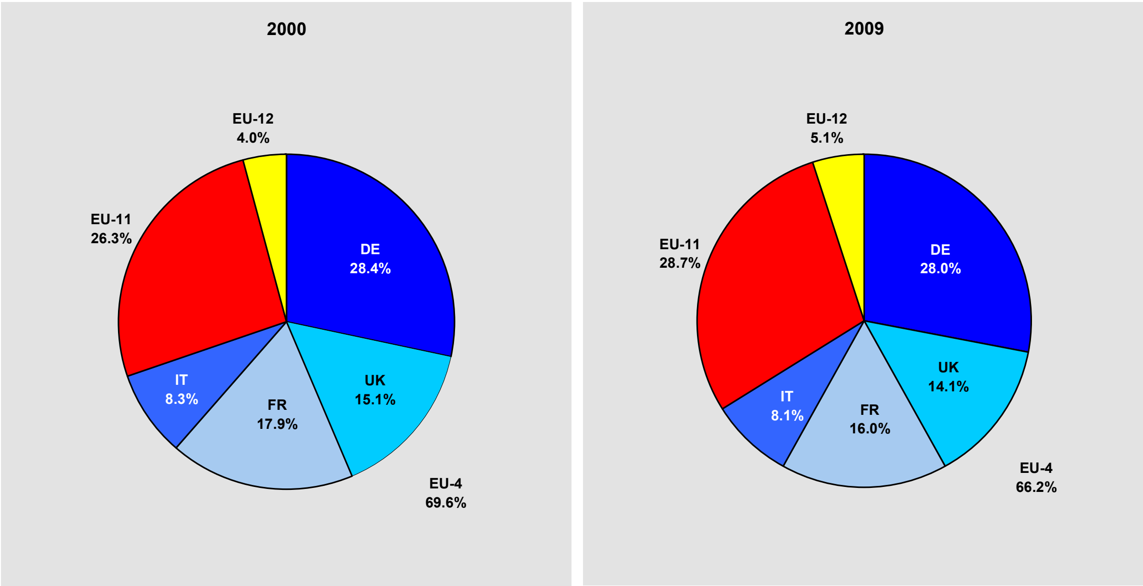
Two thirds of R&D expenditure in EU-27 is performed in the four largest Member States

Expenditure on R&D is very much concentrated in a few countries of the EU: two thirds (in Purchasing Power Parity or PPP) are performed in four countries: Germany, France, the United Kingdom and Italy (Figure I.1.7). The 11 other Member States of EU-15 combined represented 29 % of EU-27 expenditure on R&D in PPP in 2009 — barely more than Germany alone. With 5.3 % of EU-27 expenditure on R&D in PPP in 2009, EU-12 weights five times less than Germany. However the share of the four large Member States slightly decreased between 2000 and 2009.

GDP is less concentrated than R&D expenditures but the four largest Member States still account for more than half of the EU-27 GDP (not shown). As a consequence, the overall EU-27 R&D intensity is very much determined by its value in these four countries.

[12] *Junge Innovative Technolgieorientierte Unternehmen.*

Figure I.1.7 Distribution of GERD (1) within the EU, 2000 and 2009



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat
Notes: (1) GERD in the EU increased by 25% in real terms between 2000 and 2009 (from 160 billion PPS€2000 in 2000 to 201 billion PPS€2000 in 2009).
(2) EU-4: DE, FR, IT, UK.
(3) EU-11: BE, DK, IE, EL, ES, LU, NL, AT, PT, FI, SE.
(4) EU-12 : The twelve new Member States (BG, CZ, EE, CY, LV, LT, HU, MT, PL, RO, SI, SK).

R&D expenditure is more concentrated in fewer regions of Europe than GDP

The realisation of the full research potential of the enlarged ERA necessarily comes through unlocking and developing the research potential in the EU´s 'convergence regions' and outermost regions, and strengthening the capacities of their researchers to successfully participate in research activities at EU and international level.

So far R&D expenditure is very much concentrated in a few regions in the EU. Out of the 268 EU NUTS 2 regions, only about 35 (i.e. about 13 %) had R&D intensity above 2 % of GDP in 2007.[13] These regions form an 'S'-shape, located in three of the Nordic countries, in France, and in a central band from Austria to the South East of the United Kingdom, through southern Germany, the Netherlands and Belgium. The R&D intensity in eastern and southern regions of the EU is low — often below 1 % or 0.5 % of GDP.

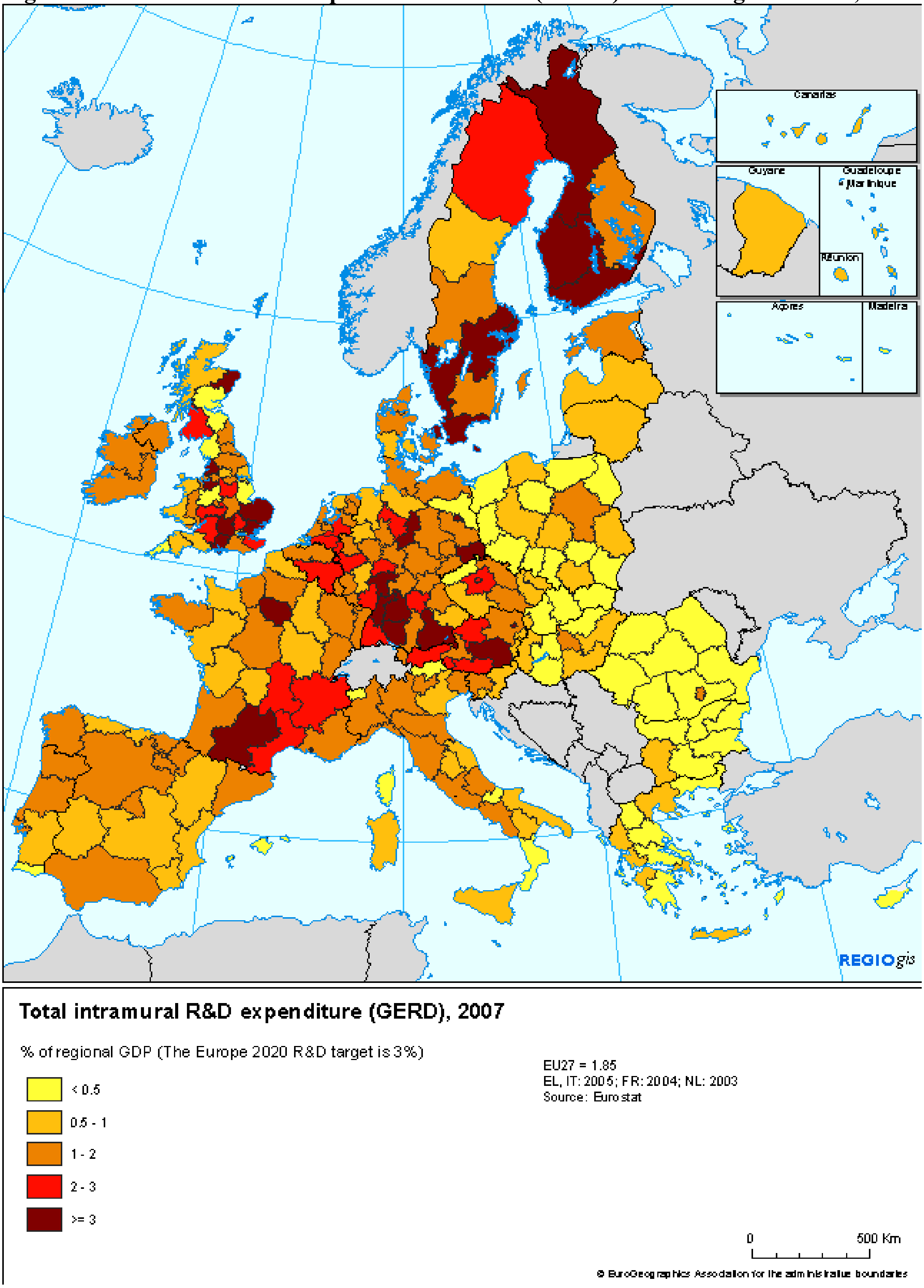
In absolute terms, half of the total EU-27 R&D expenditure is located in about 60 NUTS 2 regions in the EU, i.e. one fifth of the regions. Conversely, half of all the regions contribute to only 6 % of the total EU-27 R&D expenditure. The concentration of R&D expenditures is larger than that of GDP in the EU, indicating that disparities in the research systems are larger than disparities in the economic system. Within the research system, disparities are more pronounced in the business sector than in the public sector.

However, a slight de-concentration of R&D expenditure was observed between 2000 and 2005, as many of the very low R&D intensive regions, in particular in Central and Eastern

[13] There are in fact 271 NUTS2 regions, but for analytical purposes, Inner and Outer London as well as Région de Bruxelles – Capitale/Brussels Hoofdstedelijk Gewest, Prov. Vlaams-Brabant and Prov. Brabant Wallon have been merged.

Europe, have had a higher growth rate of R&D expenditures than the more R&D intensive regions over that period.

Figure I.1.8: Gross Domestic expenditures in R&D (GERD) as % of regional GDP, 2007



1.2. Which targets have been set for 2020 at EU level and at national level?

The EU 3 % target responds to the EU funding gap in R&D

Between 2000 and 2008, R&D intensity has increased by more than 70% in China. It also increased considerably in Korea and Japan[14]. In view of this massive increase in R&D resources in Asia and the persisting gap between itself and the United States, the European Union cannot give up its objective of substantially increasing resources devoted to R&D to comparable levels.

The table I.1.3 below also shows that in the United States and the three Asian countries, private sector R&D represents about three quarters to four fifths of total R&D in terms of expenditure, while in the EU it is slightly less than two thirds. In the three Asian countries, the main motor of the rapid growth in R&D intensity has been the private sector, although public sector R&D intensity also substantially increased in South Korea and to a lesser extent in China.

This smaller private-sector share in total R&D in the EU is even more striking in terms of researchers, since the private sector hosts less than half of the researchers in the EU, i.e. substantially less than its two-thirds share in R&D expenditure. In the United States and the three Asian countries, the share of researchers in the private sector is more aligned with the share of the private sector in total R&D expenditure.

Table I.1.3 Private sector (1) and public sector (2) R&D Intensities and private sector share of total researchers (FTE)

	EU			US (3)			Japan (4)			South Korea (5)			China		
	2000	2009	% change	2000	2008	% change	2000	2008	% change	2000	2008	% change	2000	2008	% change
R&D Intensity - private sector	1.22	1.27	3.5	2.11	2.12	0.6	2.30	2.75	19.7	1.73	2.59	: (5)	0.54	1.12	107.8
R&D Intensity - public sector	0.64	0.74	16.5	0.59	0.65	10.8	0.74	0.69	: (4)	0.56	0.78	: (5)	0.36	0.41	13.6
R&D Intensity - total	1.86	2.01	7.9	2.69	2.77	2.9	3.04	3.44	: (4)	2.30	3.37	: (5)	0.90	1.54	70.1
R&D Intensity - private sector as % of total	65.8	63.1	-4.1	78.2	76.5	-2.1	75.6	80.0	5.9	75.4	76.8	: (5)	60.0	73.3	22.2
Researchers (FTE) - private sector as % of total	48.0	47.0	-2.0	80.5	80.0 (6)	-0.6 (7)	67.5	76.3	: (4)	67.5	78.7	: (5)	50.9	68.6	34.7

Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat, OECD
Notes: (1) Private sector: Business enterprise and private non-profit sectors.
(2) Public sector: Government and higher education sectors.
(3) US: R&D Intensity does not include most or all capital expenditure on R&D.
(4) JP: There is a break in series between 2008 and 2000 for public sector R&D Intensity and researchers (FTE).
(5) KR: There is a break in series between 2008 and 2000 for R&D Intensity and researchers (FTE).
(6) 2007.
(7) 2000-2007.

The national 2020 R&D targets set up by Member States are ambitious but achievable and would bring the EU R&D intensity close to, but below, 3 % in 2020

In 2009, the EU R&D intensity gap to the 3% target is 1% GDP, i.e. about EUR 118 billion, half the total amount of EU R&D expenditures (EUR 236 billion).

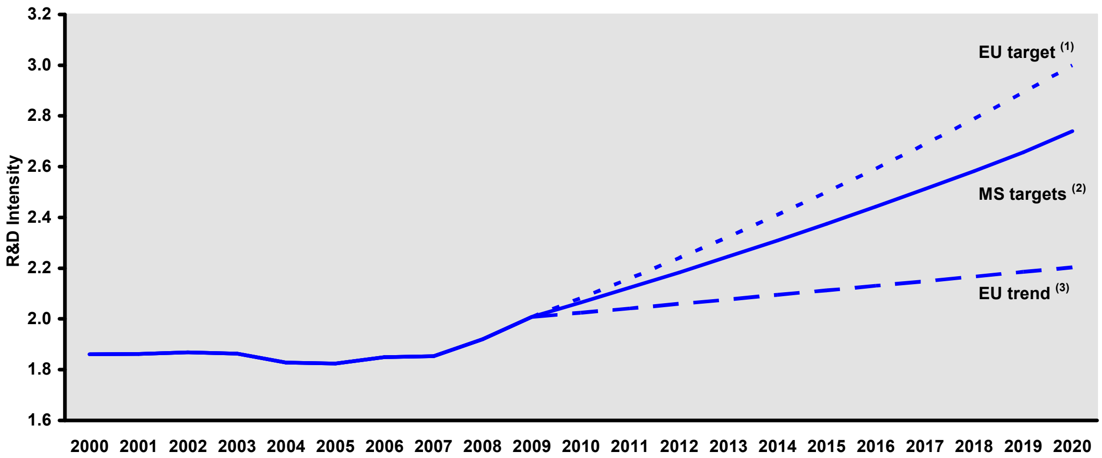
In 2010, the EU decided to maintain the 3% objective for 2020. If the 2000–2009 trend continued another decade, the EU's R&D intensity would reach 2.2% of GDP by 2020. In other words, based on the last decade's trend, the EU as a whole would fall short of the 3% target by 0.8 percentage point (i.e. 27% of the target). With respect to 2009 EU's GDP, this represents EUR 94 billion. Under the hypothesis that the EU's GDP will grow on average by

[14] However, due to a break in series between 2000 and 2008 in Korea and Japan, it is not possible to calculate a growth rate between these two years in these countries.

2 % annually, if the 2000–2009 R&D intensity trend continues, the gap to the 3 % will amount to about EUR 117 billion, as in 2009.

Member States set their own national 2020 targets (Table I.1.4 below). If Member States were to reach these national 2020 targets, the overall EU R&D intensity would be between 2.7 and 2.8 % of GDP in 2020. In other words, based on present national R&D targets, the EU as a whole would fall short of the 3 % target by 0.2 to 0.3 percentage points (i.e. 7–10 % of the target). With respect to the EU's 2009 GDP, this represents EUR 24–35 billion. Under the hypothesis that EU's GDP will grow on average by 2 % annually until 2020, the gap to all Member States reaching their target of 3 % will amount to EUR 29–44 billion.

Figure I.1.9 EU - R&D Intensity projections



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: DG Research and Innovation, Eurostat
Notes: (1) The EU target projection is based on the R&D Intensity target of 3.0% for 2020.
(2) The EU target projection is based on the R&D Intensity targets of Member States.
(3) The EU trend projection is derived from the average annual growth in R&D Intensity 2000-2009.

The 2020 targets set by Member States for themselves are both realistic and ambitious. The targets are realistic because for each Member State the chosen target is compatible with the range of 2020 values obtained with two complementary projection methods based on (1) the current sectoral composition of the country's economy and (2) the potential growth of R&D intensity based on the country's 2006–2008 R&D intensity trend or that of comparable countries. The targets are ambitious because the hypotheses underlying each projection method are ambitious.

The first method estimates potential future intensity of Business Expenditure on R&D (BERD) in a country, by assuming that in each sector R&D intensity will, in the next 10 years, approach the corresponding sectoral intensity in 2006 of the best five EU performers in that sector. These five best sectoral intensities are then applied to the present sectoral composition of the country to compute its overall BERD intensity.[15] According to this model and with the additional hypothesis that all the Member States will have achieved by 2020 the Lisbon target on the public R&D component set by themselves in 2005 for 2010, the expected EU intensity may reach 2.79 % in 2020.

[15] Note however that within a given sector an increase in intensity is likely to result both from favourable changes in composition of its sub-sectors and from increased R&D intensity of each sub-sector moving closer to the technological frontier.

The second method estimates the value that a Member State's R&D intensity would reach in 2020 using (i) its average annual growth rate between 2006 and 2008 if the latter was high, and, if it was not, using as potential benchmarks (ii) the average annual growth rate between 2006 and 2008 of the best performing countries in Europe and its main trading partners. In other words, for those countries that have had a limited or negative growth rate in 2006–2008, this method applies the average growth rate of a basket of better-performing countries with similar initial research intensities, level of economic development and economic structures[16]. With this method, the projected value for EU R&D intensity in 2020 is 3.02%.

Table I.1.4 R&D Intensity, 2009 (1) and R&D Intensity target for 2020

	Public sector (2)	Private sector (3)	Total	Target 2020
Belgium	*0.62*	*1.35*	*1.96*	2.60 - 3.00
Bulgaria	*0.36*	*0.16*	*0.53*	1.50
Czech Republic	0.60	0.92	1.53	2.70
Denmark	*0.99*	*2.03*	*3.02*	3.00
Germany	*0.90*	*1.92*	*2.82*	3.00
Estonia	0.76	*0.67*	*1.42*	3.00
Ireland	*0.60*	*1.17*	*1.77*	:
Greece	*0.42*	*0.16*	*0.58*	2.00
Spain	0.66	0.72	1.38	3.00
France	*0.81*	*1.39*	*2.21*	3.00
Italy	*0.57*	*0.69*	*1.27*	1.53
Cyprus	*0.29*	*0.17*	*0.46*	0.50
Latvia	0.29	0.17	0.46	1.50
Lithuania	0.64	0.20	0.84	1.90
Luxembourg	*0.44*	*1.24*	*1.68*	2.60
Hungary (4)	0.47	0.66	1.15	1.80
Malta	*0.21*	*0.34*	0.55	0.67
Netherlands	*0.96*	*0.88*	*1.84*	:
Austria	*0.80*	*1.95*	*2.75*	3.76
Poland	0.48	0.19	0.68	1.70
Portugal	*0.71*	*0.95*	*1.66*	2.70 - 3.30
Romania	0.29	0.19	0.48	2.00
Slovenia	0.66	1.20	1.86	3.00
Slovakia	0.28	0.20	0.48	0.90 - 1.10
Finland	*1.14*	*2.79*	*3.93*	4.00
Sweden	*1.06*	*2.54*	*3.60*	4.00
United Kingdom	*0.67*	*1.20*	*1.87*	:
EU	*0.74*	*1.27*	*2.01*	3.00

Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat
Notes: (1) EL: 2007; FI: 2010.
(2) Public sector: Government and higher education sectors.
(3) Private sector: Business enterprise and private non-profit sectors.
(4) HU: The sum of the public and private sectors is not equal to the total.
(5) Values in italics are estimated or provisional.

Please note that Table I.1.4. is slightly changed due to change of value for Poland. I will send you this revised table as the one you have may have a different value for Poland

[16] The model also introduces a series of caps to control too-high R&D growths that could be regarded as unrealistic due to the limited absorption capacity of individual research systems. These caps are organised according to an increasing scale inversely proportional to the level of their initial level of R&D intensity in 2008. More precisely, for initial R&D intensities between 3% and 4%, the maximum cap would be 40% of overall increase of the original R&D intensity. For R&D intensities between 2% and 3%, the cap would be of a 50% overall increase, between 1.5% and 2%, the cap would be of a 75% overall growth. Below an R&D intensity of 1.5%, the cap would be of 100% overall R&D intensity growth.

Unsurprisingly, according to these national objectives, the greatest progression will have to be achieved by the countries whose initial level of R&D intensity is the lowest, while countries with the highest initial R&D intensity will achieve more modest progress. The average progression of the groups of countries with a current average R&D intensity of 1.1 % and 1.9 % would be to the order of 110 % and 50 % respectively, while the progression of medium-high (2.7 %) and high (3.8 %) R&D intensity groups would be around 15 % and 10 %. The target averages of the low and medium groups of countries are therefore very ambitious and root themselves in the need to increase international competitiveness in the knowledge-economy and to respond to global and societal challenges.

2. Effect of the economic crisis on R&D investment

Highlights

In 2008–2009, R&D expenditure has been more resilient to the financial crisis than overall economic activity. Due to a more rapid drop in GDP than in R&D expenditure, the net effect of the crisis has been an increase in EU's R&D intensity from 1.85 % of GDP in 2007 to 1.92 % in 2008 and 2.01 % in 2009.

Overall, in 2008–2009 there has been good continuity in national public R&D investment trends in the EU, with sustained R&D investment in the majority of Member States. In 2009, nominal R&D budgets grew or were maintained in 17 Member States. In terms of execution, nominal R&D expenditure in the public sector grew by 1.8 % in the EU in 2009. As % of GDP, both total R&D budget and public R&D expenditure increased in the EU by 0.03 and 0.05 percentage points, up to 0.74 and 0.75 % of GDP respectively. Altogether, the data show that governments in the EU have considered R&D as a priority in times of crisis.

However, the result of the economic crisis might be a further widening of the gap between Member States with high R&D intensities and some Member States with lower R&D intensities, the latter having more difficulty in avoiding cuts in R&D spending.

In addition, first GBAORD[17] data for 2010 indicate that R&D budgets may decrease as % of GDP in more EU countries than in 2009. In the medium term, the need for fiscal consolidation may place further pressure on the ability of some European governments to maintain their investment in R&D.

Business investment in R&D was more affected than public investment in 2009. In the EU's business sector, R&D expenditure decreased by -3.1 % in nominal terms in 2009. This relatively limited decrease, however, shows that business R&D expenditure has been relatively resilient to the economic crisis in 2009. As % of GDP, business R&D expenditure even progressed by 0.03 percentage point, up to 1.25 % of GDP, due to a sharper drop in GDP.

The relative resilience of business R&D in 2009 is confirmed by the 2010 EU Industrial R&D Investment Scoreboard (hereafter the Scoreboard) which analyses the information from the world's top 1 400 R&D investing companies' latest published accounts covering fiscal year 2009. Despite large decreases in sales and profits, nominal R&D investment by these companies decreased by only -1.9 % in 2009 — a decrease unevenly distributed across industrial sectors. A substantial decrease occurred in the Automobiles and IT hardware sectors, while the Pharmaceutical sector continued to rise and consolidate its position as top investor in R&D. The decrease in R&D investment was sharper in US companies than in EU companies, but Asian companies continue their high R&D growth. The observed increase in business R&D expenditure in a number of catching-up Member States indicates that they have probably benefited from this strategic R&D persistency in large companies.

Smaller companies investing in R&D are likely to have had much more difficulty in maintaining their level of R&D investment. A rough comparison of the R&D behaviour of

[17] Government Budget Appropriations or Outlays on R&D.

large Scoreboard's companies with the evolution of domestic business R&D expenditure indicates that smaller companies investing in R&D (not covered in the Scoreboard) have considerably reduced their R&D investment in 2009 in a number of Member States.

Besides, the evolution of business investment in R&D after 2009 remains uncertain. Past observations show that fluctuations in business R&D growth are larger than fluctuations in GDP growth with a time lag of 1–2 years. Lessons from the past therefore indicate that the negative trend in business R&D started in 2009 might worsen in 2010 and in following years.

Finally, it must be noted that all official 2009 data on total R&D expenditure and on R&D expenditure in the public and business sectors shown in this chapter are still *provisional* data, subject to revision by mid-2011. 2009 GBAORD data are also still provisional in a number of Member States.

2. Effect of the economic crisis on R&D investment

Research and Innovation are widely accepted to be the centrepiece for long-term sustainable economic growth in Europe. However, despite this recognition, the strong financial and economic crisis that Europe has gone through since 2007 can deeply affect R&D investments.

In general, historical data show that private R&D investments follow economic downturns to some extent. Liquidity pressure, difficulties in finding appropriate financing, credit constraint, falls in sales and available cash-flows, and difficulties facing shorter-term payments are just some of the factors which can lead some private firms to decrease their investments in R&D. Moreover, the large public budget deficits that several European governments have run in recent years as a consequence of the stimulus packages and the lower tax revenues, have called for a need for fiscal consolidation in order to regain macroeconomic stability.

As a result, the economic crisis exposes many risks that can lead to a general drop in both public and private R&D investments in Europe, potentially jeopardising Europe's future economic growth. Therefore, it is important to gain evidence of its effects on both public and private R&D investments.

This chapter presents some of the latest available data on both public and private R&D and thus depicts an initial overview of the short-term effects that the financial and economic crisis has brought about in terms of R&D investments. Longer-term effects are more difficult to foresee and will largely depend on the strategy of both private firms and governments. It is structured around five main sections that analyse (1) the historical relationship between R&D and the business cycle, (2) the effects of the economic crisis on overall R&D, (3) on public R&D and in (4) private R&D. Finally, section (5) summarises the main preliminary findings and alerts about the unknown medium- and long-terms effects.

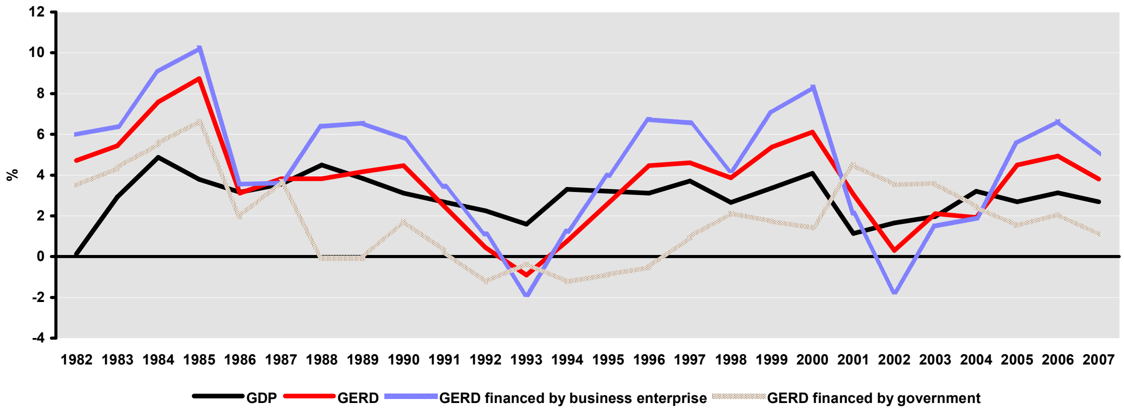
2.1. How is R&D growth related to the business cycle?

It is widely recognised that R&D and innovation are major drivers of productivity and growth. It is also commonly accepted that the positive relationship between R&D and growth is mainly driven by business R&D. This is logical to the extent that public R&D is more focused on fundamental research than business R&D. As a result, public R&D creates a positive externality for business R&D, thus increasing the capability of the business sector to undertake R&D. However, it also means that public R&D is a step further away from the market, and therefore the relationship with growth is less direct than for business R&D.

There is a strong correlation between business R&D investment and economic growth, while publicly financed R&D has a countercyclical effect

GDP and R&D expenditure (GERD) are closely correlated over time in the OECD area: Figure I.2.1 shows that R&D expenditure growth tends to follow the business cycle, with larger fluctuations than for GDP growth and a time lag of one to two years. The fluctuations are the biggest for business-financed R&D, showing that R&D financed by the business sector is the component most affected by the business cycle. In contrast, government-financed R&D growth shows smaller, often countercyclical, fluctuations like, for instance, during the economic downturn of the early 2000s.

Figure I.2.1 R&D growth (1) over the business cycle, OECD area, 1982-2007



Source: DG Research and Innovation
Data: OECD STI Scoreboard, 2009
Note: (1) Real growth per annum (%).

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In the short- to medium-term the relationship between R&D and economic growth depends on the underlying sector dynamics of a national economy

The development patterns of GDP and R&D differs between countries both in terms of timing and impact. In countries such as Austria, Latvia, the Netherlands, Slovenia and Spain, the lag occurs after just one year, indicating a rather immediate relationship between GDP and R&D, whereas in countries such as Denmark, Finland and the United States, it only occurs after 3–5 years. This could indicate that it often takes some time before R&D expenditure has an impact on GDP. In general business, R&D expenditure has shorter lag intervals with GDP, confirming a more direct relationship between business R&D expenditure and GDP growth, than between public R&D expenditure and GDP growth.

Box I.2.1 — Time-series analysis of the co-evolution of GDP and R&D expenditure

The main findings of a time-series analysis of GDP and R&D expenditure are:

The levels of R&D spending are interrelated to the levels of economic growth, but growing R&D expenditure levels might not always be completely reflected in the R&D investment intensities, since R&D intensities are temporarily influenced by the levels of GDP growth. In other words, high levels of GDP (growth) may temporarily push the R&D intensity downwards, whereas in periods of an economic downturn R&D intensities could also move upwards for a certain period of time

The evolution of GDP versus R&D expenditure and R&D personnel depends on several structural characteristics like governance structure, policy priorities, and systemic features like industry and academic structures. An understanding of R&D expenditure patterns and performance requires in-depth knowledge of these characteristics

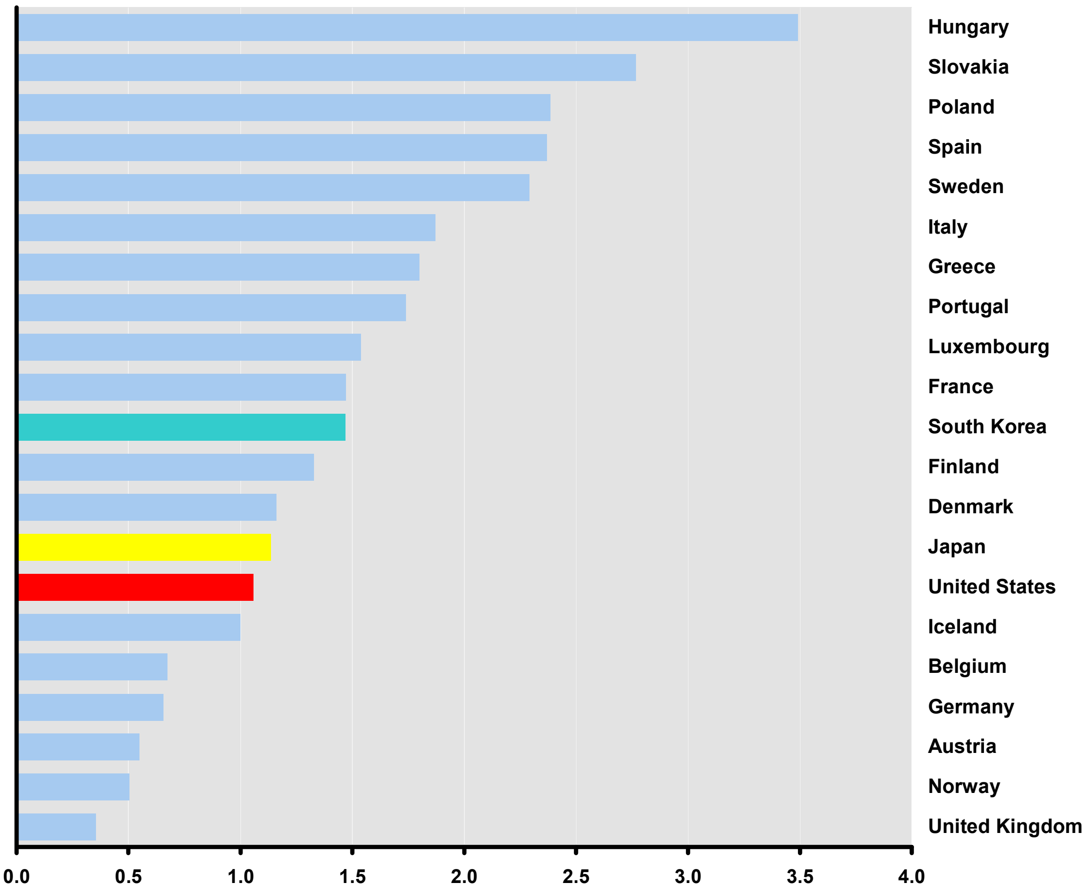
The effect of government-performed R&D is significant and positive on the number of publications and patent applications (the output side). With a time lag of 1–2 years. R&D performed by the business sector positively influences the number of patent applications, which could be expected, as the proximity to patent in the business sector is in general higher than for the public sector.

The wide differences in co-evolution of GDP and R&D expenditure between countries could be the result of specific sector developments. GDP may, for example, be growing much faster in a particular country than R&D expenditure, due to a temporary boom in certain sectors such as construction. As a result, otherwise positive developments for R&D may not result in higher R&D intensities. Similarly, in periods of declining GDP growth, R&D intensities may increase for a certain period of time. This is what happened in 2009 (see below).

The responsiveness of R&D to GDP varies widely between countries over the business cycle

Figure I.2.2 below shows the responsiveness of R&D to the business cycle (elasticity of R&D expenditure with respect to GDP). It is seen that in countries such as Hungary, Slovakia, Poland, Spain, Sweden, Italy, Greece, Portugal, Luxembourg and France, the response in R&D expenditure is 1.5 to 3.5 times the change in GDP — meaning that, based on past experience, the current crisis could lead to significant drops in R&D intensity in these countries after 2009.

Figure I.2.2 Responsiveness of R&D to the business cycle, 1981-2007



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: OECD STI Scoreboard, 2009

2.2. How did the economic crisis affect total R&D intensity?

In 2009, GDP decreased faster than R&D expenditure in the EU, resulting in an increase in R&D intensity

In nominal terms, gross domestic R&D expenditure (GERD) decreased in 12 Member States in 2009 with respect to 2008. However, GDP decreased even more sharply, so that: (i) R&D intensity decreased in 2009 in only five Member States and (ii) in these Member States the decrease in R&D intensity is less marked than in nominal GERD. For the EU as a whole, the decrease in nominal R&D expenditure amounts to about EUR 3 billion (-1.3 %, from EUR 239.7 billion in 2008 to EUR 236.5 billion in 2009). Despite this loss, EU-27's R&D intensity gained 0.09 percentage points of GDP at 2.01 % of GDP, compared to 1.92 % in 2008.

Despite the economic crisis, total R&D expenditure increased in nominal terms in 14 Member States[18] in 2009. This gave rise to relatively important increases in R&D intensity in these countries, above 0.1 percentage points of GDP in most cases.

[18] At the time of writing, 2009 data was not available for Greece.

Total R&D expenditure in Japan suffered much more from the economic crisis; it decreased by 8.3% in 2009 compared to 2008 nominally. This caused a sharp decrease in R&D intensity from 3.8% in 2008 to 3.62% of GDP in 2009[19]. Due to the unavailability of 2009 data for the United States, South Korea and China, no other international comparison is possible.

In the long term, R&D expenditure growth tends to show larger variations than GDP growth in the OECD area, with a time lag of about one to two years (see section 2.1 above). This suggests that the recent drop in GDP may still result in a larger decrease in total R&D expenditure only after 2009.

Table I.2.1 GERD and R&D Intensity - change between 2008 and 2009

	GERD (nominal) % change	R&D Intensity change in percentage points
Poland	17.7	0.07
Turkey	17.3	0.12
Russian Federation	12.7	0.15
Hungary	12.3	0.15
Bulgaria	*10.8*	*0.06*
Portugal	*8.0*	*0.16*
Ireland	*7.7*	*0.31*
Slovenia	6.5	0.20
Cyprus	*6.2*	*0.03*
Norway	*4.0*	*0.16*
Luxembourg	*3.3*	*0.12*
France	*2.5*	*0.10*
Czech Republic	2.3	0.06
United Kingdom	*1.7*	*0.10*
Germany	*1.7*	*0.14*
Netherlands	*0.4*	*0.08*
Denmark	*0.1*	*0.15*
Austria	*-0.1*	*0.08*
Italy	*-0.1*	*0.04*
Slovakia	-0.6	0.01
Spain	-0.8	0.03
Finland	-1.2	0.24
EU	*-1.3*	*0.09*
Belgium	*-1.6*	*0.00*
Israel (2)	*-2.9*	*-0.39*
Malta	-3.7	-0.02
Estonia	*-5.2*	*0.13*
Sweden	*-5.5*	*-0.08*
Croatia	-9.1	-0.06
Lithuania	-14.1	0.04
Romania	-20.9	-0.10
Latvia	-39.8	-0.16

Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat, OECD
Notes: (1) EL: Data are not available for 2008 and 2009.
(2) IL: GERD does not include defence.
(3) Values in italics are estimated or provisional.

[19] Statistics Bureau of the Minister of International Affairs and Communication in Japan.

Please note that Table I.2.1 is slightly changed due to change of value for Poland. I will send you this revised table as the one you have may have a different value for Poland

2.3. Has the economic crisis led to cuts in public R&D investment?

In nominal terms, R&D budgets increased or were maintained in 17 Member States and decreased in 7 Member States in 2009[20], but they decreased relative to GDP in only 2 Member States in the same year

Seventeen Member States were able to maintain or increase their nominal R&D budgets in 2009, a sign that Member States regard R&D as a priority to ensure a better and more rapid economic recovery and economic growth in the longer term (Table I.2.2). Seven Member States could, however, not maintain their R&D budgets at the same level as in the year before[21]. Severe cuts occurred in Lithuania already in 2008, and lighter ones in Spain[22]. In 2009, the most severe cuts occurred in Latvia, Romania and Lithuania; Latvia and Romania are the only countries where the fall in R&D budget was larger than the fall in GDP, leading to a decrease in the ratio of R&D budget to GDP that year.

According to a survey of research ministries in Member States conducted by the European Commission in 2010, 16 Member States planned to increase their R&D budget in 2010, while 4 Member States planned to decrease it[23]. However, the first data available show that relative to GDP, R&D budgets will be decreasing in more countries in 2010 than in 2009 due to the return to positive GDP growth in most countries.

In the medium term, the need for fiscal consolidation may place further pressure on the ability of some European governments to maintain their investment in R&D. According to the above-mentioned survey, nine Member States intend to increase their R&D budget in 2011, four to stabilise it and four to decrease it[24]. Keeping increasing public investment in R&D during the economic downturn and slow recovery — as in the OECD area in the early 2000s (Figure I.2.1 above) — is key to ensuring a more rapid return to sustained economic growth[25].

The GDP fall of 2009 allowed for a slight increase of the R&D budget to GDP ratio in the EU and Japan, while progress of this ratio over 2007–2009 reaches almost 20 % in South Korea

Outside Europe, the US R&D budget stayed roughly at the same nominal level in dollars in 2008 compared to 2007, but decreased sharply when measured in euros (from EUR 103.5 to EUR 96.8 billion, not shown in Table I.2.2). In Japan, the R&D budget experienced a limited rebound in 2008 but has been on a declining trend since 2004 in nominal terms. South Korea continued substantially increasing its R&D budget in 2008–2009 (+13.7%), although when

[20] Data is not available for Greece; break in series in Spain and Poland in 2009 prevents a direct comparison of 2009 with 2008 for these two countries.
[21] See preceding footnote.
[22] The appreciation of the euro compared to the British pound caused an important decrease of the United Kingdom's nominal R&D budgets in 2008 and 2009 in euro (-12.4% and -3.6% respectively), despite the increase in pounds. This has however an important impact on the EU-27 total which is expressed in euro and decreased in 2009. The same consideration holds for Sweden where the increase of R&D budgets in nominal terms vanishes almost entirely when expressed in euro.
[23] Not available in 7 Member states.
[24] Not available in 10 Member States.
[25] See also Science, Technology and Competitiveness report 2008/2009, page 7.

converted into euros this corresponds to a 9% decrease (from 6.4 in 2007 to EUR 5.8 billion in 2008, not shown in the table).

Relative to GDP, the R&D budget in the EU and Japan followed exactly the same path in 2008–2009 and could increase from 0.71% to about 0.75% of GDP thanks to the GDP fall. The US R&D budget slightly decreased relative to GDP in 2008, but is likely to have increased in 2009, as in the EU and Japan, due to the GDP fall. The 20% increase in the R&D budget to GDP ratio over 2007–2009 in South Korea outperforms all countries.

Table I.2.2 Government budget appropriations or outlays for R&D (GBAORD) - growth and as % of GDP, 2007-2010 (1)

	GBAORD (nominal) - % change			GBAORD as % of GDP			
	2007-2008	2008-2009	2009-2010	2007	2008	2009	2010
Belgium	15.8	*-2.3*	:	0.60	0.68	*0.68*	:
Bulgaria	36.5	8.4	:	0.26	0.31	0.34	:
Czech Republic	0.1	*21.2*	*0.0*	0.58	0.56	*0.68*	*0.67*
Denmark	10.6	10.4	*5.1*	0.79	0.85	0.99	*1.01*
Germany	5.3	5.8	*8.3*	0.77	0.79	0.87	*0.93*
Estonia	*34.3*	*-7.4*	:	*0.49*	*0.65*	*0.70*	:
Ireland	1.3	*-1.8*	:	0.49	0.53	*0.58*	:
Greece	:	:	:	*0.30*	:	:	:
Spain	-4.0	:	:	1.07	1.00	0.74	:
France	1.7	4.0	*1.9*	0.74	0.74	0.78	0.78
Italy	0.0	-1.6	-6.1	0.64	0.63	0.64	0.59
Cyprus	7.6	12.1	:	0.42	0.42	0.48	:
Latvia	7.5	-43.2	:	0.30	0.29	0.20	:
Lithuania	-11.3	-17.7	:	0.33	0.26	0.26	:
Luxembourg	31.3	8.6	*25.0*	0.37	0.46	0.52	*0.61*
Hungary	*16.1*	5.6	:	*0.39*	0.43	0.46	:
Malta	4.4	*4.4*	:	0.20	0.20	*0.21*	:
Netherlands	5.1	*9.2*	*-0.2*	0.69	0.70	*0.79*	*0.77*
Austria (2)	12.2	*10.9*	*9.5*	0.65	0.70	*0.80*	*0.86*
Poland	4.1	:	:	0.32	0.30	0.34	:
Portugal	16.6	*4.6*	*13.8*	0.75	0.86	*0.92*	*1.03*
Romania	33.0	-25.4	*-4.4*	0.37	0.40	0.31	*0.28*
Slovenia	5.2	46.0	:	0.52	0.51	0.78	:
Slovakia	54.0	6.5	*4.2*	0.21	0.28	0.30	*0.30*
Finland	4.3	*6.3*	*6.6*	0.97	0.98	*1.13*	*1.17*
Sweden	3.6	*10.5*	:	0.79	0.80	*0.91*	:
United Kingdom	2.0	*7.8*	:	0.65	0.65	*0.73*	:
EU	*1.0*	*-1.2*	:	*0.71*	*0.71*	*0.74*	:
Iceland	20.9	21.0	:	0.82	0.88	1.05	:
Norway	6.5	9.1	*5.0*	0.76	0.74	0.85	*0.85*
Switzerland	:	:	:	:	0.76	:	:
Croatia	:	*1.5*	:	:	0.66	*0.69*	:
Russian Federation	15.9	37.5	:	0.40	0.37	0.51	:
United States (2) (3)	1.8	:	:	1.01	1.00	1.17	:
Japan (2)	1.7	-0.2	0.7	0.68	0.71	0.75	0.75
South Korea	*14.8*	*13.7*	*12.5*	0.83	*0.91*	*1.02*	*1.09*
Israel (4)	8.6	*9.8*	:	0.60	0.62	*0.64*	:

Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat, OECD
Notes: (1) ES, PL, US: There is a break in series between 2009 and the previous years - nominal growth between 2008 and 2009 cannot be calculated.
(2) AT, US, JP: GBAORD refers to federal or central government only.
(3) US: GBAORD excludes data for the R&D content of general payment to the Higher Education sector for combined education and research.
(4) IL: GBAORD does not include defence.
(5) Values in italics are estimated or provisional.

In terms of execution, nominal R&D expenditure continued to increase in the public sector in 2009 on average in the EU, but EU-12 Member States had more difficulty in avoiding important cuts in public R&D, which may widen the gap between high and low R&D intensity countries in Europe

In most European countries R&D expenditure in the public sector resisted better than in the business sector (see below). In the majority of Member States (20), it increased in nominal terms in 2009 with respect to 2008. On average in the EU, the 2009 increase amounts to 1.8%. As a % of GDP, R&D expenditure in the public sector decreased only in Latvia, Romania and Poland and progressed in all other Member States.

Since governments are the main funders of public R&D expenditure, these observations show that a majority of European countries did not cut R&D spending and maintained R&D activities among their priorities, as observed with R&D budget data above. Member States which already had higher public R&D intensities were more often able to maintain it. The four Member States with the sharpest decrease in nominal public R&D expenditure are all EU-12 Member States. Despite support from the Structural Funds, this shows that the result of the economic crisis could be a further widening of the gap between Member States with high R&D intensities and some Member States with lower R&D intensities.

Table I.2.3 Public expenditure on R&D (GOVERD plus HERD) and Public sector R&D Intensity change between 2008 and 2009

	Public expenditure on R&D (nominal) % change	Public sector R&D Intensity change in percentage points
Turkey	26.2	0.10
Luxembourg	*22.9*	*0.10*
Poland	21.8	0.07
Russian Federation	14.4	0.06
Bulgaria	*13.0*	*0.05*
Portugal	*10.5*	*0.08*
Denmark	*10.3*	*0.14*
Finland	9.7	0.17
Sweden	*7.8*	*0.11*
Czech Republic	7.1	0.05
Norway	*7.0*	*0.10*
Slovenia	6.4	0.07
Spain	5.8	0.06
Germany	*5.3*	*0.07*
France	*5.1*	*0.06*
Netherlands	*4.9*	*0.08*
Malta	*4.6*	*0.01*
Slovakia	2.6	0.01
Italy	*2.5*	*0.03*
Israel (2)	*2.3*	*-0.03*
Ireland	*2.3*	*0.08*
Cyprus	*1.9*	*0.01*
EU	*1.8*	*0.05*
United Kingdom	*1.7*	*0.04*
Hungary	1.3	0.02
Austria	*-0.2*	*0.02*
Belgium	*-0.7*	*0.01*
Croatia	-2.8	0.00
Estonia	-7.8	0.05
Lithuania	-14.0	0.03
Romania	-32.4	-0.12
Latvia	-48.9	-0.17

Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat, OECD
Notes: (1) EL: Data are not available for 2008 and 2009.
(2) IL: GOVERD does not include defence.
(3) Values in italics are estimated or provisional.

Please note that Table I.2.3 is slightly changed due to change of value for Poland. I will send you this revised table as the one you have may have a different value for Poland

2.4. Has the economic crisis led to cuts in business R&D investment?

On average in the EU, the 2009 decrease in nominal R&D expenditure was more marked in the business sector than overall, but catching-up Member States have probably benefited from strategic R&D persistency in large companies

In most countries, the evolution of R&D expenditure in the business sector (BERD) in nominal terms in 2009 was worse than that of total R&D expenditure: (i) nominal BERD decreased in three more Member States (15) than nominal GERD (12), (ii) when BERD decreased it did so more sharply than GERD (except in Latvia, Romania, Estonia) and (iii) when it increased it did so less strongly than GERD (except in Hungary and Ireland). In some countries however, nominal BERD and GERD behaved the same way (Austria, Slovenia, United Kingdom and Lithuania). On average in the EU, the 2009 decrease in nominal R&D expenditure was more marked in the business sector than overall (-3.1% vs -1.3% respectively). As % of GDP, business R&D expenditure progressed slightly (+0.03 percentage point, up to 1.25% of GDP) due to a larger drop in GDP.

Interestingly, business R&D expenditure has increased in a number of catching-up countries, like Hungary, Bulgaria, Slovenia, Turkey, Romania, Cyprus and Poland. This indicates that large foreign R&D investors — which are responsible for most of business R&D in these countries — have increased their R&D investment in these countries. As shown below, in total, R&D investment by large R&D investing companies in the world has indeed proved relatively resilient to the crisis in 2009. Catching-up countries would therefore have benefited from this strategic R&D persistency in large companies.

In contrast, business R&D expenditure decreased sharply in some of the frontrunners in Europe, namely Sweden, Finland and Denmark. Business R&D expenditure in Sweden and Finland have probably been dragged downwards by the large Swedish and Finnish companies whose R&D investment decreased in 2009 by -6.6% and -6% respectively[26] — much more than for large companies in other countries. In the case of Denmark, large Danish companies have slightly increased their R&D investment, so that smaller R&D investing companies, in particular SMEs, are probably responsible for the downward trend (see Figure I.2.3 below).

[26] *2010 EU Industrial R&D Investment Scoreboard*.

Table I.2.4 BERD and BERD Intensity - change between 2008 and 2009

	BERD (nominal) % change	BERD Intensity change in percentage points
Hungary	22.3	0.13
Russian Federation	11.7	0.09
Ireland	*10.8*	*0.23*
Poland	8.4	0.01
Bulgaria	*7.0*	*0.01*
Slovenia	6.6	0.13
Turkey	6.1	0.02
Romania	6.1	0.02
Cyprus	*2.8*	*0.00*
United Kingdom	*1.7*	*0.06*
Norway	*1.4*	*0.06*
France	*1.1*	*0.04*
Portugal	*0.6*	*0.02*
Germany	*0.1*	*0.07*
Austria	*-0.1*	*0.06*
Czech Republic	-0.8	0.01
Estonia	*-1.9*	*0.08*
Belgium	*-2.0*	*0.00*
Luxembourg	*-2.3*	*0.02*
Italy	*-2.4*	*0.00*
EU	*-3.1*	*0.03*
Netherlands	*-4.1*	*0.00*
Israel (2)	*-4.3*	*-0.36*
Denmark	*-4.3*	*0.01*
Slovakia	-4.9	-0.01
Finland	-5.0	0.07
Spain	-6.3	-0.02
Malta	*-8.2*	-0.03
Sweden	*-10.0*	*-0.19*
Latvia	-12.4	0.01
Lithuania	-14.1	0.01
Croatia	-17.1	-0.06

Source: DG Research and Innovation Innovation Union Competitiveness Report 2011
Data: Eurostat, OECD
Notes: (1) EL: Data are not available for 2008 and 2009.
(2) IL: BERD does not include defence.
(3) Values in italics are estimated or provisional.

Please note that Table I.2.4 is slightly changed due to change of value for Poland. I will send you this revised table as the one you have may have a different value for Poland

Worldwide, despite large decreases in sales and profits, the overall decrease in large companies' R&D investment remained relatively limited in 2009

The *EU Industrial R&D Investment Scoreboard* (referred to as the Scoreboard in this section) presents information on the world's top 1 400 companies (1 000 non-EU and 400 EU) ranked by their investment in R&D. The 2010 edition is based on data from companies' published accounts intended to be their fiscal year 2009 accounts[27]. Therefore, the effect of the economic and financial crisis that began in 2008 is reflected in these data.

According to the Scoreboard, this crisis has had a stronger impact on companies' R&D investment than the 2002/2003 one. However, globally, overall companies' R&D investment turned out to be relatively resilient to the recession, with a decrease of only -1.9% in nominal terms[28], compared to -10.1% for sales and -21.0% for profits. This shows the strategic importance that large R&D investing companies attach to R&D, which they regard as a top priority. A number of companies have continued to increase R&D investment in order to strengthen their competitiveness in preparation for the recovery.

In most Member States, SMEs' R&D investment has been more affected than that of larger companies'

The Scoreboard covers the largest R&D investors in the world. The situation is likely to be different for smaller companies investing in R&D. Liquidity pressure, difficulties in finding financing, credit constraint, falls in sales and available cash-flows, and difficulties in facing shorter-term payments have affected SMEs' R&D activities very strongly.

There are as yet no official statistics on R&D investment by SMEs. However, a first insight can be obtained by comparing the 2009 evolution of BERD to the 2009 evolution of R&D investment by large companies from the Scoreboard. Due to a number of differences in the two data collections' methodologies[29], BERD data and Scoreboard data are not directly comparable. In particular, R&D investment by EU companies of the Scoreboard is not necessarily located in the EU, while BERD data record R&D expenditure executed in a country whatever the nationality of the company. However, this comparison still provides a general indication on the behaviour of smaller firms in a country, since a good part of the difference between BERD data and Scoreboard data is accounted for by them[30].

In a number of Member States (Czech Republic, Portugal, Spain, Austria, Denmark and Malta), the BERD/Scoreboard comparison in Figure I.2.3 below indicates that smaller companies have considerably reduced their R&D investment — despite the increase in total nominal R&D investment by the top R&D investing companies of these countries, BERD has still decreased in nominal terms. The reduction of R&D investment by smaller firms has therefore more than compensated the increase in R&D investment made by larger firms[31]. This phenomenon is particularly marked in the Czech Republic, Portugal, Spain and Austria. In Ireland, BERD increased as well, but less than R&D investment by large Irish firms, suggesting also that smaller firms had more difficulty than large firms in maintaining their R&D investment in this country. In Sweden, the Netherlands — and in EU-27 on average — BERD declined more than Scoreboard's companies, which indicates that R&D investment by smaller companies in these countries declined more than that of large firms.

[27] However, due to different accounting practices, it includes accounts ending from a range of date from late 2008 to early 2010.

[28] All growth rates are nominal in the EU Industrial R&D Investment Scoreboard.

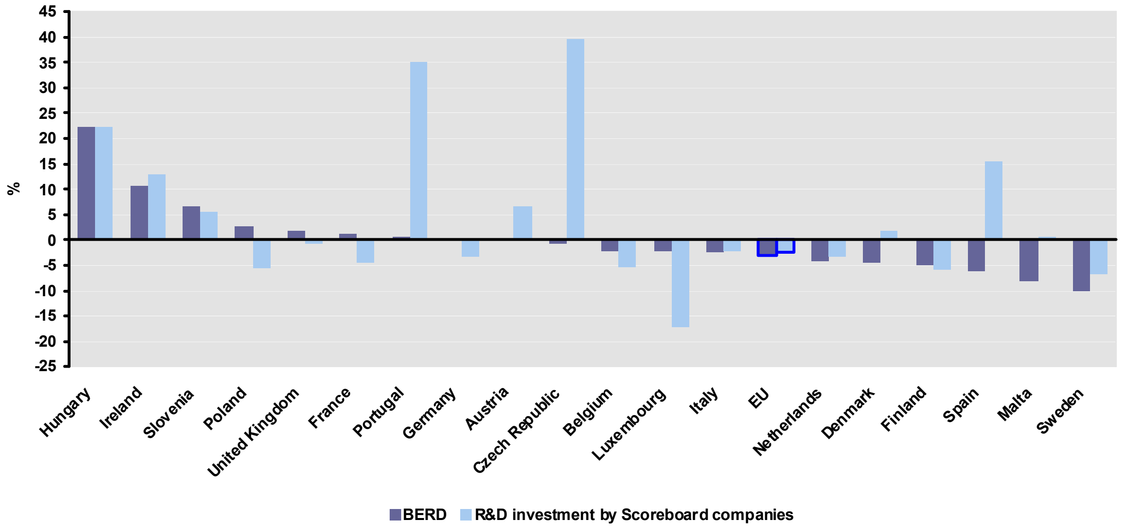
[29] For an overview of the differences, see *Science, Technology and Competitiveness key figures Report 2008/2009*, p 39.

[30] Smaller firms not included in the *Scoreboard*, in particular most SMEs, have their R&D expenditure recorded in BERD.

[31] As noted above, (part of) this increase in R&D investment by the country's large companies shown by the *Scoreboard* may have taken place in other countries, so that one cannot exclude the chance that large companies too have reduced their R&D investment in their own country.

In a number of countries however, (Slovenia, Poland, United-Kingdom, France, Germany, Belgium and Finland), the opposite phenomenon is observed: BERD resisted better than R&D investment by large Scoreboard companies. In some others (Hungary and Italy), both behaved the same way. This tends to indicate that smaller firms' R&D investment has been relatively resilient in these countries.

Figure I.2.3 BERD and R&D investment by *Scoreboard* companies - percentage change between 2008 and 2009 [(1)]



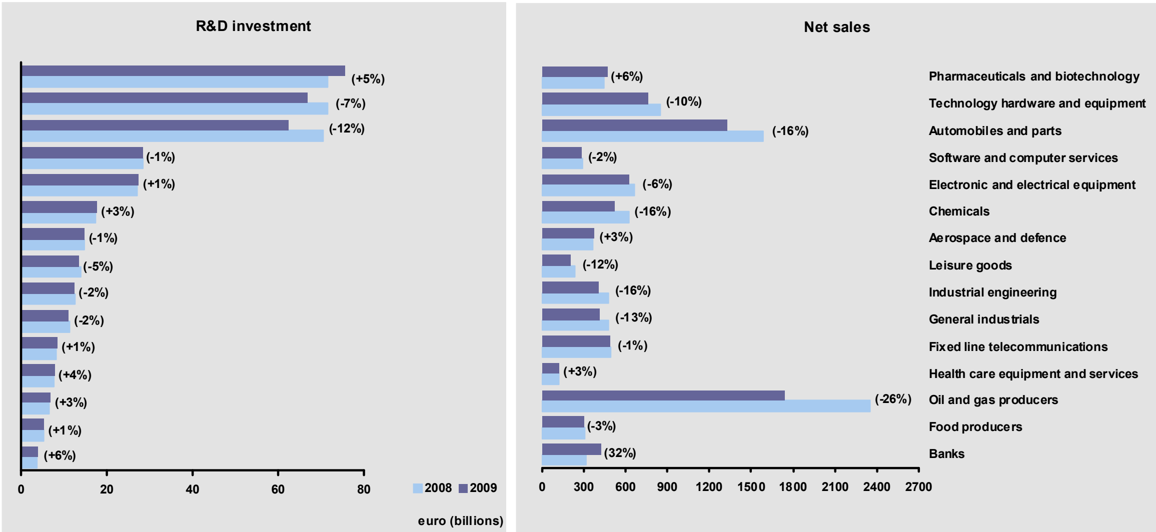
Source: DG Research and Innovation, JRC-IPTS — Innovation Union Competitiveness Report 2011
Data: Eurostat, The 2010 EU Industrial R&D Investment Scoreboard
Note: (1) Only Member States with companies in the 2009 and 2010 *Scoreboards* and with BERD available for 2008 and 2009 are included.

The effects of the economic crisis were felt differently across industrial sectors

The impact of the crisis was very different across industrial sectors. R&D investment decreased substantially in the Automobiles and IT hardware sectors (-11.6% and -6.4% respectively), while it rose further in the Pharmaceutical sector (+5.3%). The latter thereby consolidates its position as top R&D investor. This is also one of the few sectors that managed to increase sales during the crisis (+6.4%). Moreover, large pharmaceutical companies are reinforcing their position by increasing their R&D capacity through mergers and acquisitions, often involving biotech firms. The growth in R&D investment in the Alternative Energy sector continued in the *Scoreboard* (+28.7%), in particular with 9 more companies entering the Scoreboard list of the world's top 1 400 R&D investors than in the previous edition[32]. Thirteen out of the fifteen companies included in the Scoreboard in this sector are based in the EU.

[32] It should be noted that important R&D investment in alternative energy is also made by companies classified in other sectors in the *Scoreboard*, like Oil & Gas, General Industrials and Industrial Machinery.

Figure I.2.4 R&D investment and net sales of the top 10 sectors for *Scoreboard* companies, 2008 and 2009; in brackets the percentage change between 2008 and 2009



Source: DG Research and Innovation, JRC-IPTS
Data: The 2010 EU Industrial R&D Investment Scoreboard

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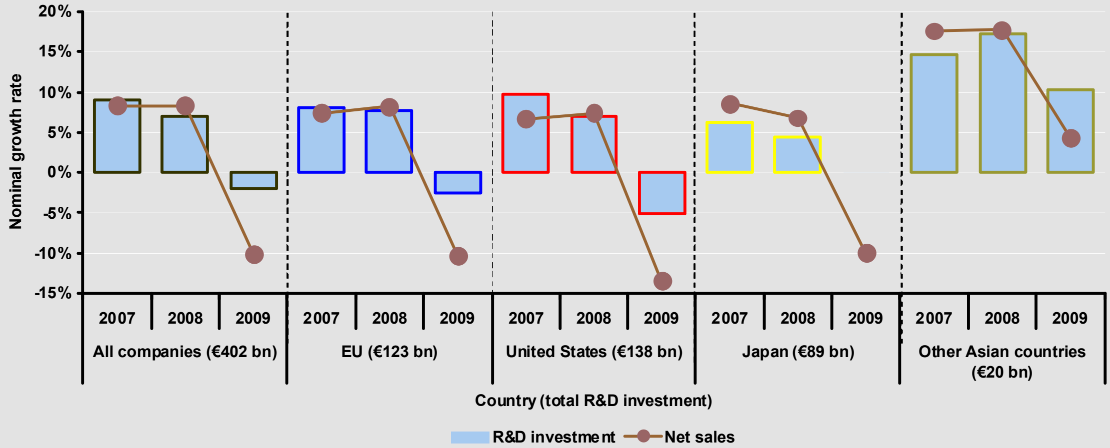
The decrease in R&D investment was sharper in US companies than in EU companies, but Asian companies continued their high R&D growth

EU companies have reduced their R&D investment less than their US counterparts (-2.6 % versus -5.1 %, respectively), despite similar drops in sales (around -10 %). More remarkable is the performance of the Japanese companies, which held the level of R&D investment of the previous year despite strong drops in sales (around -10 %) and dramatic drops in profits (-88.2 %).

Companies based in China, India and South Korea continued to rapidly increase their investment in R&D on the Scoreboard: +40.0 %, +27.3 % and +9.1 % respectively. This high R&D growth is partly due to new firms based in these countries entering the Scoreboard list of top 1 400 R&D investors worldwide, to the detriment of US and EU firms dropping out of the Scoreboard.

However, the world's R&D landscape has maintained its characteristic sector composition with US companies dominating in high R&D-intensive sectors and the EU companies in medium-high ones.

Figure I.2.5 Growth rates of R&D investment and net sales for *Scoreboard* companies



Source: DG Research and Innovation, JRC-IPTS
Data: The EU Industrial R&D Investment Scoreboards (2008, 2009, 2010), DG Research and Innovation, JRC

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The evolution of business investment in R&D after 2009 remains uncertain

Business R&D investment has proved to be relatively resilient to the recession in 2009. However, the situation might still worsen in 2010. As observed in section 2.1, fluctuations in business-financed R&D growth are usually larger than fluctuations in GDP growth and have a time lag of one to two years. The limited decrease in business R&D investment observed in 2009 might therefore be only the beginning of a negative trend.

Moreover, a recently conducted 'Business R&D Investment Trends'[33] survey on the 1 000 most R&D intensive companies in the EU[34], showed that (1) business R&D is expected to grow by 2% per year over the 2010–12 period (i.e. half the expectations of the previous survey), (2) almost half of the surveyed companies expected a contraction of their research agenda, (3) 25% of their R&D was carried out outside the EU and (4) business R&D investment is expected to grow faster outside the EU, particularly in the United States, China and India.

[33] The 2009 EU Survey on *R&D Investment Business Trends* is part of the Industrial Research Investment Monitoring Activity (IRMA) of DG Research and Innovation and the Joint Research Centre.
[34] The surveyed companies account for almost EUR 48 billion, i.e; over one third of total R&D investment.

3. Public investment in research and education

Highlights

Public funding of R&D and education is under the direct control of governments. Consequently, policymakers are directly accountable for its evolution. Evidence shows that the share of the R&D budget (GBAORD) in total government expenditure has progressed in 20 Member States between 2000 and 2008[35]. However, at 1.5 % on average in the EU in 2008, the share of R&D budget in total government expenditure has not progressed since 2000.

The share of domestic R&D expenditure financed by the public sector is larger in less research-intensive countries. In the most research-intensive countries, the business sector is the predominant source of funds (around 75 % of R&D funds). Altogether in the EU, the public sector finances slightly more than one third of R&D expenditure and the private sector slightly less than two thirds.

Progress of government-financed R&D expenditure as % of GDP is observed in countries with low levels of government-financed R&D intensity, while decline and stagnation in those with higher levels prevail. In EU-27, on average, government-financed R&D expenditure has stagnated at around 0.65 % of GDP since 2000.

In many Member States, a substantial part of government support to business R&D is now indirect through R&D tax incentives which represent up to 0.13 % of GDP in Belgium. A more complete view of total government R&D support is therefore given by adding this indirect support to government-financed R&D expenditure and to the GBAORD. A full quantification of public R&D support should also include the funding from the EU budget.

An increase of investment in research and innovation is mainly visible in the EU budget. In nominal terms, the annual EU funding of RTDI has been multiplied by 18 over the last 25 years. More than 11 % of the total EU budget was devoted to RTDI in 2009, compared to less than 3 % in 1985. In 2009, EU RTDI funding represented about 16 % of the sum of Member States' civil R&D budgets (civil GBAORDs), compared to 3 % in 1985.

In the EU, public funding in education is eight times higher than public funding in R&D. The Member States with the highest R&D intensity are in general also those with the highest education expenditure to GDP ratio. Governments of the Nordic countries invest most in both education and research.

[35] GBAORD data is available for 2009 and, for some countries, 2010 (see Chapter 2 of this Part); however, GBAORD as % of total government expenditure is available up to 2008 only.

3. Public investment in research and education

3.1. How much are governments investing in R&D at national and at European level?

In the Europe 2020 Strategy, the EU has maintained its objective of devoting 3% of its GDP to R&D without specifying the relative efforts of the public and private sectors to reach this objective.

The 2002 Barcelona Objectives targeted an increase in both the overall expenditure on R&D (to approach 3% of EU GDP allocated to R&D by 2010) and the share of R&D expenditure funded by the public and private sectors. According to the Barcelona Objectives, one third of total R&D expenditure should be funded by the public sector and two thirds by the private sector. Public funding of R&D is under the direct control of policymakers, so that they are directly accountable for its evolution.

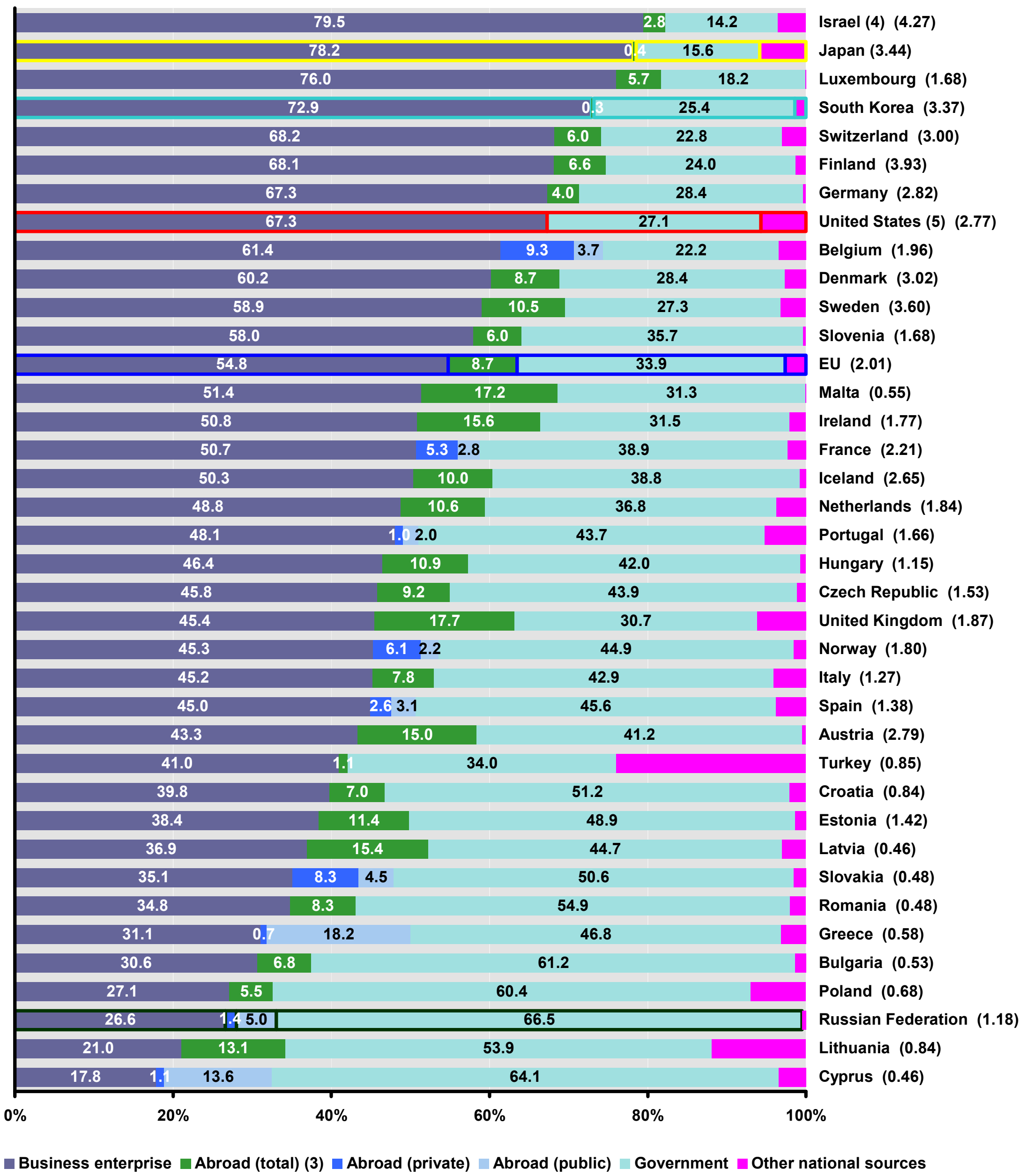
Altogether, the public sector finances slightly more than one third of R&D expenditure in the EU and the private sector slightly less than two thirds

In 2008, the government sector financed 33.9% of total R&D expenditure in EU-27, while (domestic) business enterprise financed 54.8% of it (Figure I.3.1). The third important source of funds (almost 9%) is 'abroad' (both private and public sources), which includes cross-border intra-EU funding, as well as funding from the European Commission (through the Framework Programme and Structural Funds for R&D). For the countries that provide an up-to-date breakdown public/private of this 'abroad' source of funds, this breakdown is shown on Figure I.3.1, and is to be added respectively to the government and (domestic) business sources of funds. Government financed R&D as described in this chapter does not include state aid for research, development and innovation, which is described in chapter 2 of part IIII of the report.

Altogether, the public sector therefore finances slightly more than one third of R&D expenditure in the EU and the private sector slightly less than two thirds. The government sector accounts for a large share of R&D funding in most of the EU-12 Member States[36] and in the Southern European countries. More than 50% of R&D expenditure in Cyprus, Lithuania, Romania, Poland, Bulgaria and Slovakia is funded by the government sector. Conversely, high R&D-intensive Member States such as Germany, Finland, Sweden and Denmark are characterised by a high involvement of the private sector in the financing of domestic R&D activities.

[36] The EU-12 Member States are the 12 countries which joined the European Union in 2004 and 2007.

Figure I.3.1 R&D expenditure by main sources of funds, 2009 [(1)]; in brackets R&D Intensity, 2009 [(2)]



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011

Data: Eurostat, OECD

Notes: (1) EL: 2005; BE, LU, NL, NO, IL: 2007; EU, BG, DE, ES, FR, IT, CY, PT, IS, CH, US, JP, CN, KR: 2008; AT: 2010.

(2) EL: 2007; IS, CH, US, JP, CN, KR: 2008; AT, FI: 2010.

(3) Abroad has been broken down by public and private sector for those countries for which this breakdown is available and up-to-date.

(4) IL: Defence is not included.

(5) US : Most or all capital expenditure is not included; Abroad is included in business enterprise.

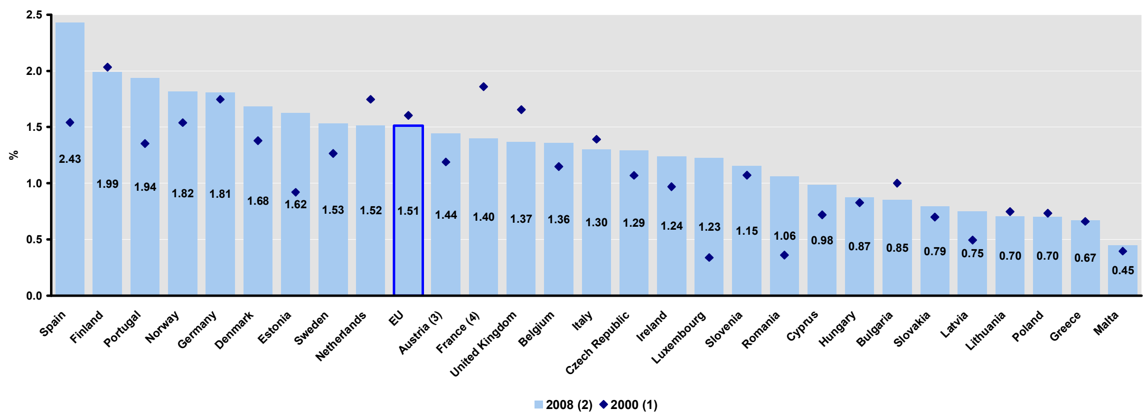
Please note that Figure I.3.1. is slightly changed due to change of value for Poland. I will send you this revised figure as the one you have may have a different value for Poland

The share of R&D budget in total government expenditure has progressed in 20 Member States between 2000 and 2008[37]

Between 2000 and 2008, the countries that have considerably increased (by more than 50 %) the share of R&D budget in total government expenditure are Luxembourg, Romania, Estonia, Spain, Latvia and Portugal, all countries with a relatively low intensity (as % of GDP) of public funding for R&D in 2000. Substantial increases also occurred in Cyprus, Ireland, Denmark, Sweden, Austria, Czech Republic and Belgium.

On average in the EU, the R&D budget (GBAORD) represented a slightly smaller share in total government expenditure in 2008 (1.5 %) than in 2000 (1.6 %). This is to a large extent due to the sharp decrease observed in France, the United Kingdom and the Netherlands which is counterbalancing the progress observed in the above-mentioned countries. However, the break in series in 2006 in France prevents any comparison of this indicator between 2008 and 2000. In addition, in these countries, government support to R&D is increasingly provided through R&D tax incentives (see Figure I.3.4 below) which are not included in GBAORD.

Figure I.3.2 GBAORD as % of general government expenditure 2000 (1) and 2008 (2)



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat
Notes: (1) DK, UK: 2001; EU, CZ, SK: 2002; CY, MT, PL: 2004; HU: 2005.
(2) EL: 2007; DK, LU: 2009.
(3) AT : GBAORD refers to federal or central government expenditure only.
(4) FR: There is a break in series between 2006 and the previous years.

Progress of government funding is observed in countries with low levels of government-financed R&D intensity, while decline and stagnation prevail in those with higher levels

Between 2000 and 2009[38], R&D expenditures financed by government as % of GDP increased in 20 Member States (Figure I.3.3). It grew by more than 100 % in Luxembourg and Ireland, by 50 % to 80 % in Estonia, Romania, Spain, Cyprus and Austria, and by 7 % to 30 % in Denmark, Czech Republic, Lithuania, Hungary, Slovenia, Malta, Latvia, Finland and Sweden. In total over this period, 15 Member States have managed to increase by more than 10 % their government-financed R&D intensity which shows their commitment towards

[37] GBAORD data is available for 2009 and, for some countries, 2010 (see Chapter 2 of this Part); however, GBAORD as % of total government expenditure is available up to 2008 only.

[38] For data availability reasons, the actual period covered differs across countries, see footnote to Figure I.3.3.

higher levels of research intensity. In contrast, decreases of R&D expenditure financed by government are observed in Belgium, Italy, Bulgaria, Poland and Slovakia.

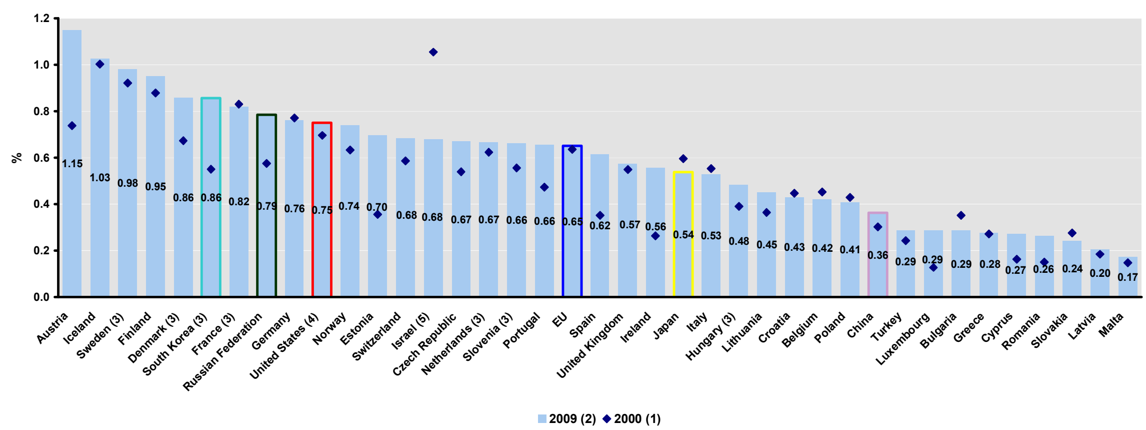
With the exception of Austria and Denmark, R&D expenditure financed by government in proportion of GDP tended to decrease or remain stable in the Member States where it was above 0.6 % of GDP in 2000. In contrast, it tended to increase in those Member States where it was low or very low (below 0.4 % of GDP), except in Bulgaria, Poland and Slovakia. Although the dispersion of government-financed R&D intensities across Member States remains large, it has therefore been reduced since 2000.

At EU aggregate level, R&D expenditures financed by government have remained stable around 0.65 % of GDP since 2000. Additional public sources from abroad (European Commission, International Organisations, other governments, see Box I.3.2) can be estimated at around 0.05 % of GDP[39] in Member States, which brings R&D expenditures financed by public sources up to 0.7 % of GDP at EU-27 aggregate level. Austria is the only Member State to have reached (and even gone beyond) the 1 % target for public sources. The other Member States whose public financing of R&D are very close to this level are Sweden and Finland.

In order to account for all public R&D support, one needs to add the indirect public support (through R&D tax incentives) to government and public sources from abroad.

A particular focus on the evolution of publicly financed R&D expenditure in 2009 during the economic crisis is to be found in Chapter 2 of this Part.

Figure I.3.3 GERD financed by government as % of GDP, 2000 (1) and 2009 (2)



Source: DG Research and Innovation
Data: Eurostat, OECD
Notes: (1) DK, EL, SE, IS, NO: 2001; HR: 2002; IT, MT: 2005.
(2) EL: 2005; BE, LU, NL, NO, IL: 2007; EU, BG, DE, ES, FR, IT, CY, PT, IS, CH, US, JP, CN, KR : 2008, AT: 2010.
(3) DK, FR, HU, NL, SI; SE, KR: Breaks in series occur between 2000 and 2009.
(4) US: GERD does not include most or all capital expenditure.
(5) IL: GERD does not include defence.

Innovation Union Competitiveness Report 2011

Please note that Figure I.3.3 is slightly changed due to change of value for Poland. I will send you this revised figure as the one you have may have a different value for Poland

Indicators on government-financed R&D do not include indirect public support of business R&D through R&D tax incentives

[39] The breakdown between the different sources of funds from 'abroad' is not provided by all Member States, therefore a precise EU-27 aggregate of these sources cannot be calculated. The estimate of 0.05 % of GDP for public sources from abroad is based on 2007 data from 20 Member States (see Box I.3.2).

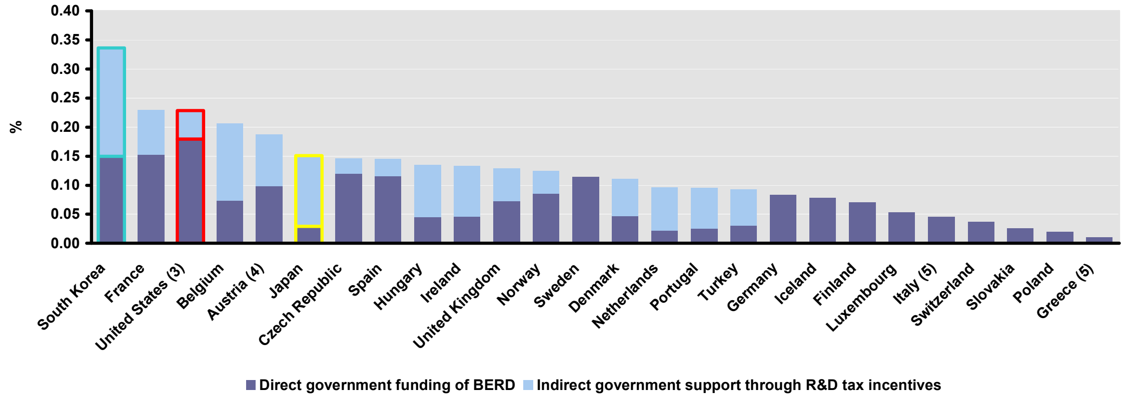
Government-financed R&D includes only direct funding of R&D through grants, loans and procurements that governments give to private firms. Indirect government funding through R&D tax incentives (R&D tax credits, R&D allowances, reduction in R&D workers' wage taxes and social security and accelerated depreciation of R&D capital) is not recorded in government-financed R&D.

The omission of the tax expenditures from the measurement of government-financed R&D leads to incomplete indicators on public R&D support. To get a more exhaustive view of government R&D support, it is necessary to estimate the cost of R&D tax-incentive schemes in countries that have put them in place.

In many Member States, a substantial part of public support of R&D is indirect through R&D tax incentives

Figure I.3.4 shows the government's foregone revenue due to R&D tax incentives as a % of GDP along with the direct government funding of business R&D[40]. In certain countries, most of the government support of business R&D is done through R&D tax incentives. In the EU, this is the case of Belgium, Denmark, Hungary, Ireland, the Netherlands and Portugal. Other EU Member States (France, Austria, the United Kingdom, Czech Republic and Spain) provide a substantial share of their public support to business R&D through R&D tax incentives, while others have no R&D tax incentives at all.

Figure I.3.4 Direct and indirect government funding of business R&D and tax incentives for R&D (1) as % of GDP, 2008 (2)



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011

Data: OECD (based on national estimates from the Working Party of National Experts in Science and Technology (NESTI) R&D tax incentives questionnaire, January 2010 and OECD, Main Science and Technology Indicators database).

Notes: (1) The R&D tax expenditures estimates do not cover sub-national R&D tax incentives.
(2) EL: 2005; IE, ES, LU, NL, AT, PL, SE, JP: 2007; EL: 2005.
(3) US: The R&D tax expenditure estimate covers the research tax credit but excludes the expensing of R&D.
(4) AT: The R&D tax expenditure estimate covers the refundable research premium but excludes other R&D allowances.
(5) IT (volume tax credit of 10%) and EL (tax credit of 50% for incremental R&D) provided R&D tax incentives but the cost of those incentives was not available.

40 Data are available for OECD countries only.

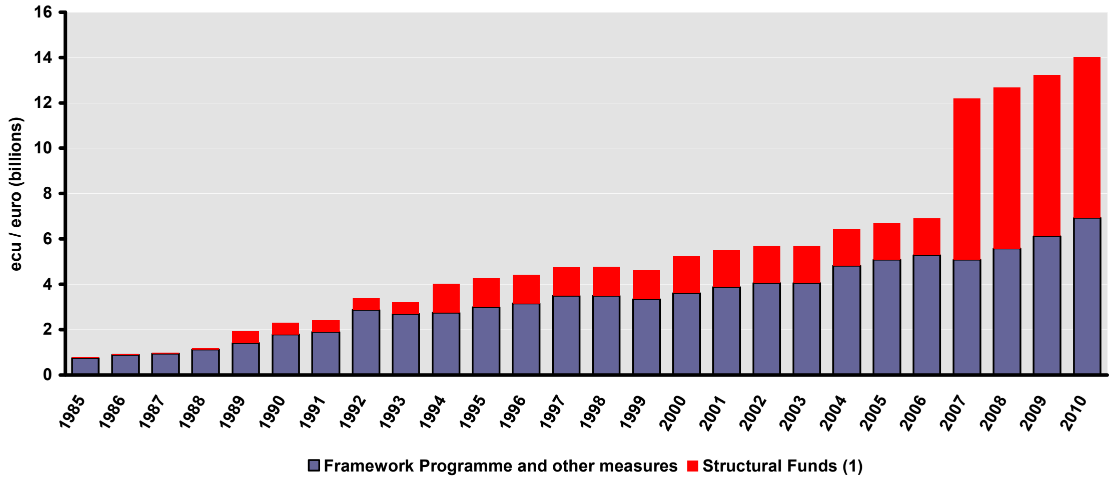
Box I.3.1 — R&D tax incentives in Belgium

More than half of public support to business R&D in Belgium is done through R&D tax incentives. As in most countries, Belgium's fiscal incentives are tax credits or allowances and capital expensing. In Belgium, they cover R&D expenditures but also include a deduction for patent income. Additional fiscal incentives are provided through reductions in R&D workers' wage taxes and social security contributions.[41]

A major increase in public funding to R&D has taken place in the EU budget

In nominal terms, the annual EU funding of R&D[42] has been multiplied by 18 over the last 25 years (Figure I.3.5), thanks to a considerable increase in FP funding (annual funding multiplied by more than 9) and to a dramatic increase of Structural Funds for R&D after 2007. Structural Funds now represent slightly more than half of EU funding to R&D and innovation.

Figure I.3.5 Evolution of European Commission funding of RTDI, 1985-2010



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat, DG REGIO
Note: (1) Estimated average annual funding.

EU R&D funding now represents about 16% of the sum of Member States' civil R&D budgets

This considerable increase of EU funding for R&D in absolute terms is also remarkable relative to the total civil R&D budget of Member States (total EU civil GBAORD, Figure I.3.6): in 2009, EU R&D funding (Framework Programme and Structural funds) represented 16% of the sum of Member States' civil R&D budgets, compared to 3% in 1985[43]. About 11% of the total EU budget[44] was devoted to R&D in 2009, compared to less than 3% in 1985.

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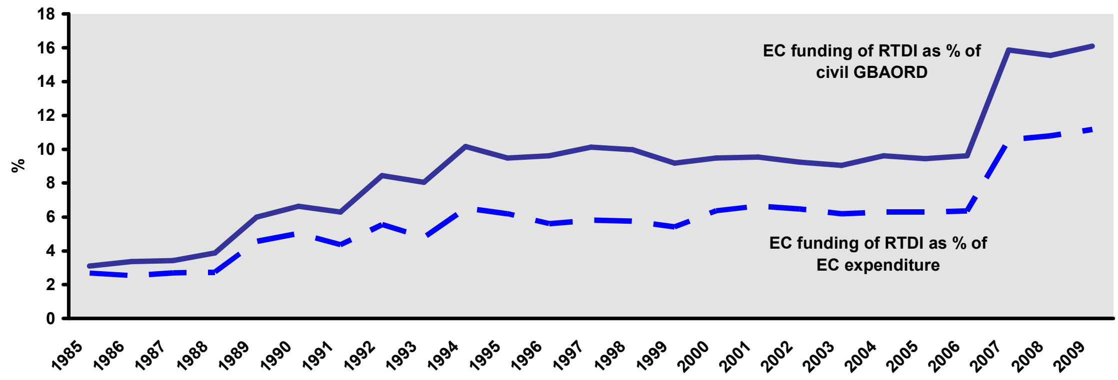
[41] *Measuring Innovation*, OECD, 2010; see also Part II, chapter 1.
[42] Structural Funds for R&D include innovation activities: Research, Technology Development and Innovation (RTDI).
[43] The sum of Member States' civil R&D budgets for a given year is calculated from the Member States composing the EU that year.
[44] European Commission's budget.

The increase in the share of EU R&D funding in total EU funding and in Member States' civil R&D budgets was steadily sustained during the period 1988–1994 with FP2, FP3 and the beginning of Structural Funds. The year 2007 marked another important and more radical step forward with the beginning of FP7 and the new Structural Funds period[45].

Figure I.3.6 Evolution of European Commission fundng of RTDI [(1)] as % of total European Commission expenditure and as % of total EU [(2)] civil GBAORD, 1985-2009



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat, DG REGIO, DG Budget
Notes: (1) European Commission funding of RTDI was estimated by DG Research.
(2) 1985: EU-10; 1986-1994: EU-12; 1995-2003: EU-15; 2004-2006: EU-25; 2007-2009: EU-27.

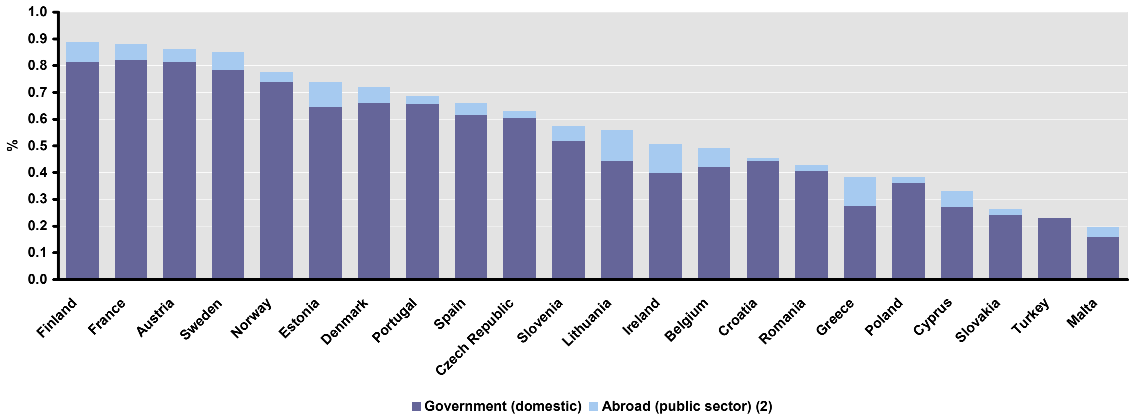
Box I.3.2 — Public sources of funds for GERD: adding public funding from abroad to government funding

When monitoring progress towards the EU 1% Barcelona Objective for public sources of funds for R&D, government funding is used as a proxy for all public funding of R&D in a Member State. However, government is not the sole public source of funds for R&D. There are public sources from abroad: the European Commission, other governments and international organisations. The European Commission in particular is a significant additional public source of funds for R&D in Member States, through the Research Framework Programme and Structural Funds used for R&D activities. Adding the public funding from abroad to government funding gives a better account of the intensity of public funding for R&D in a Member State (Figure I.3.7). However, this data is not available in all Member States. Besides, the latest year available for the further breakdown of the abroad source of funds is 2008 for most Member States, while data on government funding is available for 2009 (Figure I.3.3).

In government funding, only direct funding of R&D is recorded. To give a more exhaustive measure of total public support to R&D, indirect government support through R&D tax incentives has to be added (Figure I.3.8). However, this data is not available in all Member States. The evolution of the sum of direct and indirect government funding with direct public funding from abroad is to be compared to the public objective that Member States had fixed for themselves in 2005 (1% of GDP in the majority of the cases).

[45] Both lines in Figure I.3.6 represent the evolution of the same quantity, namely European Commission funding of RTDI, over the years. The fact that both lines evolve similarly over time indicates that the rates of growth of both denominators, namely total EU-27 civil GBAORD and total European Commission expenditure, have been of similar magnitude.

Figure I.3.7 GERD financed by the public sector as % of GDP, 2008 (1)



Source: DG Research and Innovation
Data: Eurostat
Notes: (1) EL, IE: 2005; BE, DK, AT, SE, NO: 2007; SK: 2009.
(2) Abroad (public sector) includes the European Commission, international organisations and other national governments.
(3) BG, DE, IT, LV, LU, HU, NL and UK are not included on the graph because GERD financed by abroad (public sector) is not available for these Member States.

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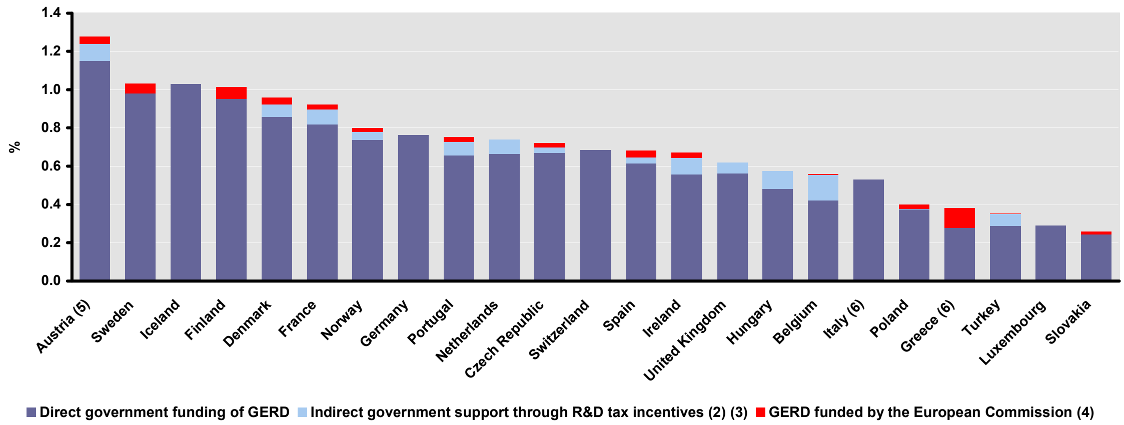
Total public R&D support includes direct and indirect government funding of R&D as well as European Commission funding of R&D

In terms of GDP, R&D tax incentives in Member States range from 0 (Spain and Czech Republic) to 0.13 % of GDP (Belgium). Adding this amount of indirect government funding to the direct public (government and abroad-public) funding displayed in Figure I.3.7 provides a more complete quantification of total government R&D support (Figure I.3.8[46]). The European Commission's direct funding of R&D[47] completes the picture of total public support to R&D in each Member State. In some cases, the addition of R&D tax incentives and European Commission funds brings public support substantially closer to the 1 % objective fixed by many Member States. Total public support to R&D amounts to 0.6 % of GDP in Belgium for instance, against 0.42 % of GDP with the sole direct government funding.

[46] As in Figure I.3.7, due to the unavailability of R&D tax incentives data in non-OECD countries, only European Countries that are also members of the OECD are included in this figure.
[47] Through EU Framework Programmes for Research, Technology and Development (RTD) and Structural Funds for RTD.

Figure I.3.8 GERD funded by public sources (direct and indirect support) as % of GDP, 2008 (1)



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011

Data: Eurostat, OECD (based on national estimates from the Working Party of National Experts in Science and Technology (NESTI) R&D tax incentives questionnaire, January 2010).

Notes: (1) The latest year available was used for each indicator.
(2) DE, IT, LU, PL, SK, FI, SE, IS, CH have no R&D tax incentives.
(3) The R&D tax expenditures estimates do not cover sub-national R&D tax incentives.
(4) GERD funded by the European Commission is not available for: DE, IT, LU, HU, NL, UK, IS, CH.
(5) AT: The R&D tax expenditure estimate covers the refundable research premium but excludes other R&D allowances.
(6) IT (volume tax credit of 10%) and EL (tax credit of 50% for incremental R&D) provided R&D tax incentives but the cost of those incentives was not available.

3.2. Is overall public funding for knowledge creation growing?

Besides R&D, the public sector invests massively in education and financially supports innovation activities in firms. Together with R&D, education and innovation form the three edges of the Knowledge Triangle. While it is possible to measure public funding in education and in R&D, there is currently no reliable measure of public funding of innovation.

The European governments which invest most in knowledge are reaching funding levels above 7% of GDP

At EU-27 aggregate level, Member States' governments invested about eight times more in education (5.06% of GDP) than in R&D (0.63% of GDP) in 2007. Governments of the Nordic countries invest most in these two areas (between 7% and 8% of GDP).

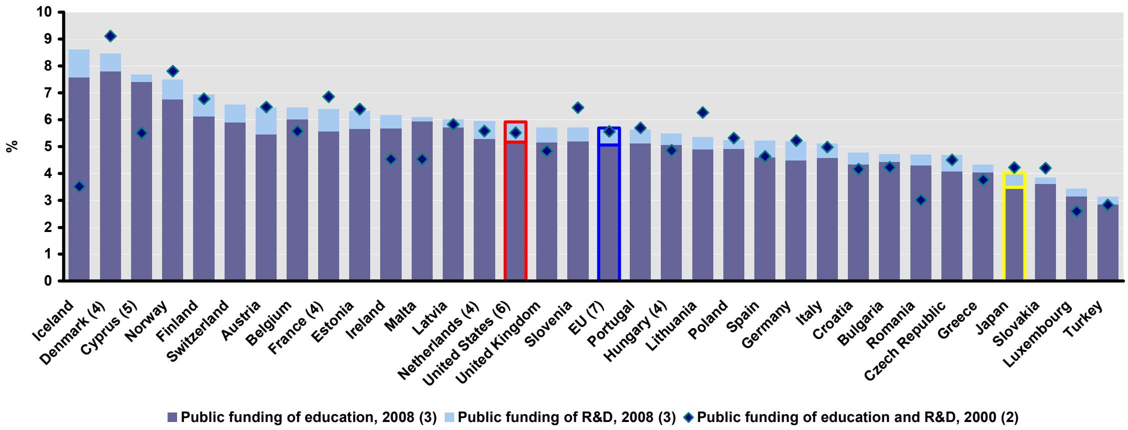
Private funding of education represented 0.7% of GDP on average in the EU in 2007, with most Member States contributing between 0.5% and 0.8% of GDP[48]. The United Kingdom and Cyprus are notable exceptions with 1.7% and 1.3% of GDP respectively. Private funding of education is even much more important in Japan and above all in the United States, where it amounted respectively to 1.6% and 2.6% of GDP in 2007. In total, public and private investment in education relative to GDP was one third higher in the United States (7.77% of GDP) than in the EU (5.76% of GDP) in 2007.

The evolution of total public funding to education and R&D is mainly driven by public funding to education since it is almost one order of magnitude higher than public funding to R&D. Iceland, Cyprus, Ireland, Malta and Romania are the countries in which the increase has been most important, followed by Belgium, the United Kingdom, Hungary, Spain,

[48] This private part of education funding is not included in Figure I.3.9.

Croatia, Bulgaria, Spain and Luxembourg. In all other countries, public funding to education and R&D barely changed or decreased.

Figure I.3.9 Public funding of education and R&D (1) as % of GDP, 2000 (2) and 2008 (3)

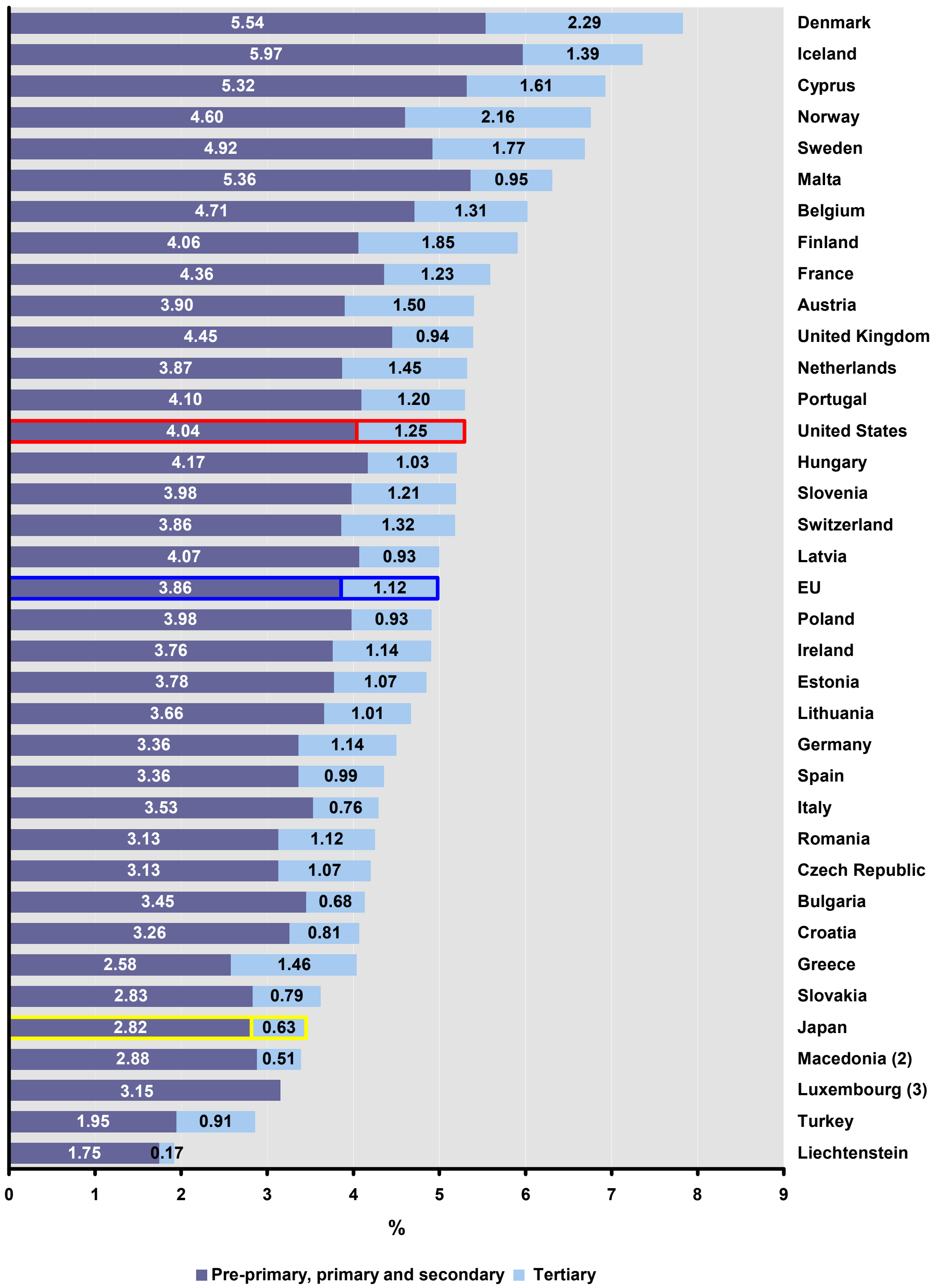


Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat, OECD
Notes: (1) Public funding of R&D from abroad is not included.
(2) DK, EL, SI, IS, NO: 2001; MT, HR: 2002, LU: 2003; IT: 2005.
(3) CH: 2004; EL: 2005; TR: 2006; EU, BE, DK, DE, LU, NL, PL, PT, SI, UK, NO, US: 2007.
(4) DK, FR, HU, NL: Breaks in series occur between 2000 and 2008.
(5) CY: Funding for students studying abroad is included.
(6) US: Public funding of R&D does not include most or all capital expenditure.
(7) EU does not include EL, IT, LU, SI, SE.
(8) SE: Data are not available.

In the EU on average, more than three quarters of public expenditure on education concern pre-primary, primary and secondary education and about one quarter concerns tertiary education

Public expenditure on tertiary education as % of GDP is by far the highest in the Nordic countries, followed by Austria, the Netherlands and Greece. The public sector in the United States invests about 12.6% more than the EU in tertiary education. The main difference between the EU and the United States however comes from the private sector, which is a major source of funds for tertiary education in the United States, while it is much more limited in the EU.

Figure I.3.10 Public expenditure on education as % of GDP, 2007 (1)



Source: DG Research and Innovation

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Data: Eurostat

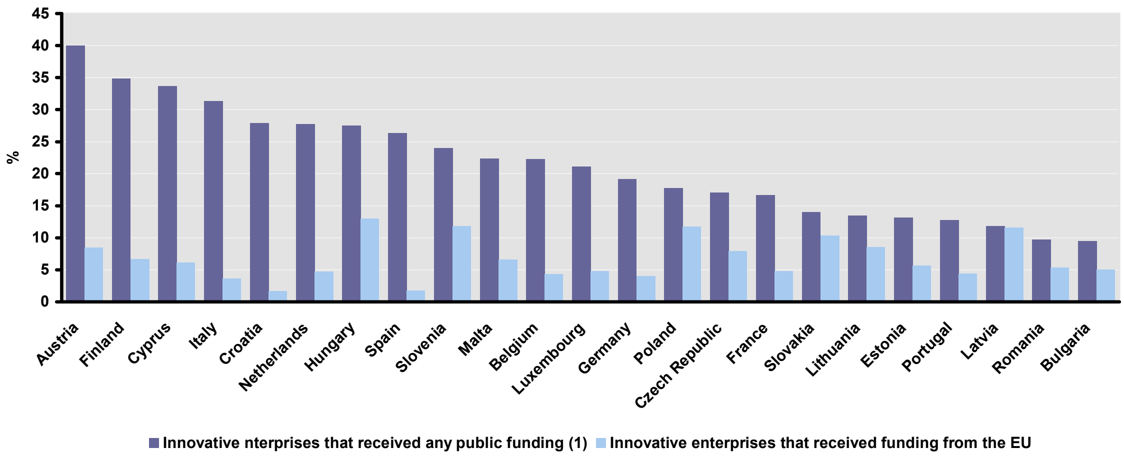
Notes: (1) MK: 2003; EL: 2005; TR: 2006.
(2) The former Yugoslav Republic of Macedonia.
(3) LU: Data are not available for tertiary education.

In a majority of European countries, between 15% and 30% of innovative enterprises received public funding between 2006 and 2008

Public funding also supports innovation activities in enterprises. In a majority of the European countries providing this data, between 15% and 30% of innovative enterprises had received some public funding in 2008, i.e. funding from central and/or government and/or from the EU. In a few cases, this share goes beyond 30%. The amount of public funding that this support to innovative enterprises represents is not known.

In Member States, the share of innovative enterprises that received EU funding ranges from 1.7% (in Spain) to 13% (in Hungary). Unsurprisingly, this share is higher in Member States that receive large amounts of Structural Funds.

Figure I.3.11 Shares of innovative enterprises that received public funding, 2006-2008



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat
Note: (1) Funding from central government, local or regional authorities or the EU.

12% of EU budget supports Research, Education and Innovation

In 2009, the Framework Programme and Structural Funds supporting RTDI activities represented about 11% of the EU budget (Figure I.3.6). Adding the Community Innovation Programme (0.37% of EU budget over 2007–2013) and the Life-Long-Learning Programme[49] (0.71% of EU budget over 2007–2013) brings the total EU support to Research, Innovation and Education to about 12% of EU budget.

[49] The Lifelong Learning Programme includes the school education (Comenius), higher education (Erasmus), vocational training (Leonardo da Vinci) and adult education (Grundtvig).

4. Investing in human resources for R&D

Highlights

Europe is ageing, and so is its population of researchers. In view of 2020, it is crucial to increase the knowledge-intensity of its labour force to counteract EU's loss of productivity, and in particular increase the share of researchers in the business sector. Over one million additional researchers are needed, in particular in the private sector.

There are promising signs in the considerable increase of new tertiary education and doctoral graduates in the EU, but the large stock of researchers are not being employed in the business sector to the same extent as in its major competitors in the world economy.

With more than 895 000 students receiving a tertiary degree in Science and Engineering in 2008, the European Union produces an impressive resource in human capital for R&D - more than twice as much as in the United States. The number of tertiary degrees in the EU has increased at an average annual rate of nearly 5.0 % per year over the period 2000–2008.

The number of doctorates awarded in 2008, at 111 000, is more than twice the number awarded in the United States, mirroring the impressive potential of EU's human resources for a knowledge-based economy. The number of doctorates in Science and Engineering follows the same pattern with respectively 47 000 for the EU and 23 000 for the United States.

The EU, the United States and China have almost the same number of researchers in absolute terms. In 2008, there were 1.5 million FTE researchers in the EU compared to 1.6 million in China and – in 2007 - 1.4 million in the United States. Compared to 2007, China has now passed the EU and the United States in total number of researchers. However, the employment pattern of these researchers is not similar. The number of researchers in the public sector in the EU is more than twice the number of researchers in public sector in the United States.

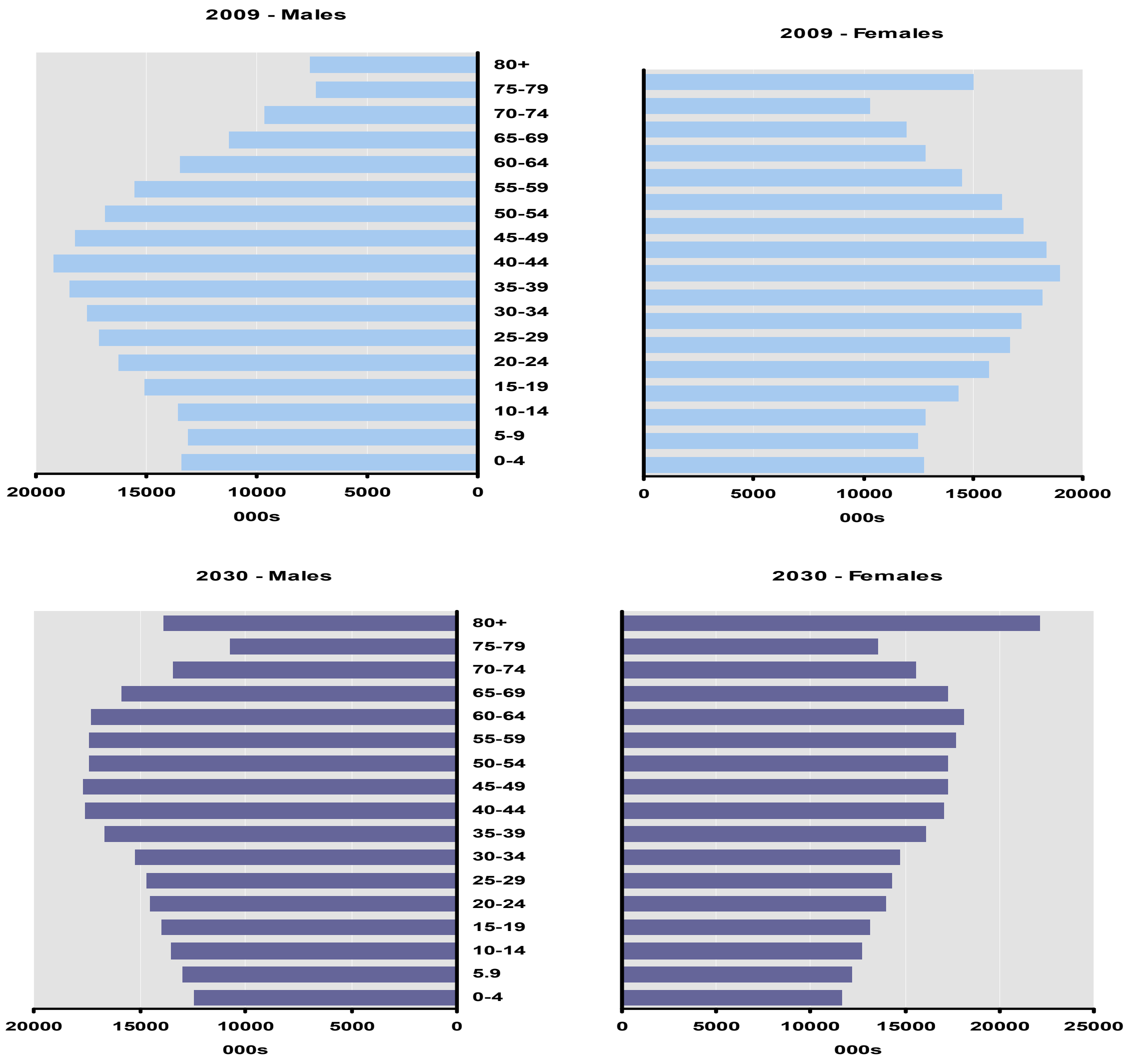
Despite these impressive resources, both in terms of stock of researchers and in terms of in-flow, the EU is lagging behind where the human resources employed by business for R&D are concerned. Only 690 000 researchers work in the private sector of the EU compared to 1 113 000 in the United States and more than 490 000 in Japan. In the EU less than one out of two researchers are employed in the private sector; in the United States this accounts for four out of five researchers and in Japan and China approximately two out of three researchers are employed in the business sector. The EU is catching up, albeit slowly, in terms of researchers employed in the business sector

4. Investing in human resources for R&D

4.1. What are the demographic prospects for the coming decades?

In the face of the economic challenge of a massive increase in the number of elderly while the number of young people is decreasing, massive investment into education and research is needed to ensure sufficient competitiveness over the next decades. According to the Eurostat population projections Europop2010, in 2011, the EU's population of working age is due to peak, and from 2011 onwards the size of the potential labour force is expected to decrease[50]. The resulting challenges ahead of the EU are twofold: a decreasing number of young Europeans will have to create the wealth to finance living expenditures for the increasing number of elderly Europeans in an increasingly competitive world[51]. Highly skilled human resources are the necessary pre-requisite for Europe to rise to this challenge.

Figure I.4.1. EU- population by age group, 2009 and 2030 (projections)



Source: DG Research and Innovation
Data: Eurostat

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Achieving the 3% R&D intensity target will require changes beyond the mere research and innovation actors, and will have broader implications for both the economy and the educational and labour systems, that will be required to provide and utilise increasing numbers of new skills, including research skills. An increasing number of researchers will

[50] http://ec.europa.eu/social/main.jsp?langId=en&catId=103&newsId=434&furtherNews=yes.
[51] For an up to date overview of the increase in world competitiveness in research and innovation, see the Overview section in the beginning of this report and the Competitiveness chapter in Part III, chapter 4. See also the European Competitiveness report 2010, COM(2010) 614

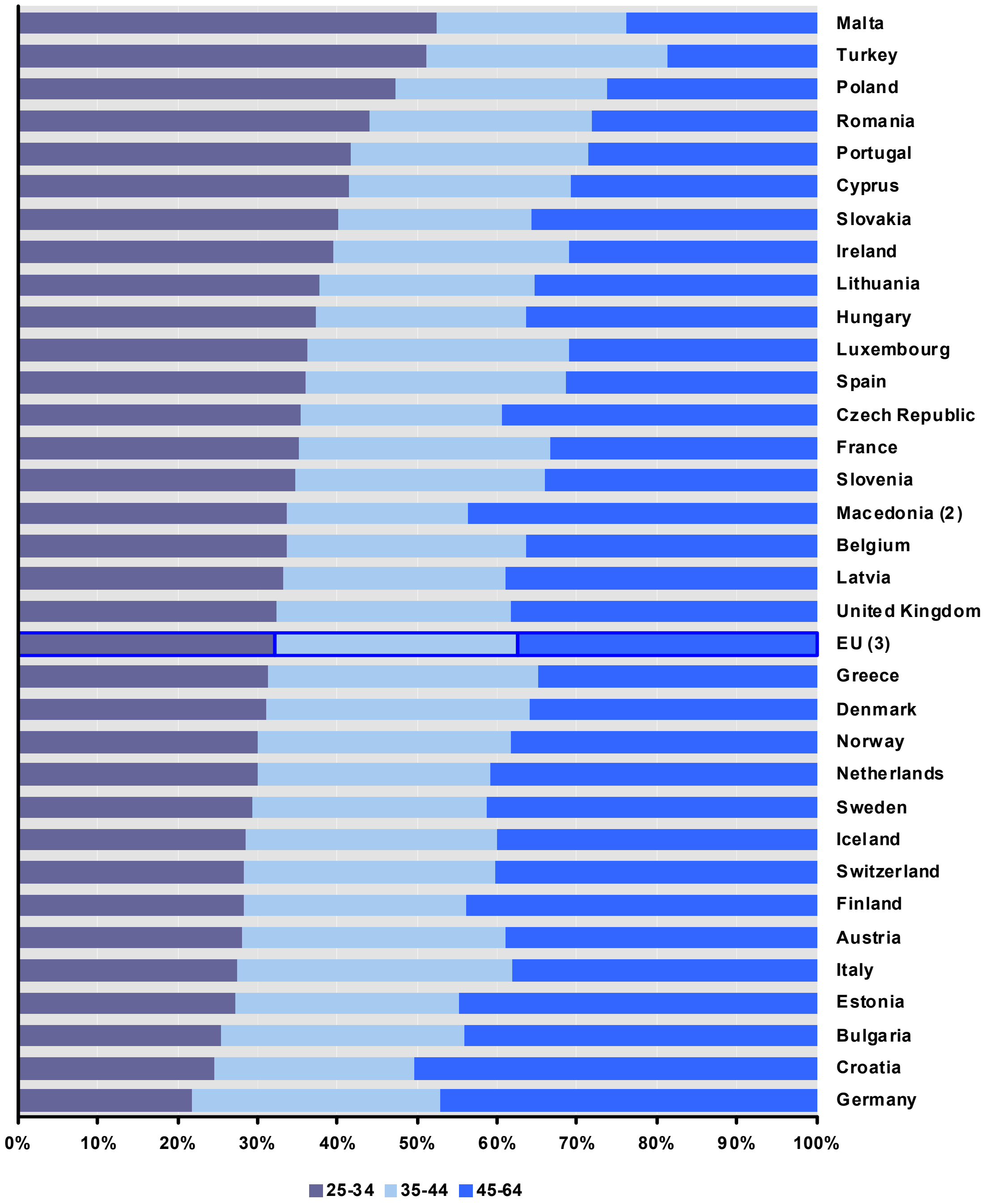
have to be trained or attracted if rises in R&D (private and public) budgets are to be absorbed efficiently. Beyond this quantitative challenge, there is also a qualitative dimension that will need to taken into account, as many of the new researchers will be needed in different scientific fields and will have to be employed in the private sector.

In order to avoid any bottlenecks in the scientific, technological and economic transformation of the European Union, it is important to assess and estimate (quantify) the needs for new skills, and especially the needs for new researchers.

Almost 40% of the human resources in science and technology in the EU are 45 years or older

Overall the core of human resources in science and technology (HRSTC) in Europe are rather mature. 37% of HRST core is more than 45 years old (see Figure I.4.2 below). In Member States with high or medium-high R&D intensities (Austria, Denmark, Germany, Finland and Sweden), the share of individuals younger than 34 is very low. The human resources in science and technologies are on average younger in countries with medium and low R&D intensities: in Poland, Malta, Ireland, Portugal and Turkey the share of individuals younger than 35 is above 40%, indicating a relatively young population of human resources in science and technology.

Figure I.4.2 Human Resources in Science and Technology - Core (HRSTC) - % distribution by age group, 2009 (1)



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat
Notes: (1) LU: 2008.
(2) The former Yugoslav Republic of Macedonia.
(3) EU does not include LU.

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

The growth rate in the number of researchers is somehow consistent with the increase in the absolute R&D budgets in the EU, but they are much higher than the R&D intensity growth in the European Union. For 2020, the combination of an increase in R&D intensity and of economic growth will require a very sharp increase in the number of HRST staff.

The estimation of the number of researchers needed is complex because many of the variables affecting this estimate co-evolve[52] over time and therefore the accuracy of any estimate based on past data can only be tentative and needs to be handled with caution. The number of researchers, however, is directly linked to the absolute level of research investment available in one economy. As such, research funding can happen in two ways:
1- Increases in GDP with a constant evolution of R&D intensity
2- Increases in Research intensity with a flat GDP growth

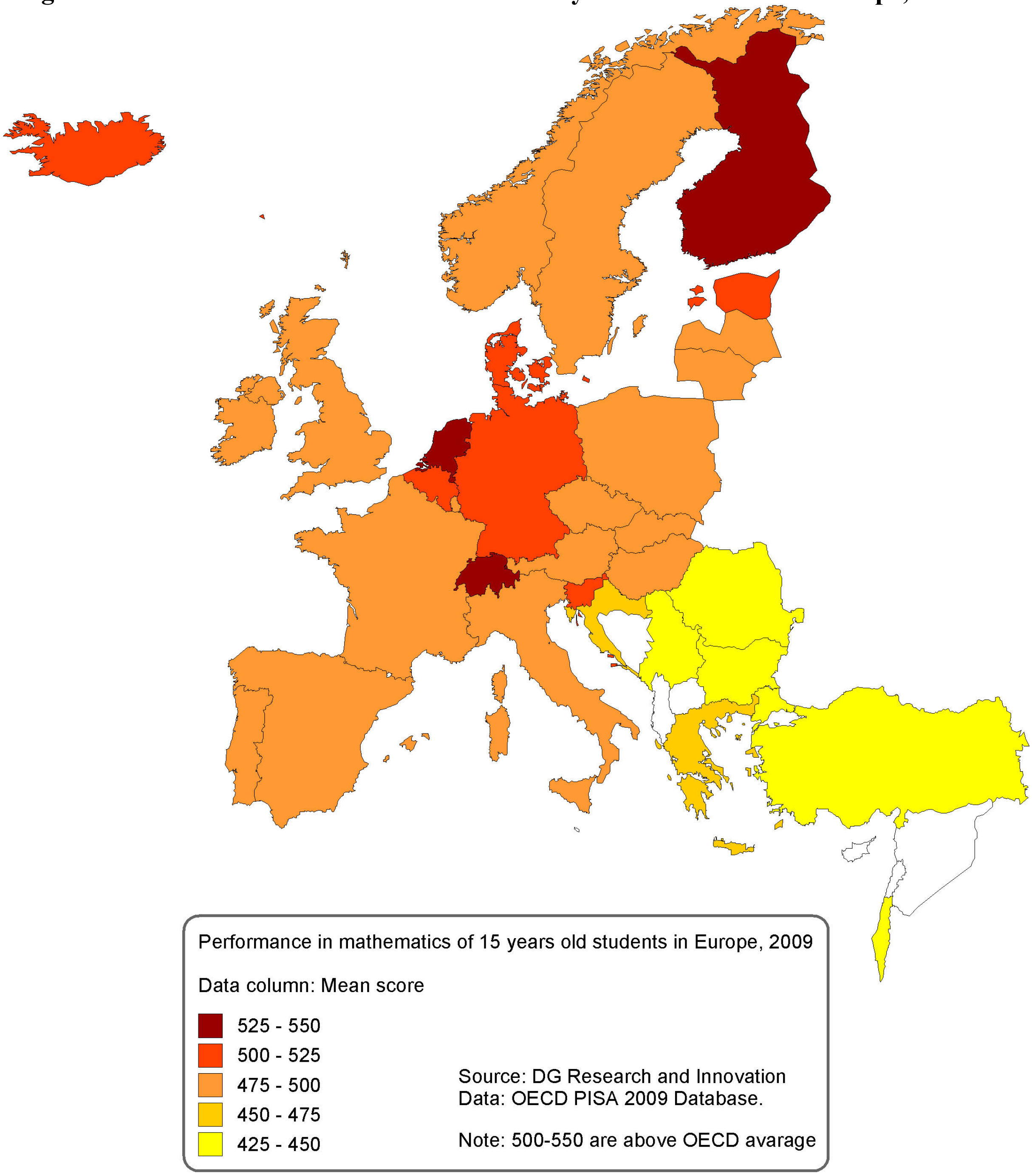
In the case of the EU, the total research investment is expected to grow thanks to (1) an increase of GDP in the economy, and (2) an increase in Research intensity that may pass from 1.9% in 2008 to 3% in 2020. An estimation based on these assumptions ends up with the need of additional one million researchers by 2020.[53] This estimation does not include the additional need of researchers to substitute those leaving their employment for retirement.

The quality of the future human resources is of crucial importance

Public expenditures in education (all levels) is below the EU average of around 5% of GDP in 13 Member States, in particular in Southern and Eastern European countries.[54] Those Member States that have a relatively low public investments in primary, secondary and tertiary education also (with some exceptions) have a relatively weaker performance by high school students in the PISA study of OECD (see map below), raising potential concerns about the quality of the future labour force. Only 8 European countries have a score which is above OECD average.

[52] The rate of economic growth, the economic structure or the scientific and technological specialisation of an economy are variables that are closely interrelated with research investments and the number of HRST staff needed, and their changes affect each other.
[53] For the specific calculations, see the Methodological annex to this report.
[54] See figure I.3.9. in Part I, chapter 3.2 on public investments in knowledge.

Figure I.4.3. Performance in mathematics of 15 years old students in Europe, 2009



4.2. Is Europe training sufficient researchers and skilled human resources?

Today's students are the future human resources in research and development. Therefore, this section presents the current picture on the number of tertiary degrees in the EU in the period 2000–2008. In particular, the focus lies on the analysis of tertiary degrees (ISCED 5) and of doctoral degrees (ISCED 6), given that these graduates provide the main 'pool' of potential employees which meets the demand for scientists and researchers.

Based on the International Standard Classification of Education (ISCED 97) 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,' and ISCED 5B are programmes which are 'practical/technical/occupationally specific'. The ISCED 6 level, 'second stage of tertiary education leading to an advanced research qualification', is reserved for tertiary programmes which 'are devoted to advanced study and original research and are not based on course-work only.'[55]

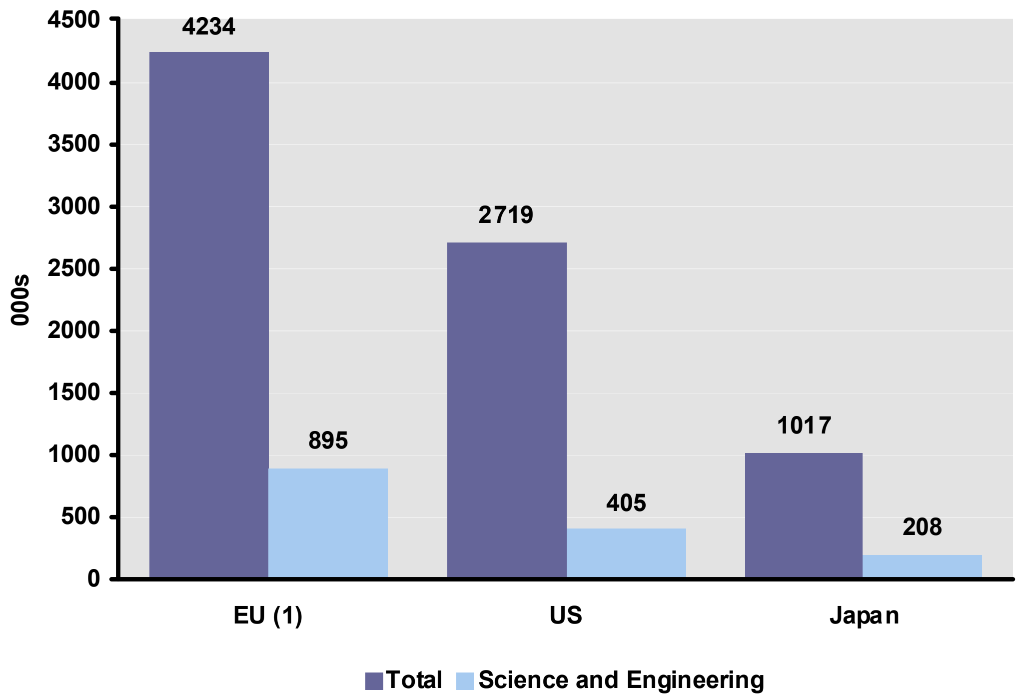
[55] For a documentation of ISCED 1997, see the following document: http://www.uis.unesco.org/TEMPLATE/pdf/isced/ISCED_A.pdf.

The EU has a higher number of graduates from the first stage of tertiary education than the United States and Japan, as well as a higher share of graduates in Science and Engineering

These graduates provide the bulk of Human Resources in Science and Technology for industry as well as a talent pool for doctoral students (and future researchers). Figure I.4.4 provides a comparison between the EU, the United States and Japan for the number of tertiary degrees and the share of Science and Engineering tertiary degrees awarded in 2008. 4.2 million degrees were awarded in the EU compared with 2.7 million in the United States and about 1 million in Japan. Expressed in percentage of the number of tertiary graduates, the figures are of respectively of 21% (EU), 15% (United States) and 20% (Japan)

The number of Science and Engineering degrees (ISCED 5) awarded in the EU increased from about 784 000 in 2004 to 895 000 in 2008. In 2008, the EU exhibits a considerably larger production of Science and Engineering degrees compared to the United States (405 000) and Japan (208 000). Together with the 47 000 doctorate graduates (ISCED 6) in Science and Engineering, the EU produced 940 000 S&E graduates in 2008.

Figure I.4.4 Tertiary graduates, ISCED 5, 2008



Source: DG Research and Innovation Innovation Union Competitiveness Report 2011
Data: Eurostat
Note: (1) EU: Total science and engineering was estimated by DG Research and Innovation.

The trends are very different between countries. A number of countries have dramatically stepped up their efforts in the training of Science and Engineering graduates, such as Croatia, the Czech Republic, Poland, Portugal, Romania and Slovakia. Strong innovation performers such as Austria, Finland and Germany have also maintained a significant growth of S&E graduates, whereas France and the United Kingdom remain nearly static, although they still produce the largest number of S&E graduates. 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 Science and Engineering graduates.

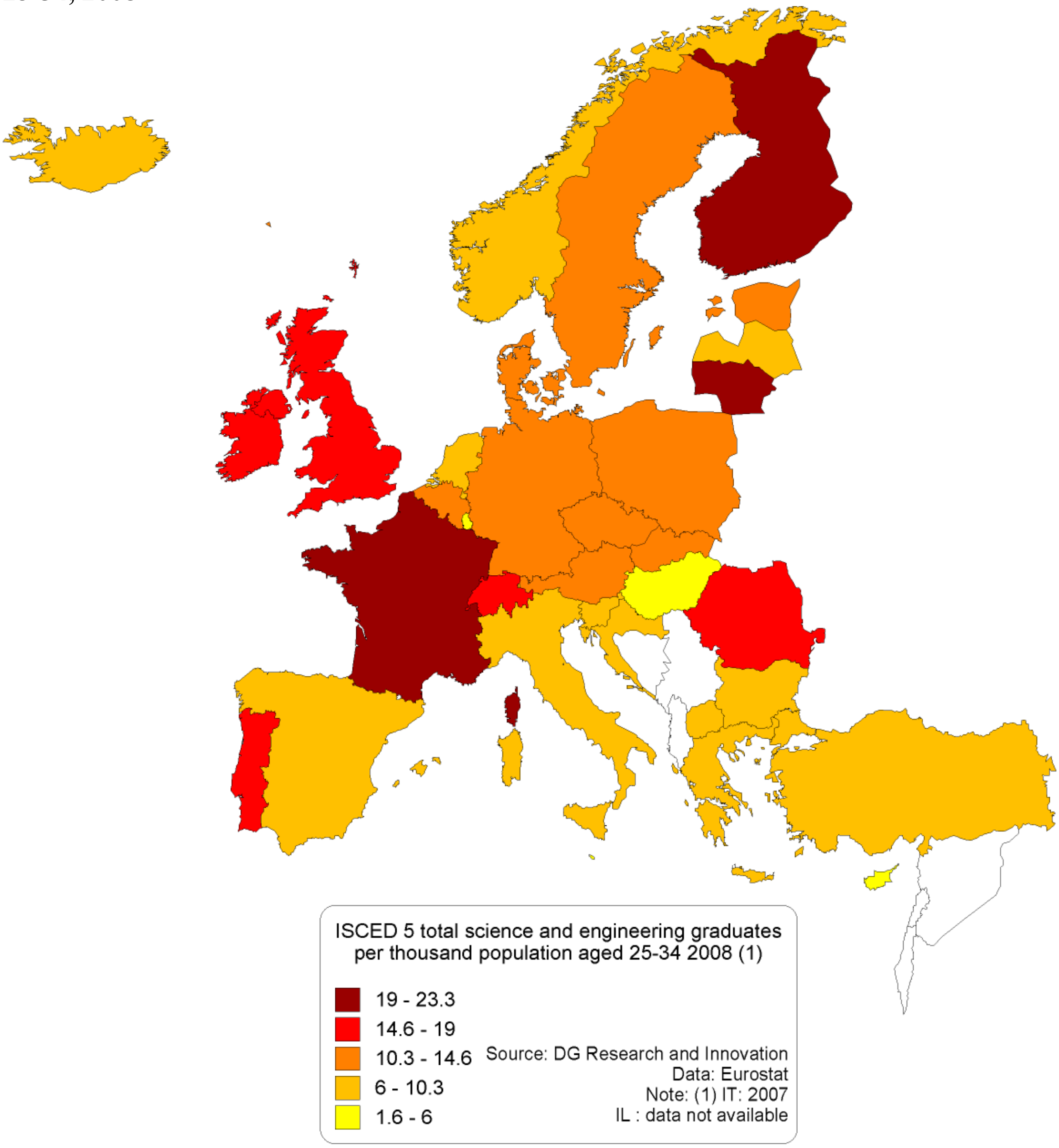
Table I.4.1 Tertiary graduates - Total ISCED 5 and Science and Engineering, 2000 and 2008

	Total ISCED 5			Science and Engineering		
	2000 (1)	2008	Average annual growth 2000-2008 (2)	2000 (1)	2008 (3)	Average annual growth 2000-2008 (4)
Belgium	67078	95368	4,5	12287	14451	2,0
Bulgaria	46319	54309	2,0	7947	9613	2,4
Czech Republic	37481	86593	11,0	8848	21341	11,6
Denmark	38222	48652	3,1	8059	9216	1,7
Germany	276314	441731	6,0	70225	113408	6,2
Estonia	7626	11184	4,9	1441	2241	5,7
Ireland	41508	58984	4,5	14190	14037	-0,1
Greece	46840	65550	8,8	12326	16120	6,9
Spain	254218	283734	1,4	62911	71825	1,7
France	497785	610135	2,6	148811	156474	0,6
Italy	198265	385603	8,7	44961	77579	8,1
Cyprus	2800	4200	5,2	333	517	5,7
Latvia	15220	24031	5,9	2405	3005	2,8
Lithuania	24799	42178	6,9	6403	8802	4,1
Luxembourg	680	330	-8,6	99	110	1,3
Hungary	59166	62190	0,6	6902	8303	2,3
Malta	1997	2781	4,2	185	354	8,4
Netherlands	76927	121014	5,8	11630	16320	4,3
Austria	23191	41439	7,5	6754	11560	6,9
Poland	426704	552407	3,8	43454	87782	10,6
Portugal	51751	79146	5,5	9261	27383	14,5
Romania	134000	308204	18,1	31836	50534	9,7
Slovenia	11201	16816	5,2	2500	2838	1,6
Slovakia	22253	63371	14,0	4555	12928	13,9
Finland	34344	58124	6,8	9438	15319	6,2
Sweden	39342	56809	4,7	11440	12892	1,5
United Kingdom	492513	659594	3,7	134401	136749	0,2
EU (5)	3500154	4234477	4,9	784711	*894583*	*3,3*
Iceland	1777	3604	9,2	351	480	4,0
Liechtenstein	61	141	18,2	25	31	4,4
Norway	29277	33983	1,9	4736	4817	0,2
Switzerland	54899	76089	5,6	12316	14949	3,3
Croatia	16570	26444	9,8	3262	5989	12,9
Macedonia (6)	3841	11110	14,2	1161	1961	6,8
Turkey	187956	441004	11,2	56450	96381	6,9
United States	2106146	2718558	3,2	353104	405110	1,7
Japan	1069243	1017478	-0,6	231926	208074	-1,3

Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat
Notes: (1) PL: 2001; CH: 2002; RO, LI, HR: 2003; EU, EL: 2004.
(2) PL: 2001-2008; CH: 2002-2008; RO, LI, HR: 2003-2008; EU, EL: 2004-2008.
(3) IT: 2007.
(4) IT: 2000-2007; PL: 2001-2008; CH: 2002-2008; RO, LI, HR: 2003-2008; EU, EL: 2004-2008.
(5) EU: The value for Science and Engineering for 2008 was estimated by DG Research and Innovation.
(6) The former Yugoslav Republic of Macedonia.

Figure I.4.5 illustrates the share of new graduates in Science and Engineering in the population aged 25-34 reflecting the addition of Science and Engineering graduates to the working population. France, Finland and Lithuania are the leading Member States in that respect.

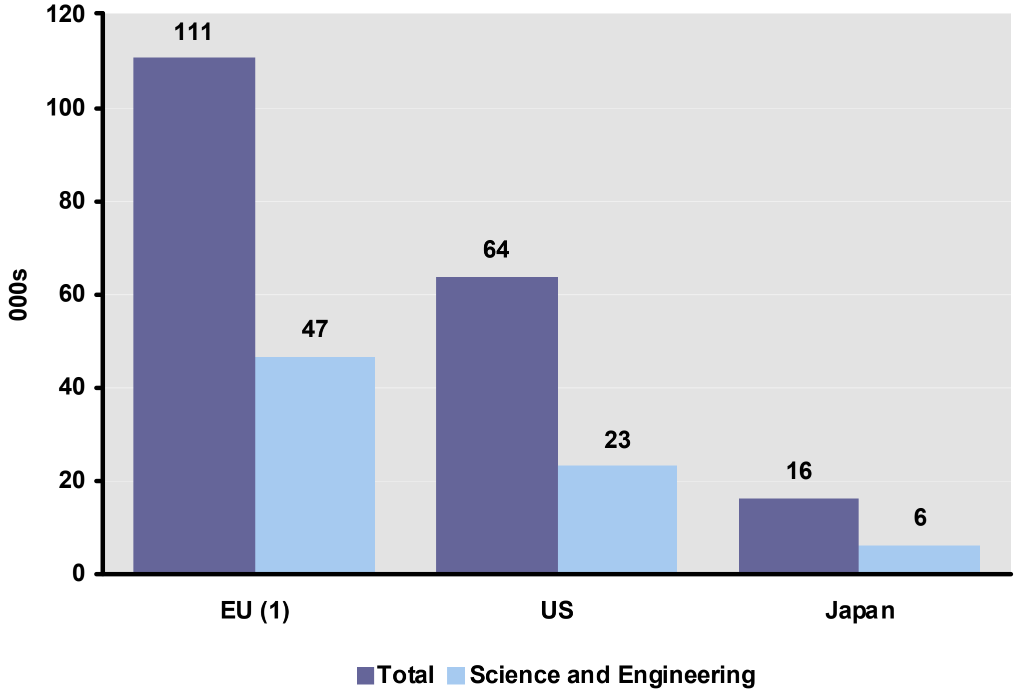
Figure I.4.5. New graduates in Science and Engineering per thousand population aged 25-34, 2008



The EU produces almost twice as many Science and Engineering doctoral degrees as the United States - 47 000 Science and Engineering doctoral degrees were awarded in the EU in 2008 compared with 23 000 in the United States

Figure I.4.6 provides a comparison between the EU, the United States and Japan for the number of doctoral degrees awarded in 2008 (tertiary graduates at level ISCED 6), as well as for the share of Science and Engineering doctoral degrees awarded. In 2008, around 111 000 doctoral degrees were awarded in the EU compared with 64 000 in the United States and 16 000 in Japan.

Figure I.4.6 Tertiary graduates, ISCED 6, 2008

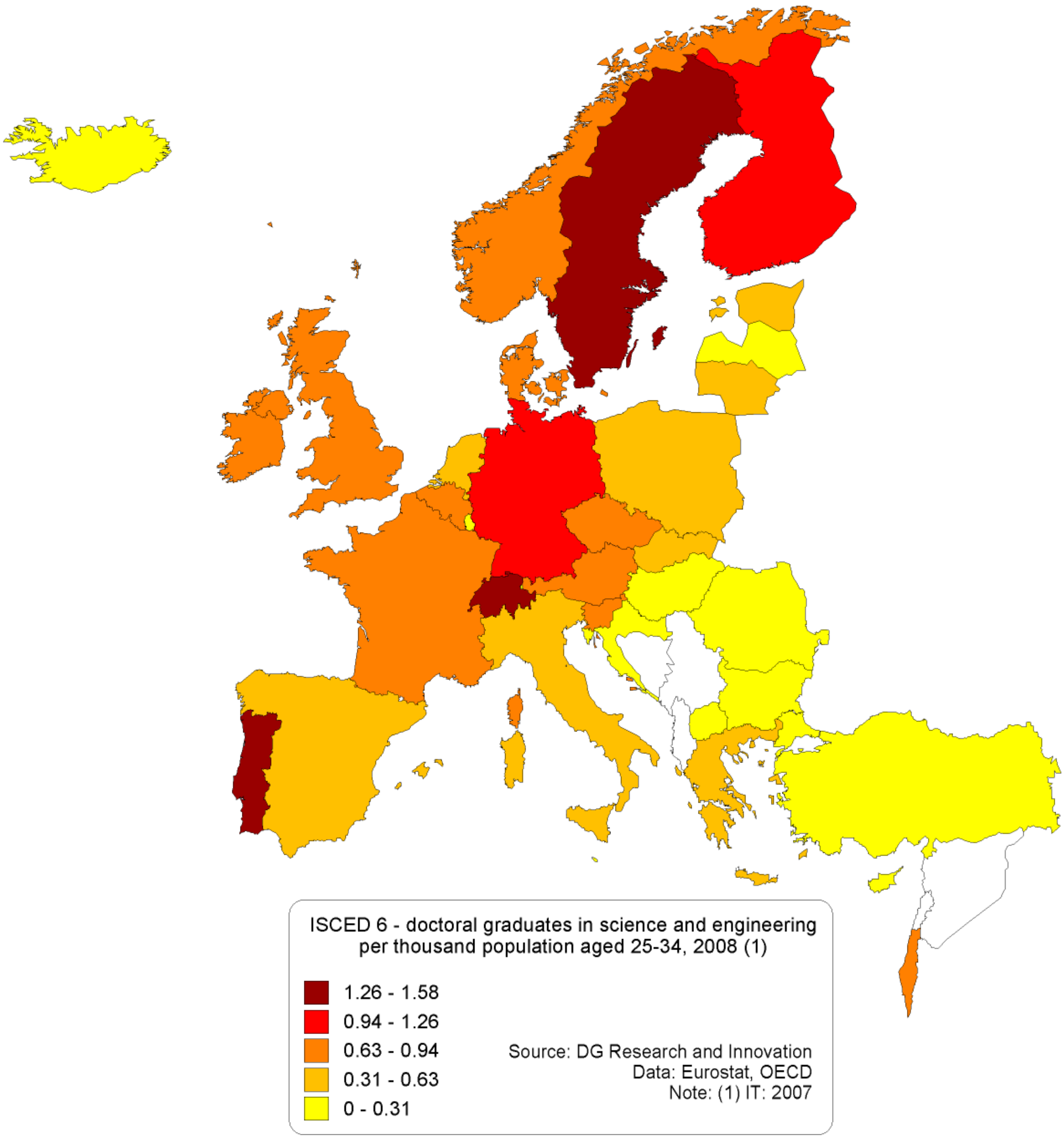


Source: DG Research and Innovation Innovation Union Competitiveness Report 2011
Data: Eurostat
Note: (1) EU: Total science and engineering was estimated by DG Research and Innovation.

Relative to the population aged 25–34, number of new doctoral graduates is the highest in Sweden, Finland, Germany and Portugal. On the contrary, several Eastern European countries, as well as Spain and Greece, show a very low intensity of new doctoral graduates in their population.

Figure I.4.7 below, seen in relation with figure I.4.5 above, highlights some interesting differences between countries. The leading countries in the overall production of Science and Engineering graduates were Finland, France and Estonia while the leading ones in terms of doctoral graduates in Science and Engineering are Sweden, Switzerland and Portugal. Secondly, despite their recent efforts a number of EU-12 Member States and Associated countries have not managed to close the gap in terms of doctoral graduates. Some of them, however (e.g. the Czech Republic and Slovenia) are now on a par with countries such as Austria, France, the United Kingdom and Ireland.

Figure I.4.7. New doctoral graduates in Science and Engineering per thousand population aged 25-34, 2008



Concerning the overall doctoral degrees in the EU, Germany, the United Kingdom, Italy and France have awarded the highest numbers of doctoral degrees — about 26 000, 17 000, 13 000 and 11 000, respectively. Spain follows with around 7 000 doctoral degrees each year. These six countries account for 70 % of the total number of doctoral degrees awarded in the EU in 2008 (see table I.4.2).

The annual growth rate of tertiary degrees in Science and Engineering in the EU was similar to the average for all fields. This rate is similar to the trends observed in the Unites States and Japan.

About 111 000 doctoral degrees were awarded in 2008, with 46 000 doctoral degrees in Science and Engineering. Between 2004 and 2008, the number of doctoral degrees in the EU increased at an average annual rate of 3.8 % per year. In Science and Engineering the annual growth rate (4.0 %) was slightly higher

These global figures hide a number of important differences between countries. The number of doctoral degrees decreased both globally and in Science and Engineering in Germany, while it increased very slowly in France, Finland and Sweden. Countries such as Italy, the Czech Republic, Portugal, Slovakia, Cyprus and Malta have been catching up with double digit growths. Estonia, Ireland and Latvia are close in terms of growth.

Table I.4.2 Tertiary graduates - Total ISCED 6 and Science and Engineering, 2000 and 2008

	Total ISCED 6			Science and Engineering		
	2000 (1)	2008	Average annual growth 2000-2008 (2)	2000 (1)	2008 (3)	Average annual growth 2000-2008 (4)
Belgium	1147	1880	6,4	632	917	4,8
Bulgaria	399	601	5,3	129	223	7,1
Czech Republic	895	2382	13,0	510	1239	11,7
Denmark	795	1102	4,2	397	446	1,5
Germany	25780	25604	-0,1	9820	9495	-0,4
Estonia	117	161	4,1	42	89	9,8
Ireland	501	1090	10,2	282	584	9,5
Greece	1295	1406	2,1	830	526	-10,8
Spain	6007	7302	2,5	2169	2855	3,5
France	10404	11309	1,0	5945	6644	1,4
Italy	4044	12591	15,3	1629	4597	16,0
Cyprus	13	28	10,1	3	15	22,3
Latvia	40	139	16,8	26	54	9,6
Lithuania	442	369	-2,2	161	151	-0,8
Luxembourg	:	8	:	:	:	:
Hungary	717	1141	6,0	297	257	-1,8
Malta	6	11	7,9	1	5	22,3
Netherlands	2489	3214	3,2	842	1052	2,8
Austria	1790	2205	2,6	752	927	2,6
Poland	4400	5616	3,5	1388	1895	4,5
Portugal	2504	4863	8,7	823	2184	13,0
Romania	2580	3271	4,9	708	913	5,2
Slovenia	296	405	4,0	119	199	6,6
Slovakia	446	1655	17,8	170	576	16,5
Finland	1797	1951	1,0	666	795	2,2
Sweden	3049	3625	2,2	1530	1804	2,1
United Kingdom	11568	16606	4,6	6157	7268	2,1
EU (5)	95350	110535	3,8	39885	*46597*	*4,0*
Iceland	2	23	35,7	0	11	:
Liechtenstein	0	0	:	0	0	:
Norway	658	1231	8,1	82	533	26,4
Switzerland	2800	3426	3,4	1146	1372	3,0
Croatia	321	494	9,0	131	175	6,0
Macedonia (6)	34	87	12,5	17	18	0,7
Turkey	2124	3754	7,4	636	1126	7,4
Israel	688	1427	9,5	406	716	7,3
United States	44808	63712	4,5	16287	23146	4,5
Japan	12192	16296	3,7	4744	6288	3,6

Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat
Notes: (1) PL: 2001; CH: 2002; RO, LI, HR: 2003; EU, EL: 2004.
(2) PL: 2001-2008; CH: 2002-2008; RO, HR: 2003-2008; EU, EL: 2004-2008.
(3) IT: 2007.
(4) IT: 2000-2007; PL: 2001-2008; CH: 2002-2008; RO, HR: 2003-2008; EU, EL: 2004-2008.
(5) EU: The value for Science and Engineering for 2008 was estimated by DG Research and Innovation.
(6) The former Yugoslav Republic of Macedonia.

4.3. How large is the current stock of Human Resources for Science and Technology in Europe?

The following section will look more into detail into the current stock of human resources available in Europe. Table I.4.3 gives a general picture on the human resources in S&T in the EU. It provides data on HRST and its sub-groups, Scientists and Engineers and Researchers.

The active population for the EU in 2009 (referring to the total labour force, which includes both employed and unemployed persons) was about 239 million. The total employment was about 218 million. Human resources in Science and Technology accounted for 43.9% of the active population. Those who have successfully completed a tertiary-level education in an S&T (Science and Technology) field of study (HRSTE) accounted for 32.7% of the active population and 36.0% of the total employment, while the share of the active population having both completed a tertiary level education and been employed in an S&T occupation (HRSTC) accounted for 16.7%. Therefore only half of the tertiary education graduates in an S&T field of study were employed in S&T occupations.

Total R&D personnel accounted for 1.46% of the active population. Researchers were estimated to be more than 2.1 million or 0.91% of the active population in headcounts, while researchers in FTEs accounted for 1.5 million or 0.63% of the active population.

Table I.4.3 EU - Human Resources in Science and Technology by sub-group, R&D personnel and researchers, 2009 (1)

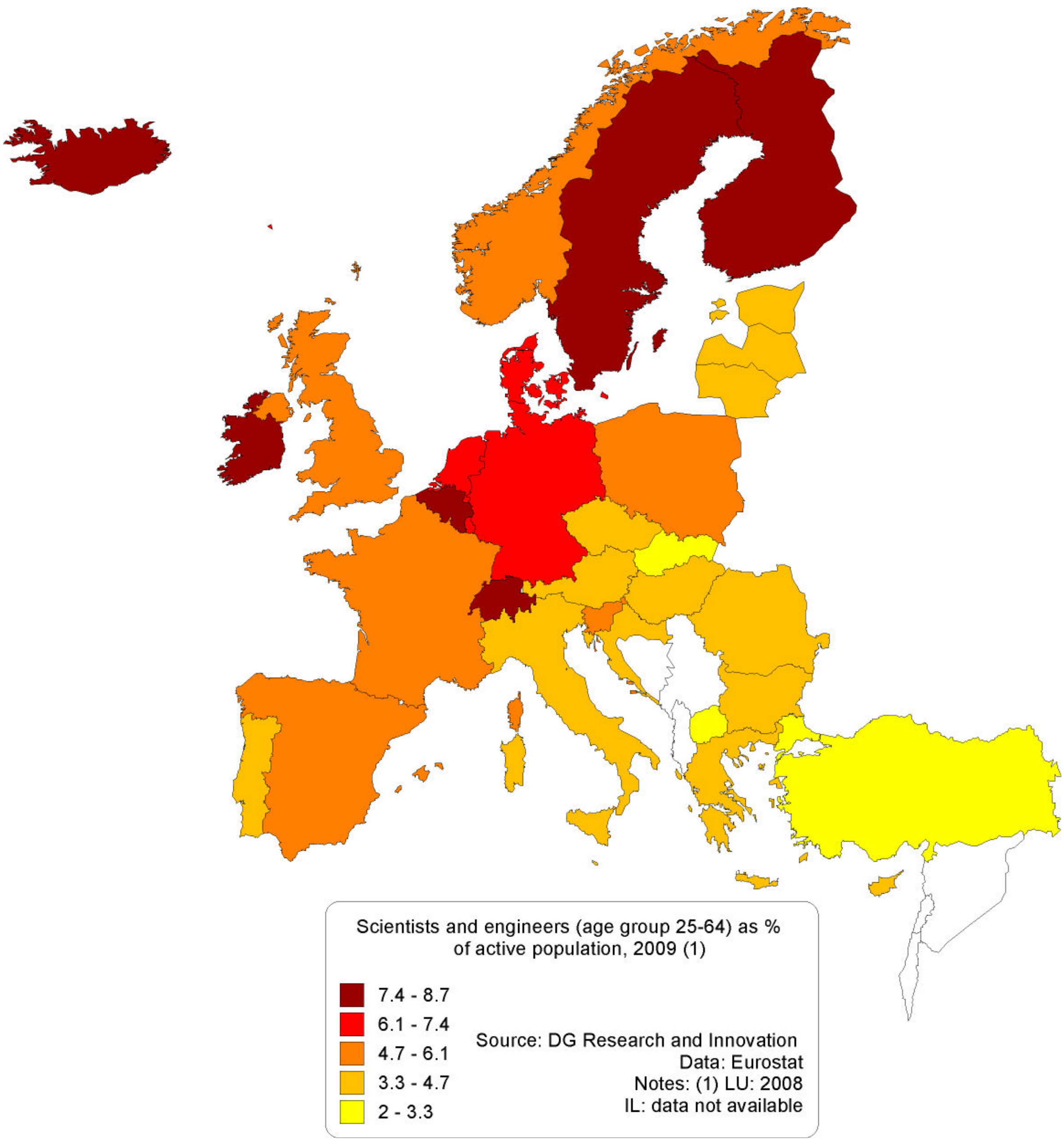
	Total (000s)	as % of active population	as % of total employment
Total active population	239281	:	:
Total employment	217813	91,0	:
HRST - Human Resources in Science and Technology (2)	104839	43,9	48,2
HRSTE - Human Resources in Science and Technology - Education (2)	78281	32,7	36,0
HRSTO - Human Resources in Science and Technology - Occupation (2)	66514	27,8	30,6
HRSTC - Human Resources in Science and Technology - Core (2)	39955	16,7	18,4
SE- Scientists and Engineers (2)	11778	4,9	5,4
Total R&D personnel (Head Count)	*3438*	1,46	1,57
Total R&D personnel (FTE)	*2455*	1,03	1,11
Researchers (Head Count)	*2158*	0,91	0,98
Researchers (FTE)	*1505*	0,63	0,68

Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat
Notes: (1) Total R&D personnel (Head Count) and researchers (Head Count) refer to 2007; Total R&D personnel (FTE) and researchers (FTE) refer to 2008.
(2) EU does not include LU.
(3) Values in italics are estimates.

The largest share of scientists and engineers are in Belgium, Finland, Iceland, Ireland and Switzerland

Scientists and engineers account for 4.8% of the active population and 5.1% of total employment. Figure I.4.8 below presents the share of scientists and engineers as a percentage of total labour force in 2009. Belgium, Iceland, Finland, Ireland and Switzerland dispose of percentages of 8% or more, while the share of scientists and engineers is lowest in Turkey, Slovakia and Macedonia.

Figure I.4.8 Scientists and engineers (age group 25-64) as % of active population, 2009



Concerning researchers, their number increased by almost 30% at an average annual growth rate of 3.8% between 2000 and 2008 in the EU, while R&D intensity stagnated. In 2008, there were 6.3 researcher FTEs per thousand labour force in the EU, versus 5.0 in 2000. Since 2000, the number of researchers in FTEs in the EU has increased from 1.1 million to 1.5 million in 2008. The respective increase in the United States was from 1.3 to 1.4 million (in 2007). In Japan, the number of researchers in FTEs increased approximately 1.3% per year from 0.6 to 0.7 million. China experienced the largest increase in the number of researchers in FTEs, from 0.7 to almost 1.6 million (10.8% p.a.).[56]

This growth was not homogeneous across sectors, as the average annual growth rate for researchers in higher education increased by 5%, in the private sector by 3.5%, and in government by just 1.2%. The percentage of researchers in the total labour force is also growing, albeit at slightly lower speed (average annual growth of 2.9% between 2000 and 2008

The share of researchers per thousand labour force was highest in Finland and Denmark in 2008, and lowest in Italy, Poland, Romania, Bulgaria and Latvia

Figure I.4.9 and TableI.4.4 illustrate the total numbers of researchers (FTEs) in 2008. Finland has the highest penetration of researchers in the workforce with 15 researchers per 1 000 labour force. Also, other Nordic countries (Iceland, Denmark, Norway and Sweden with around 10 researchers employed) have a high number of researchers per 1 000 employed. To complete the top five we find Luxembourg in second and the United Kingdom in fifth place. Romania, Cyprus, Malta, Bulgaria and Latvia have the lowest numbers, in a striking contrast between Romania's 2 and Finland's 15 researchers per 1 000 employed.

The share of researchers in the private sector to total researchers differs significantly between the EU and other major economies. In the EU, less than half of researchers (46%) are employed in the private sector. This share is significantly higher in the United States (79.1% data, 2007)) and Japan (68%). In addition, 66% of all Chinese researchers work in the business sector.

The number of researchers in the private sector has increased in the EU slightly more than in the United States and Japan

In terms of growth, the number of researchers employed in the private sector has increased by 3.5% between 2000 and 2008 in the EU against 1.2% in the United States and 2% in Japan. The performance of major European economies has been patchy with respect to the growth of researchers in the private sector with countries such as France, Italy in the average or slightly above, the United Kingdom and Germany lagging behind. Finland, although starting from a very high level has remained stable. The number of researchers in the private sector has been decreasing sharply in three EU-12 Member States (Latvia, Slovakia and Romania) between 2000 and 2008 and decreasing also to a lesser extent in Poland, illustrating the difficulties of industry in those three countries to remain in the competition. In contrast, some countries have been doing very well over the period (Cyprus, Estonia, Greece, Spain, Lithuania, Portugal, Slovenia and Turkey).

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[56] For graphs benchmarking the EU with other major research-intensive countries in the world, see the first section of the report 'Overall picture', Chapter 2.2.

Figure I.4.9 Researchers (FTE) per thousand labour force, 2008.

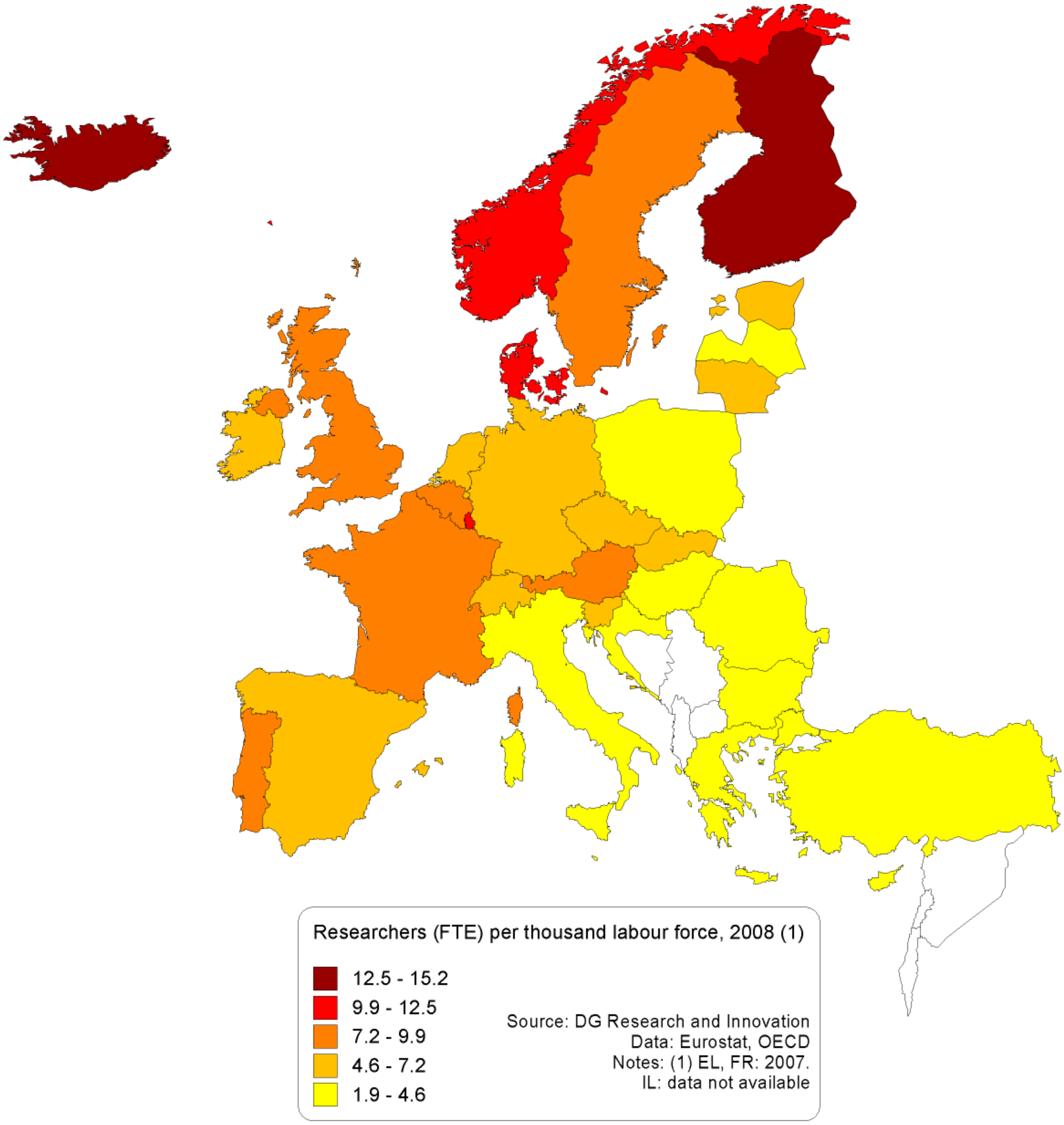


Table I.4.4 Total researchers (FTE) and business enterprise researchers (FTE), 2000 and 2008

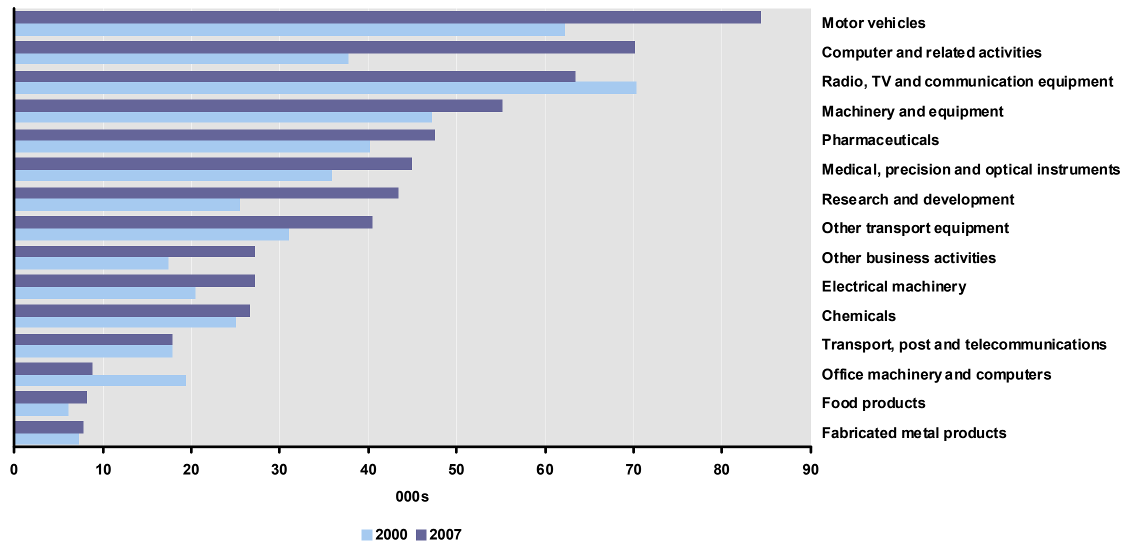
	Total researchers (FTE)			Business enterprise researchers (FTE)		
	2000 (1)	2008 (2)	Average annual growth 2000-2008 (3) (4)	2000 (5)	2008 (6)	Average annual growth 2000-2008 (7) (8)
Belgium	30540	*36382*	*2,2*	16684	*17838*	*0,8*
Bulgaria	9479	*11384*	*2,3*	1139	*1491*	*3,4*
Czech Republic	13852	29785	7,2	5533	13253	9,3
Denmark	25547	*30945*	*2,6*	15747	*19634*	*2,6*
Germany	257874	*299000*	*1,9*	*153120*	*178000*	*1,9*
Estonia	2666	*3979*	*5,1*	274	*1233*	*20,7*
Ireland	8516	13709	6,1	5631	*7428*	*3,5*
Greece	14371	*20817*	*6,4*	3234	*6090*	*9,5*
Spain	76670	130986	6,9	20869	46375	11,3
France	172070	215755	3,3	88479	118568	5,0
Italy	66110	*96303*	*4,8*	26099	*35645*	*3,5*
Cyprus	303	*885*	*14,3*	77	*205*	*13,0*
Latvia	3814	4370	1,7	995	487	-8,5
Lithuania	7777	8458	1,1	288	1168	19,1
Luxembourg	1646	*2282*	*4,2*	1399	*1537*	*1,2*
Hungary	14406	18504	5,6	3901	7912	9,2
Malta	436	*524*	*4,7*	199	*249*	*5,8*
Netherlands	42088	*51052*	*2,4*	20022	*26578*	*3,6*
Austria	24124	*34377*	*6,1*	16001	*21769*	*5,3*
Poland	55174	*61831*	*1,4*	9821	*8934*	*-1,2*
Portugal	*16738*	*40563*	*11,7*	*2358*	*10589*	*20,7*
Romania	20476	19394	-0,7	12690	6309	-8,4
Slovenia	4336	7032	6,2	1380	3058	10,5
Slovakia	9955	12587	3,0	2420	1649	-4,7
Finland	41004	40879	-0,1	23397	24132	0,8
Sweden	45995	*48220*	*0,9*	27884	*33378*	*7,9*
United Kingdom	*170554*	*261406*	*1,7*	91145	*94279*	*0,5*
EU (5)	*1118988*	*1504575*	*3,8*	*524844*	*689867*	*3,5*
Iceland	1859	2308	3,1	853	1117	3,9
Norway	20048	26006	3,8	11296	13305	2,4
Switzerland	26105	25142	-0,5	16275	10332	-5,5
Croatia	8572	6697	-4,0	1253	1098	-2,2
Turkey	23083	57759	10,7	3702	21019	21,3
United States	*1293582*	*1412639*	*1,3*	1041300	1130500	1,2
Japan	647572	656676	1,9	421363	492805	2,0

Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat
Notes: (1) EL, SE, IS, NO: 2001; DK, AT, HR: 2002; MT, FI: 2004.
(2) EL, FR, US: 2007; TR: 2009.
(3) EL: 2001-2007; IS, NO: 2001-2008; JP: 2002-2007; AT, HR: 2002-2008; HU, MT, FI: 2004-2008; CZ, UK: 2005-2008; DK, SE: 2007-2008.
(4) CZ, DK, HU, NL, SE, UK, JP: Breaks in series occur between 2000 and 2008.
(5) EL, FR, SE, UK, IS, NO: 2001; DK, AT, HR: 2002; MT, FI: 2004.
(6) EL, FR: 2007; IT, TR: 2009.
(7) EL: 2000-2007; FR: 2001-2007; UK, IS, NO: 2001-2008; ES: 2002-2007; AT, HR: 2002-2008; MT, FI: 2004-2008; CZ: 2005-2008; DK, SE: 2007-2008.
(8) CZ, DK, ES, SE: Breaks in series occur between 2000 and 2008.
(9) Values in italics are estimated or provisional.

The main increase in the number of researchers (FTEs) in the business sector from 2000 to 2007 took place in the sector of Computer and related activities with growth of over 86 %

The number of researchers in FTEs in the business sector by selected NACE Rev.1.1 sectors in 2000 and 2007 is presented in Figure I.4.10. The stock of researchers in the business enterprise sector grows unevenly between the various sectors of economic activity. Most sectors have experienced an increase in the number of researchers employed, except for Office machinery and computers, and for Radio, TV and communication equipment, reflecting the decrease in competitiveness of the European industry in those domains. Other sectors, however, have increased substantially the stock of researchers: in Computer and related activities, Research and development, and other business activities, the overall increase in the period 2000–2007, is substantial (86 %, 71 %, and 56 %).

Figure I.4.10 EU - business enterprise researchers (FTE) (1) by selected NACE sector, 2000 and 2007



Source: DG Research and Innovation

Innovation Union Competitiveness Report 2011

Data: MORE Study: NIFU STEP based on Eurostat data.

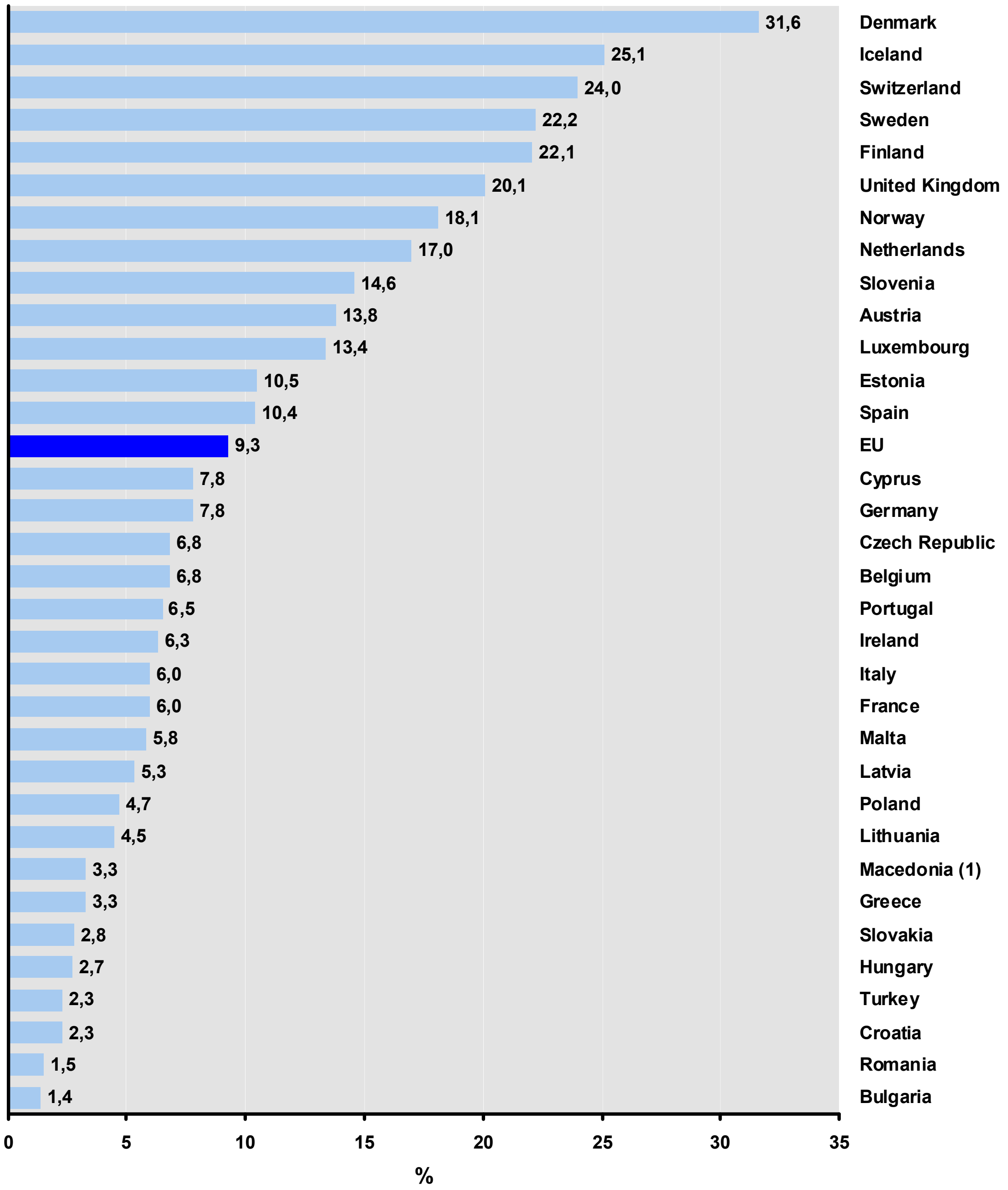
Note: (1) Estimated values.

The rate of participation in Adult Lifelong Learning is highest in Sweden, Denmark, Switzerland, Iceland and Finland, with more than 20% of the population aged 25–64 participating in education and training

Participation in measures of adult lifelong learning is crucial to keep the labour force skilled and up to date with progress in technology and innovation. This is particularly relevant with regard to the use of ICT-related innovations, as well as also to adaptation to new forms of organisations and innovation paradigms. Lifelong learning counters the depreciation of human capital, and might even increase the formation of skills and resources for innovation-related growth, as lifelong learning measures bring together the experience of trained people with new technologies and procedures. The overarching priority of the Lifelong Learning programme is to reinforce the contribution of education and training to the priorities and headline targets of the EU 2020 Strategy, which aims, amongst others, at enhancing creativity and innovation at all levels of education and training by promoting the acquisition of transversal key competences and by establishing partnerships with the wider world, in particular business, in order to make education and training institutions more open and relevant to the needs of the labour market and society at large. In 2009, the most performing countries in terms of innovation in the EU, Sweden, Denmark, Finland and the United Kingdom, together with Iceland and Switzerland[57] had more than 20% of population aged 25–64 participating in education and training. In contrast, adult lifelong learning is lowest in low performing countries, where 5% or less of the population aged 25–64 participated in lifelong learning measures.

[57] See the Innovation Union Scoreboard, 2010

Figure I.4.11 Participation in Adult lifelong learning - % share of population aged 25-64 participating in education and training, 2009



Source: DG Research and Innovation
Data: Eurostat
Note: (1) The former Yugoslav Republic of Macedonia.

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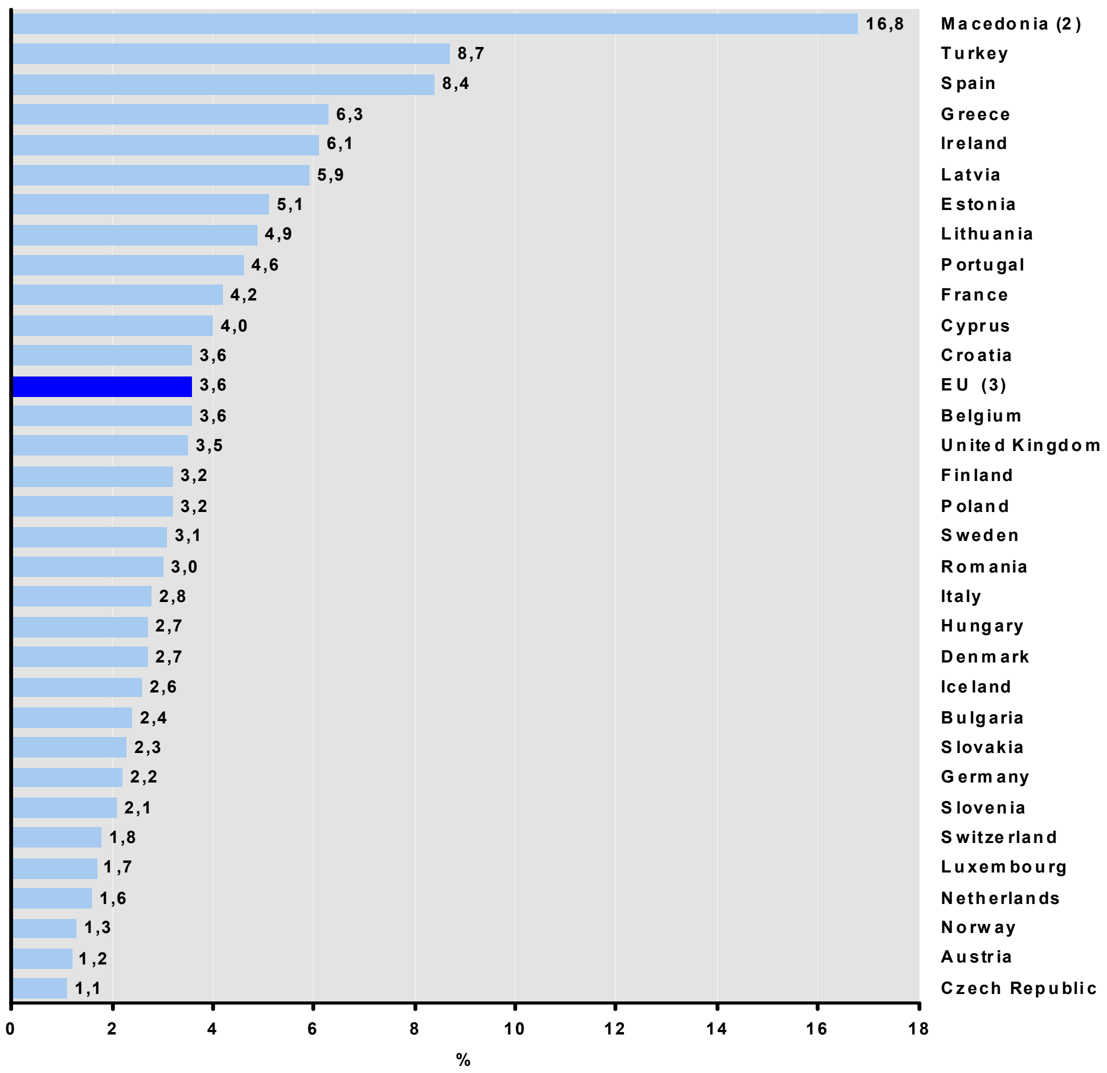
In an innovative economy there should be a shortage of Human Resources for Science and Technology. Albeit lower than global employment figures, the unemployment ratio in this category at European level remains significant

Figure I.4.12 presents the unemployment ratios available concerning the wider population of Human Resources in Science and Technology (HRST) in Europe in 2009. Unemployment of Human Resources for Science and Technology as share of total unemployment is highest in Macedonia, Turkey, Spain, Greece, Ireland and the three Baltic states. On the contrary, the Czech Republic, Austria and Norway have achieved unemployment ratios below 1.5%.

Figure I.4.12 Unemployed Human Resources in Science and Technology as % of total unemployment, 2009 (1)



Source: DG Research and Innovation
Data: Eurostat
Notes: (1) LU: 2008.
(2) The former Yugoslav Republic of Macedonia.
(3) EU does not include LU.

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5. Business sector investment in R&D

Highlights

At EU aggregate level, R&D expenditure financed by business enterprise has remained almost unchanged since 2000 at around 1.05 % of GDP. Additional business sources from abroad can be estimated at around 0.12 % of GDP, and private-non-profit funding of R&D amounts to 0.03 % of GDP in the EU, which brings R&D expenditure financed by private sources to 1.20 % of GDP at EU-27 aggregate level, far from the 2 % target.

Among Member States, with the exception of Austria and Slovenia, the sharpest increases between 2000 and 2009 are observed in countries that were at a very low level of business financed R&D (0.5 % of GDP and less). However, in addition to Austria and Slovenia, non-negligible increases also occurred in Denmark, Finland and Germany, which shows that further increases are still possible in Member States which already have high intensities of R&D financed by business.

Business R&D is more concentrated than GDP in Europe. Business R&D intensity is above 1 % of GDP in barely more than one quarter of NUTS 2 regions. However, innovation is more than R&D: other intangible assets create value. Different structures of intangibles investment — in particular the respective weights of R&D investment and organisational investment in total investment in intangibles — point to different innovation models across countries.

In 2007, R&D expenditure by affiliates of foreign parent companies represented between 20 % and 70 % of domestic business R&D expenditure in European countries[58]. In each of them, this share has not changed much since 2000, except in Poland, the Czech Republic and Slovakia where it increased substantially.

In the manufacturing sector, which performs most of total business R&D, foreign R&D expenditure is predominantly intra-European. In addition, despite a rising share of emerging countries in overseas R&D expenditures of US multinationals, Europe remains by far the most important location for US overseas R&D.

Altogether, in the four economies — the EU, the United States, South Korea and Japan — the main R&D performing sectors are manufacturing high-tech and medium high-tech sectors that make more than 70 % of total BERD in each economy. Manufacturing high-tech sectors, in particular, largely determine the overall level of business R&D intensity in a country.

In the EU, most of the sectors that perform the vast majority (80 %) of the EU BERD — in particular the manufacturing high-tech sectors — have become more research intensive since 1995. However, at the same time, the weight of these sectors in the EU economy has decreased, counterbalancing the research intensification observed at sector level. Overall, the result is a limited increase in the EU business R&D intensity since 1995 and stagnation since 2000.

[58] A large part of R&D expenditure by foreign affiliates in a country is financed locally, i.e. without funds coming from abroad. This high share of domestic business R&D performed by foreign affiliates in Europe is therefore consistent with a much lower share of domestic business R&D funded by business abroad.

Important conclusions can be drawn about the relationship between a country's R&D investment in the business sector and its economic structure, by comparison with countries outside the EU:
- The main reason for the R&D gap between the EU and the United States in manufacturing industry is the *larger* and *more research intensive* American high-tech industry;
- The very high business R&D intensity of South Korea is linked to the structure of its economy, clearly less dominated by services than the EU or the United States (the weight of the main high-tech and medium high-tech sectors in South Korea's economy is almost twice as large as in the EU or US economy).
- The very high business R&D intensity of Japan (and its growth) highlights an exceptionally high and growing research intensity in particular in the high-tech sector 'office machinery and computers', and in large, medium high-tech sectors that are more research-intensive than in the other economies. In addition, the weight of the high-tech sectors in Japan's economy is one third larger than in the EU's economy.

Within the high-tech industry, ICT sectors play a prominent role in business R&D. Worldwide, the ICT industry occupies and maintains its position as a leading R&D investing sector by R&D expenditure and patenting activity. The chapter shows that:
- Europe has been, and is still, lagging behind its main competitors in terms of ICT R&D investment and ICT R&D patenting, with significant differences between the Member States. There are significant differences across ICT sub-sectors indicating regional specialisation and also differentiating dynamics between the EU, US and Asian countries.
- This lag is largely due to the share of the EU ICT sector in the economy, its industrial composition and the size of its companies. For example, large EU ICT companies are smaller than their US equivalents, and did not grow as quickly in the last few decades. This is a particular weakness in the most promising segments, for example in the 'computer services and software' sub-sector, where EU Internet companies have failed so far to achieve a truly global scale. A growing part of the R&D gap can be observed in this sector.
- Europe is an important location for foreign ICT R&D investment, but international cooperation in R&D is evolving from a dominant EU–US relationship to global networking where the US–Asia relationship is taking a growing share. Here too, it seems that US companies are grasping opportunities more rapidly than EU ones.

These findings point to the need for structural change in EU's economy to ensure its competitiveness in an increasingly knowledge-based world economy. A broader analysis of EU's structural change is presented in Part V.

5. Business sector investment in R&D

5.1. Is the business sector increasing its funding to R&D?

In the Europe 2020 Strategy, the EU has maintained its objective to devote 3 % of its GDP to R&D without specifying the relative efforts of the public and private sectors to reach this objective.

The 2002 Barcelona Objectives targeted an increase in both the overall expenditure on R&D (to approach 3 % of EU GDP allocated to R&D by 2010) and the share of R&D expenditure funded by the public and private sectors. According to the Barcelona Objectives, one third of total R&D expenditure should be funded by the public sector, two thirds by the private sector.

Chapter 3 focused on public funding of R&D. This chapter looks at private funding of R&D, i.e. funding by the business sector.

The evolution of R&D expenditure financed by business sector varies across Member States

At EU aggregate level, R&D expenditure financed by business sector has remained stable at around 1.05 % of GDP since 2000. Additional business sources from abroad can be estimated at around 0.12 % of GDP, and private-non-profit funding of R&D amounts to 0.03 % of GDP in the EU, which brings R&D expenditure financed by private sources to 1.20 % of GDP at EU-27 aggregate level, far from the 2 % target. In only two Member States, Finland and Sweden, business-financed R&D intensity is above of 2 % of GDP[59]. All other Member States are below 1.5 % of GDP, except Denmark, Germany and Austria[60] (see Box I.5.1).

Between 2000 and 2009[61], R&D expenditure financed by business sector as % of GDP increased in 16 Member States (Figure I.5.1). It grew by more than 200 % in Estonia and Portugal, by 50 % to 80 % in Cyprus, Hungary and Austria, and by 7 % to 50 % in Slovenia, Spain, Latvia, Italy, Denmark, Ireland, Bulgaria, Finland, Czech Republic, Germany and Malta. In contrast, the sharpest decreases (by 20 % and more) of R&D expenditure financed by the business sector are observed in Luxembourg, Sweden and Slovakia.

With the exception of Austria and Slovenia (see Box I.1.2 on Austria in Chapter 1 of this Part), the sharpest increases between 2000 and 2009 are observed in countries that were at a very low level of business-financed R&D (0.5 % of GDP and less). This is in part due to the simple statistical fact that absolute changes have different importance relative to the level of starting point, so that a very low starting point makes it possible to reach very high growth rates more easily. However, in addition to Austria and Slovenia, non-negligible increases also occurred in Denmark, Finland and Germany, which shows that further increases are still possible in Member States which already have high intensities of R&D financed by business.

A particular focus on the evolution of business-financed R&D expenditure in 2009 during the economic crisis is to be found in Chapter 2 of this Part.

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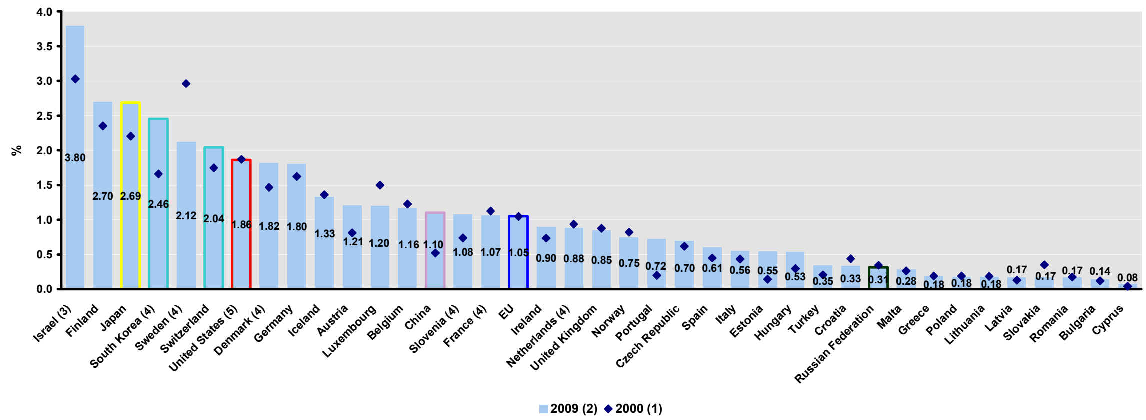
[59] Below the national private target of 3 % set by each of these two countries.

[60] In Austria , abroad-business financed R&D expenditure at the level of 0.41 % of GDP in 2007. If this value has been maintained until 2010, added to the 1.21 % of GDP financed by business enterprise in 2010 (Figure I.5.1 and footnote (2) to this figure) and with the addition of 0.01 % of GDP by private-non-profit sector, R&D financed by private sources amounted to 1.63 % of GDP in 2010 in Austria.

[61] For data availability reasons, the actual period covered differs across countries, see footnote to Figure I.5.1.

Figure I.5.1 GERD financed by business enterprise as % of GDP, 2000 (1) and 2009 (2)



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat, OECD
Notes: (1) DK, EL, SE, IS, NO: 2001; HR: 2002; IT, MT: 2005.
(2) EL: 2005; BE, LU, NL, NO, IL: 2007; EU, BG, DE, ES, FR, IT, CY, PT, IS, CH, US, JP, CN, KR : 2008; AT: 2010.
(3) IL: GERD does not include defence.
(4) DK, FR, NL, SI, SE, KR: Breaks in series occur between 2000 and 2009.
(5) US: GERD does not include most or all capital expenditure.

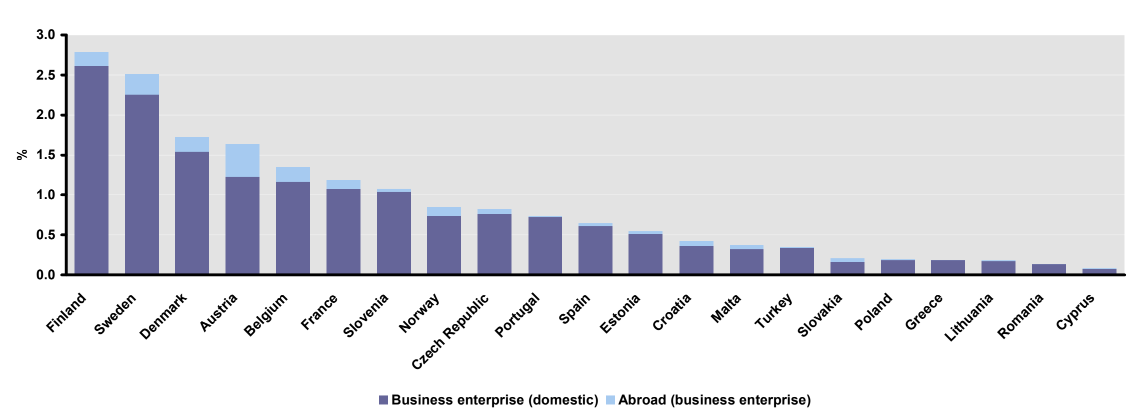
Please note that Figure I.5.1 is slightly changed due to change of value for Poland. I will send you this revised figure as the one you have may have a different value for Poland

Box I.5.1 — Business sources of funds for GERD: adding business funding from abroad to domestic business funding

When monitoring progress towards the EU 2 % target for private sources of funds for R&D, (domestic) business sector funding is used as a proxy for all private funding of R&D in a Member State. However, in any Member State, a 'business sector abroad' also finances R&D expenditure. Adding the business funding from abroad to domestic business funding gives a better account of the intensity of business funding for R&D in a Member State (Figure I.5.2). However, this data is not available in all Member States.

To exhaustively account for all private sources (beyond business sources), R&D financed by Private-Non-Profit (PNP) sector should also be added, to account for all private sources of funding for R&D. This source of funds is, however, very small on average in the EU (0.03 % of GDP) and not added in Figure I.5.2. Denmark, Sweden and the United Kingdom are the Member States with by far the largest amount of R&D financed by PNP, namely 0.08–0.09 % of GDP. Most Member States are around or below 0.03 % of GDP.

Figure I.5.2 GERD financed by business enterprise (domestic and abroad) as % of GDP, 2008 (1)



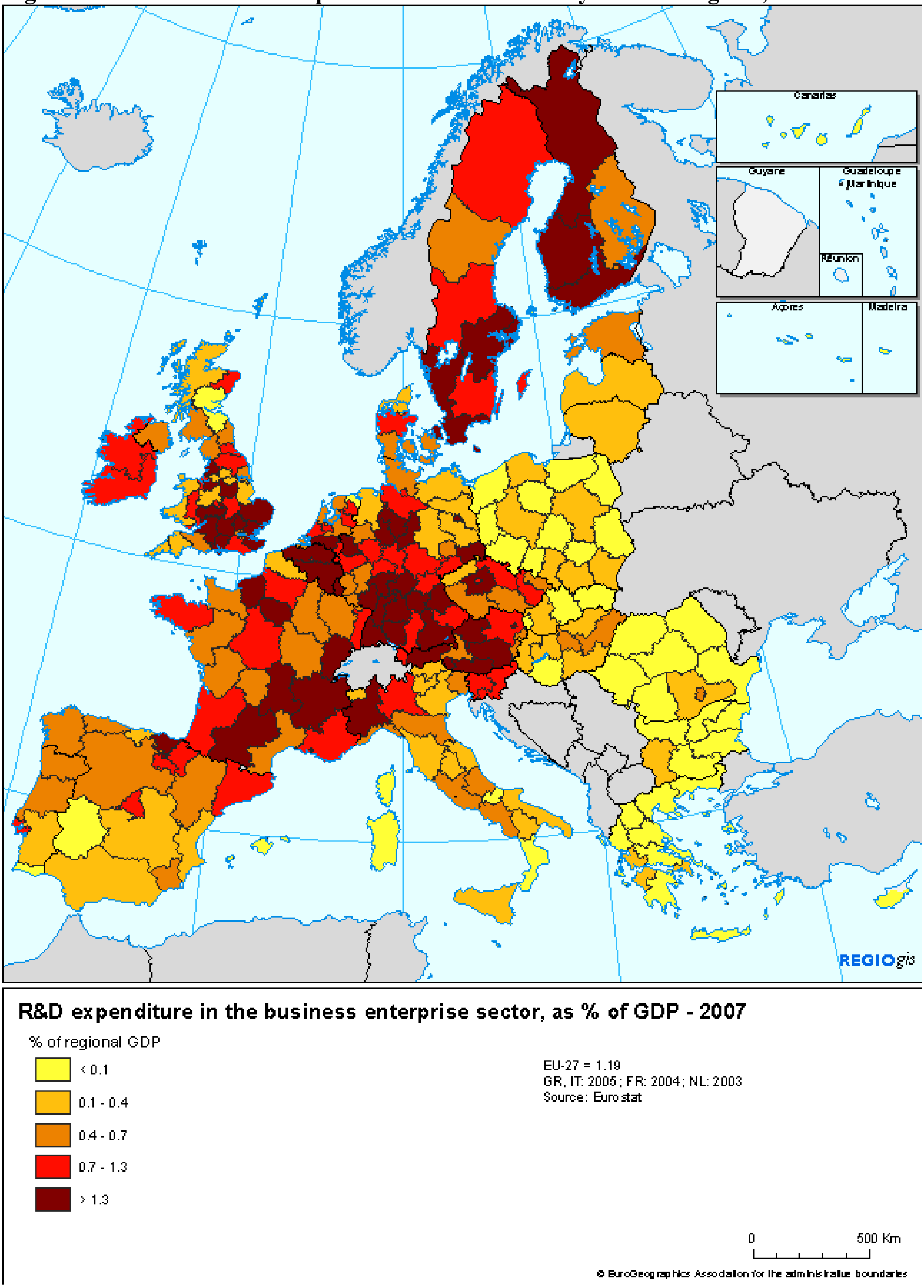
Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat
Notes: (1) EL: 2005; BE, DK, AT, SE, NO: 2007; SK: 2009.
(2) BG, DE, IE, IT, LV, LU, HU, NL and UK are not included on the graph because GERD financed by abroad (business enterprise) is not available for these Member States.

Business R&D intensity is above 1 % of GDP in barely more than one quarter of NUTS 2 regions

Out of the 268 EU NUTS 2 regions, only 32 (i.e. about 12 %) had in 2007 a business R&D intensity above 2 % of GDP, and 40 between 1 % and 2 %. These regions are located in Nordic countries, in France, and in a central band from Austria across the south of Germany, the Netherlands and Belgium to the South East of the United Kingdom. The business R&D intensity in most eastern and southern regions of the EU is below 0.5 % of GDP. R&D activities in these regions are often still dominated by public R&D activities.

However, a slight convergence was observed between 2000 and 2007, as many of the very low business R&D intensive regions, in particular in Southern, Central and Eastern Europe, have had a higher growth rate of business R&D intensity than the more business R&D intensive regions over that period.

Figure I.5.3. Business R&D expenditure as % of GDP by NUTS 2 regions, 2007



Innovation is more than R&D: other intangibles matter in creating value

Firms' efforts to create innovations require R&D, human capital (education) and skills (training), organisational capital, design and ICT along with tangible capital and adequate financial sources[62]. Investment in intangible assets is innovation-related investment.

The intensity of innovation efforts can be measured by investment in intangible assets (see Box I.5.2) in relation to GDP. Figure I.5.4 presents investment in intangibles (R&D, organisational competence, and other factors) as a share of conventional GDP in 2005, based on national accounts in Europe[63]. Investment in intangibles ranges from 9.1 % of GDP in Sweden and the United Kingdom to around 2 % of GDP in Greece. This is considerably higher than the scientific R&D investment (2.5 % of GDP in Sweden and 0.1 % of GDP in Greece, see Figure I.5.4)[64], which demonstrates the importance of intangibles for innovation and competitiveness in each country.

Box I.5.2 — Measuring investment in intangibles: the INNODRIVE project[65]

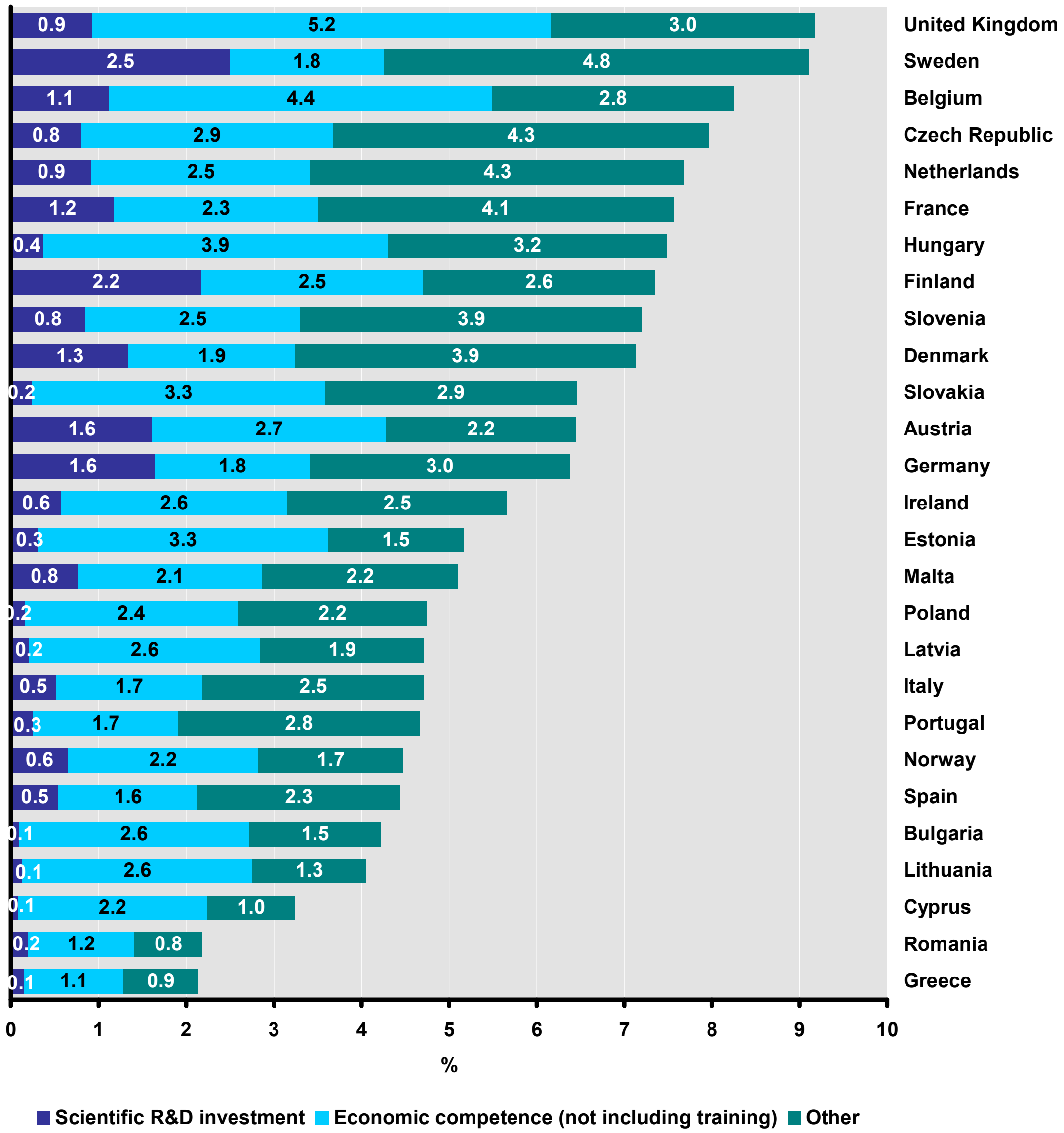
The European political agenda recognises the importance of investment in innovation as a driver of 'smart growth'. A central theme for the smart-growth strategy is that intangible assets need to be considered as innovation-related investment creating future value. Presently, intangibles are considered as cost and have not been included as investment in National Accounts; they are imprecisely valued in company-level balance of accounts. This means that their contribution to growth and productivity is not measured adequately.

INNODRIVE-project produces new estimates of intangibles for EU-27 countries and Norway following the Corrado, Hulten and Sichel (2006) typology[66]: computerised information (mainly software); innovative property (mainly scientific and non-scientific R&D, mineral exploration, copyright and licence costs, spending for artistic originals); economic/firm competences (spending on reputation, advertising, firm specific training and organisational capital).

All R&D-intensive countries (Sweden, Finland, Germany) tend also to rank above average in terms of their investment in intangibles. However, some countries that are not particularly R&D-intensive rank very high on this broader measure of innovation intensity (Belgium 8.3%; the Czech Republic 8 %; the Netherlands 7.7 %; France 7.6 %, Hungary 7.5 %). This result points to a type of innovation model which emphasises organisational competence as one of the key drivers of growth.. Sweden, the United Kingdom and France are also intensive in other types of intangibles (training, non-scientific capital, and database and software)[67].

62 The chain-link model of innovation and the national-innovation approaches stress these elements and their interactions.
63 In Luxembourg new financial product share is set at five times the EU27 average.
64 GDP measures come from national accounts which do not include the new intangibles. The capitalisation of intangibles implies an average increase of 5.5 per cent of the GDP for the EU-27 over the period 1995-2005 (See INNODRIVE Policy Brief February 2011).
65 Project funded by the FP7 SSH cooperation programme, Grant no. 214576.
66 Corrado/Hulten/ Sichel (2006), Intangible Capital and Economic Growth, NBER Working Paper No 11948, National Bureau of Economic Research, Cambridge, MA.
67 See INNODRIVE Policy Brief February 2011.

Figure I.5.4 Investment in intangibles as % of GDP, 2005

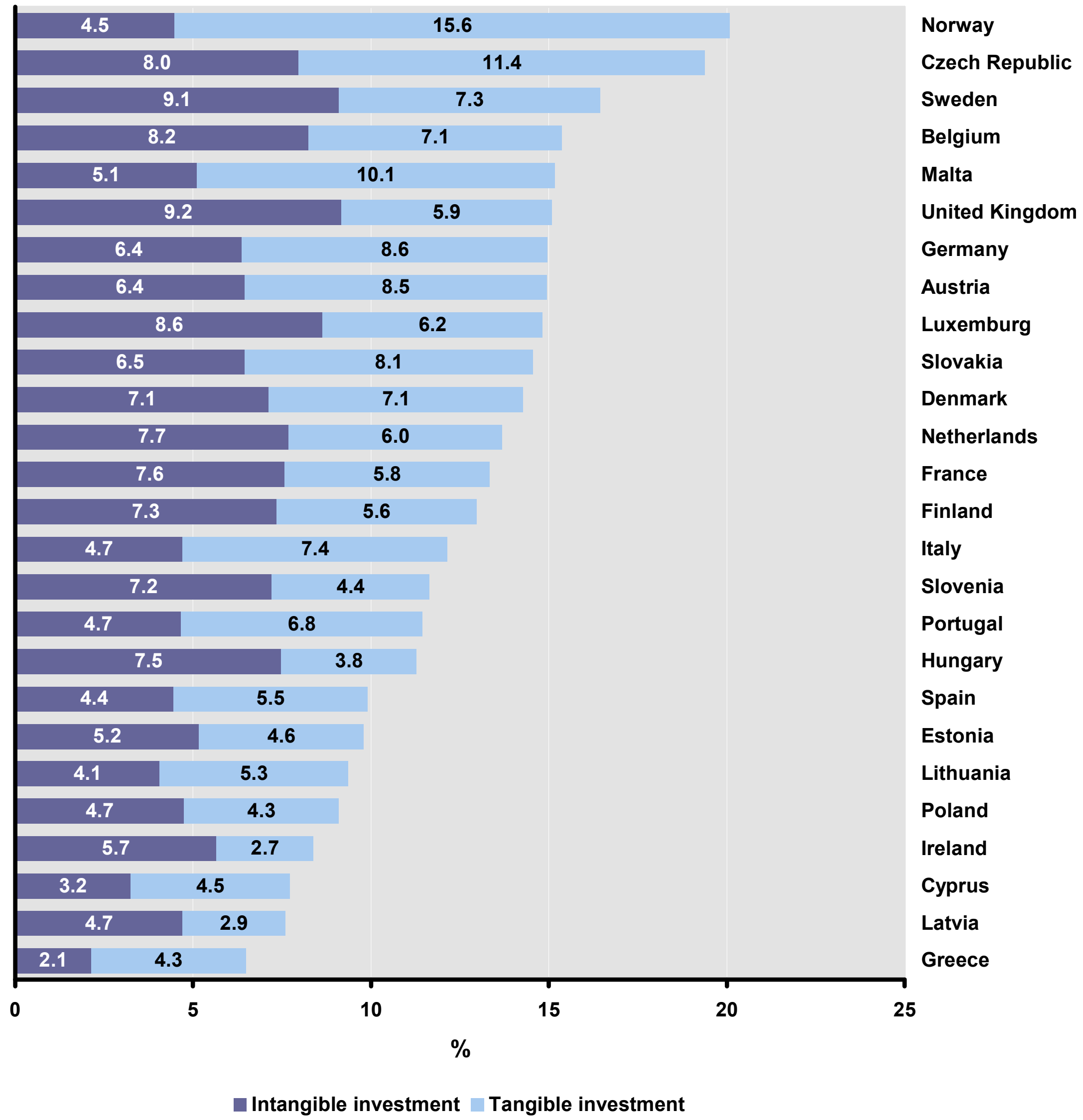


Source: DG Research and Innovation
Data: INNODRIVE project

Innovation Union Competitiveness Report 2011

Figure I.5.5 shows the relative importance of intangibles in overall investment, which can be seen as an indication of the degree of transition towards a knowledge economy in 2005.

Figure I.5.5 Intangible and tangible investment as % of GDP, 2005



Source: DG Research and Innovation
Data: INNODRIVE project

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Different structures of intangible investment point to different innovation models across countries

The different structures of intangibles across countries point to different innovation models related to technological and non-technological innovations. The structure of intangibles differs considerably in the United Kingdom and Finland, which can be taken as two opposite examples of organisational-capital-driven and R&D-driven economies respectively[68].

Figures I.5.6 and I.5.7 show how the structure of intangible capital has evolved over the period 2000–2007 in Finland and 2000-2006 in the United Kingdom, based on firm-level data[69]. In Finland, according to the expenditure-based approach[70], the investment rate in all intangibles (R&D, ICT and organisational-capital investment) was around 6% of the new value added[71] in 2000 and 8% in 2007. The corresponding figures for the United Kingdom are 10% (2000) and almost 11% (2006). While the totals are close in these two countries, the composition is, however, very different: the total is dominated by organisational investment in the United Kingdom, but largely dominated by R&D investment in Finland.

When using a performance-based approach[72] the importance of organisational investment increases in both countries. This is explained by the widely observed gap between productivity and the wage costs of organisational workers. Using the performance-based approach, organisational investment is now closer to R&D investment in Finland. In the United Kingdom, organisational investment exceeds R&D investment regardless of the estimation method, although the difference seems to fade out in 2005–2006.

However, over the years 2000–2007, organisational investment (the largest component of organisational competence in the national estimates) has decreased in both countries when the productivity of organisational-type work is used to construct these estimates. This decline may call for new types of innovation policy measures which go beyond R&D investment.

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[68] INNODRIVE project collects firm-level data on intangibles for six European countries: Czech Republic, Finland, Germany, Norway, Slovenia and the United Kingdom.

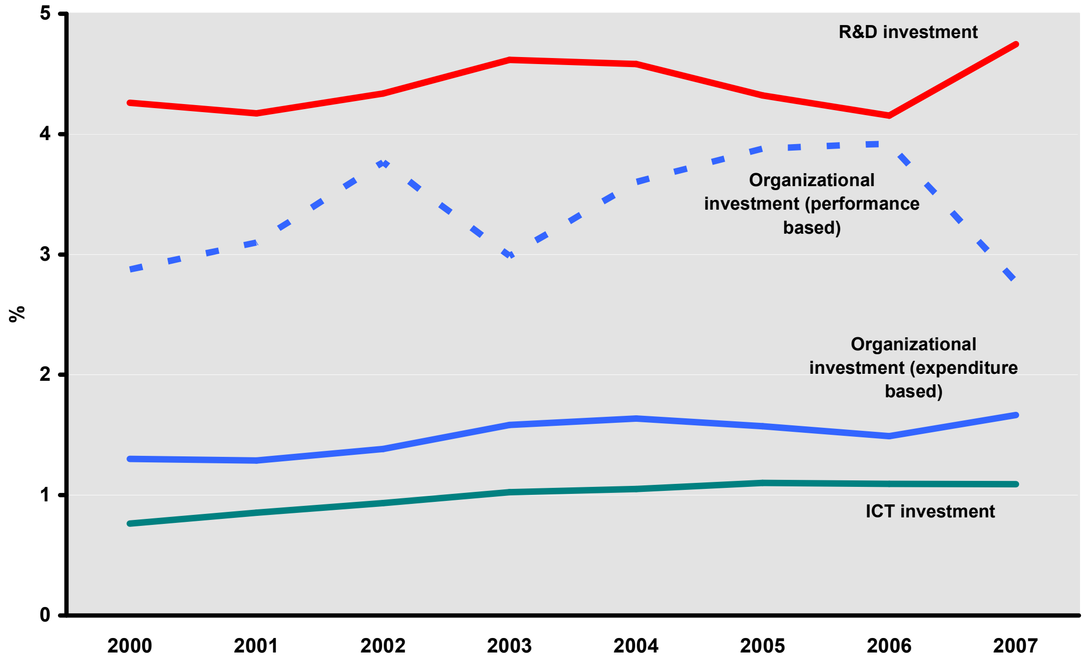
[69] The data collection methodology of INNODRIVE allows the aggregation of micro-level firms' data to national measures of intangible capital formation (expenditure-based approach to measure firms' investments). This methodology is a great advantage for various types of economic analysis.

[70] The expenditure-based approach gives only part of the picture regarding the value of intangibles when they are owned by the firm and when employees are not fully compensated for the value of intangible production.

[71] New value-added figures are generated in the respective business sectors to include investment in intangibles.

[72] The performance-based approach with productivity estimate replacing wage costs gives a better understanding about the value of intangibles when they are owned by the firm and employees are not fully compensated for the value of intangible production. This is explained by the widely observed gap between productivity and wage costs of organisational workers.

Figure I.5.6 Finland - investment in intangibles as % of new value added, 2000-2007 (1)

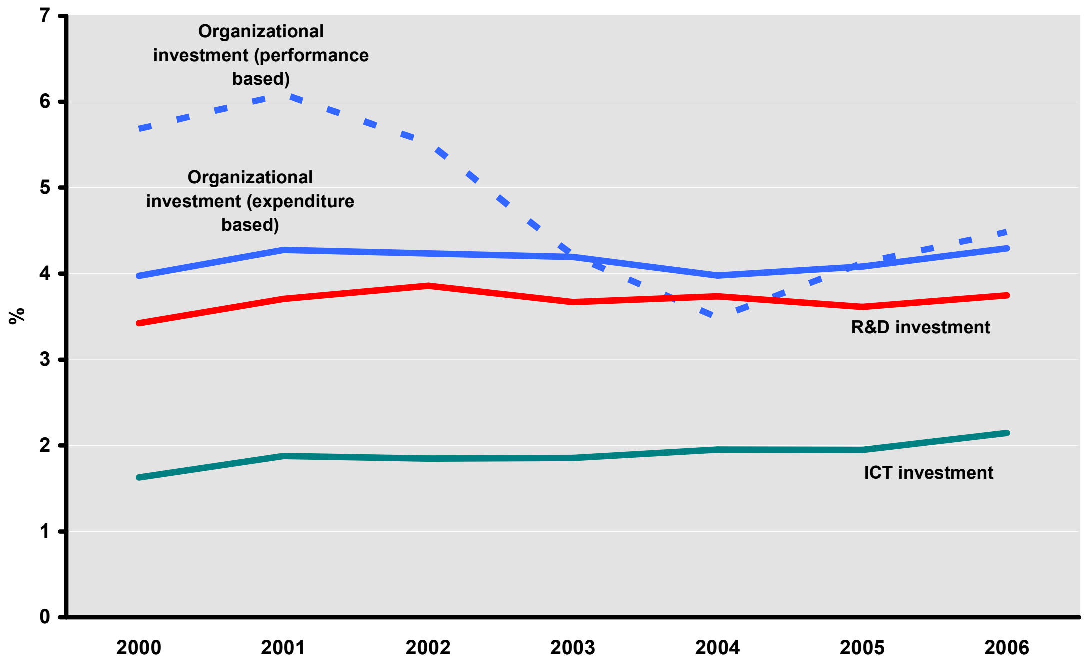


Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011

Data: INNODRIVE project, based on data from the Confederation of Finnish Industries, Asiakastieto company information database.

Note: (1) The data refer to the non-farm market sector. NACE 1.1 sections CA, DF, E, F, J are not included.

Figure I.5.7 United Kingdom - investment in intangibles as % of new value added, 2000-2006 (1)



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: INNODRIVE project, based on Annual Survey of Hours and Earnings, Labour Force Survey, Annual Business Inquiry.
Note: (1) The data refer to the non-farm market sector. NACE 1.1 sections CA, DF, E, F, J are not included.

5.2. Is Europe attracting foreign funding to R&D?

A large part of business R&D in the world is performed by a small group of companies operating on a global scale. Multinational enterprises (MNEs) play a major role in the internationalisation of R&D and innovation with their growing investment in R&D abroad. While the majority of the R&D investment is still concentrated in the home countries, often close to the MNEs' headquarters, foreign affiliates of MNEs play an important role within the multinational network when organising their R&D and innovation activities on a global scale.

In this section, a foreign affiliate is an enterprise resident in a country over which an institutional unit *not resident* in this country has control[73].

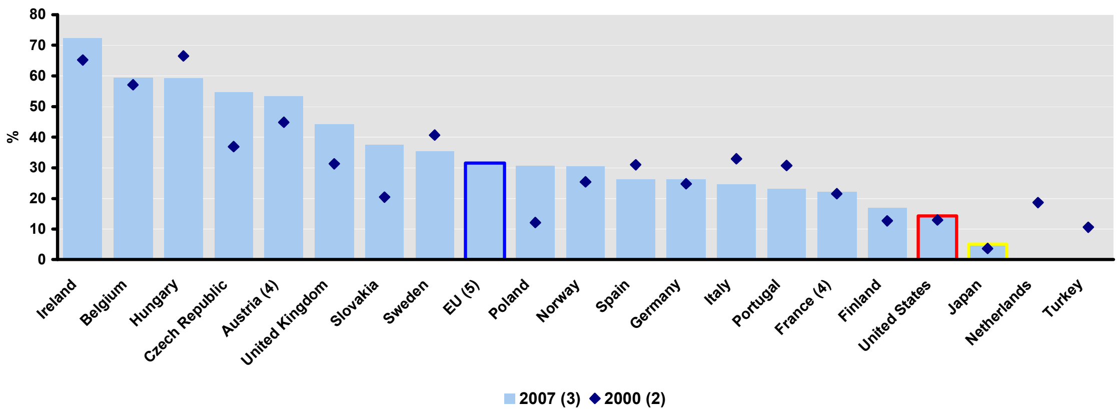
[73] Control is determined according to the concept of 'ultimate controlling institutional unit (UCI)'. The UCI is the institutional unit, proceeding up a foreign affiliate's chain of control, which is not controlled by another institutional unit. Foreign affiliates in a country can be created through greenfield investments of the parent foreign company or through acquisition of, or merger with, a domestic firm by a foreign firm. This definition includes affiliates of foreign affiliates.

In 2007, foreign R&D expenditure represented between 20 % and 70 % of domestic business R&D expenditure in European countries

In five of the sixteen European countries that provide this data, more than 50 % of domestic business R&D expenditure is performed by affiliates of foreign companies (inward R&D, figure I.5.8). For the eleven other European countries, the share of foreign affiliates in domestic business R&D ranges from 20 % (slightly less in Finland) to 45 %, compared to 14.3 % and 5.1 % in the United States and Japan respectively. Except for Ireland, the higher values observed in European countries are due to the intra-European cross-border business R&D investment which prevails (see below).

In the majority of the European countries that provide the data, the share of foreign affiliates in domestic business R&D has increased between 2000 and 2007. The increase in Poland, Czech Republic, Slovakia and the United Kingdom is particularly pronounced.

Figure I.5.8 Inward R&D expenditure (1) as % of R&D expenditure by business enterprise 2000 (2) and 2007 (3)

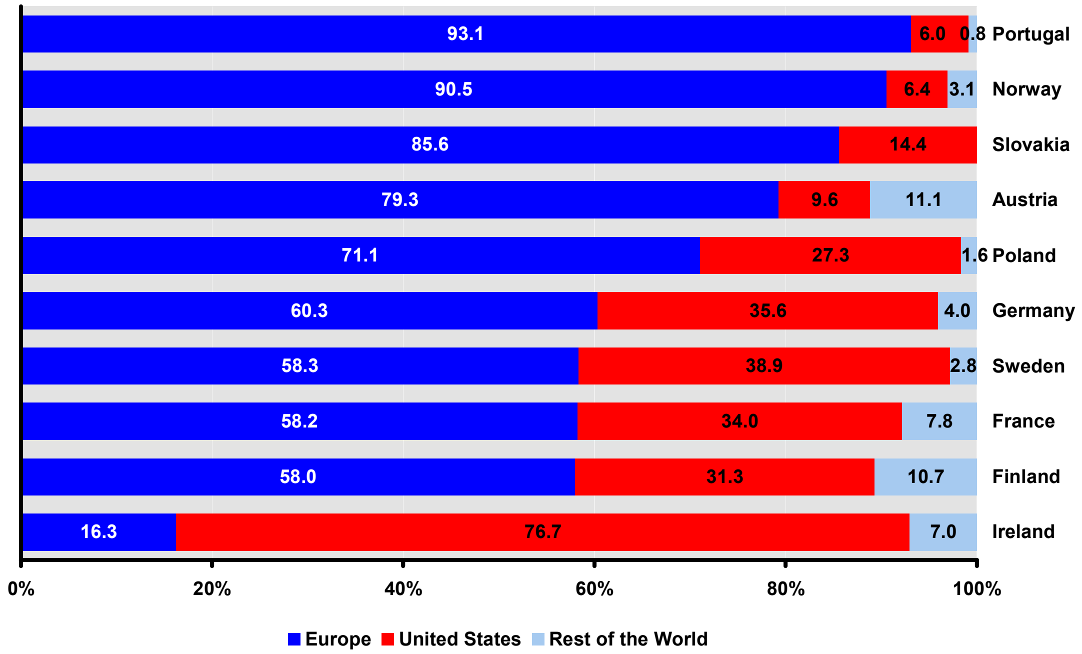


Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat, OECD
Notes: (1) R&D expenditure of foreign affiliates.
(2) DE, IE, ES, FR, IT, PT, SE: 2001; BE, HU, NO: 2003; AT: 2004.
(3) ES: 2005; FI: 2006; FR, IT, HU, UK, US: 2008; NL, TR: data are not available.
(4) FR, AT: Breaks in series occur between 2000 and 2008.
(5) EU does not include BG, DK, EE, EL, ES, CY, LV, LT, LU, MT, NL, RO, SI, FI.

Foreign R&D expenditure in the manufacturing sector are predominantly intra-European

Intra-European foreign R&D expenditure contributes significantly to the high shares of foreign R&D investment in European countries (Figure I.5.9). With the exception of Ireland, in all European countries for which this data is available, more than 58 % (and up to 93 %) of R&D expenditure by foreign affiliates in the manufacturing sector is performed by affiliates of a European parent company. In contrast, in Ireland, US firms are by far the largest foreign R&D investors.

Figure I.5.9 Inward R&D investment in manufacturing - % shares by investing region [(1)]



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: OECD
Note: (1) IE: 2005; FI: 2006.

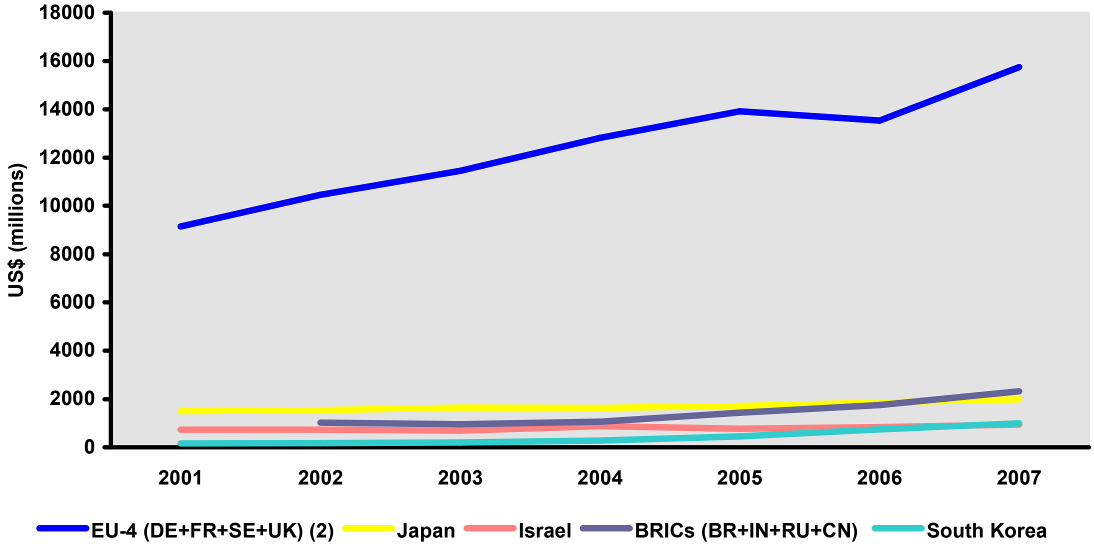
Although rising fast, R&D expenditure by affiliates of US companies in emerging countries is much smaller than their R&D expenditures in European countries

Figure I.5.10 below shows that Europe is still a very attractive location for overseas R&D activities for US companies. In contrast to the period 1995–2001, when the EU share of foreign US R&D investment dropped by almost 10 percentage points (from 70.4 % to 61 %)[74], the EU share remained stable between 2000 and 2007. In 2007, more than 60 % of US companies' overseas R&D expenditures were still located in EU-27.

The share of emerging countries (Brazil, Russia, India and China) and South Korea is rising, but the gap between the EU and these countries remains large. In absolute terms, inflows of US R&D expenditures to the EU are increasing. Therefore despite having a slightly decreasing share in overseas R&D expenditures of US multinationals, Europe remains by far the most important location for US overseas R&D.

[74] OECD, *The internationalisation of business R&D: evidence, impacts and implications*, DSTI/STP(2007)28, October 2007.

Figure I.5.10 R&D expenditure of overseas subsidiaries of United States multinational firms, 2001-2007 (3)



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Austrian Institute of Technology based on the OECD FATS database
Notes: (1) 2006 and 2007: Only majority-owned foreign affiliates.
(2) The four EU Member States in receipt of the most R&D expenditure of overseas subsidiaries of US multinational firms.

When examining company-level data, the share of R&D conducted by companies headquartered in the EU outside has increased slowly but steadily during recent years and is expected to continue to do so, particularly in India and China[75]. Not only do larger companies engage much more internationally, but the tendency for faster growth of R&D investment outside the EU has also been found in smaller companies[76]. Those companies that have been increasing their R&D over the period 2005–2011 invested predominantly within the EU (but also in China, India and the US), while those which decreased their R&D investment between 2005 and 2008 have done so exclusively in the EU (with R&D in the other three macro regions remaining stable or slightly increasing).

Both patterns suggest that an increasing share of the global BERD is being taken by emerging countries. From a policy-makers' point of view, concerns may arise if the structure of R&D investment in the EU is seriously affected, e.g. when critical mass of R&D for a certain sector is gradually lost. Yet, the trend for EU firms to locate R&D activities abroad, should not be seen as a trend to be reversed, as the study shows that the EU firms that exploit global technological expertise are also the companies that manage to maintain the strongest production activities in the EU. In fact, the absolute amount of R&D investment in the EU is expected to increase by around 40% between 2005 and 2012. This reveals that R&D internationalisation is not a zero-sum game but also a way to enrich the R&D activity at home.

[75] The 2009 EU Survey on R&D Investment Business Trends is part of the Industrial Research Investment Monitoring Activity of the Joint research Centre and DG RTD.
[76] Cincera, M., Cozza, C., Tübke, A. and Voigt, P.: 'Doing R&D or not, that is the question (in a crisis…), JRC-IPTS Working Papers on Corporate R&D and Innovation, 12/2010.

5.3. What is the link between the business R&D deficit and economic structure in Europe?

In the research-intensive economies, the business sector is the main funder of R&D (see Figure I.3.1) as well as the main performer of R&D. In the EU, the R&D intensity of the business sector was equal to 1.25 % of GDP in 2009, barely higher than in 2000 (1.21 % of GDP). In comparison, business R&D intensity amounted to 2.01 % of GDP in 2008 in the United States (as in 2000).

In each economy, the overall level of business R&D intensity results from the relative sizes of its economic sectors and their respective research intensities. About 85 % of business R&D is performed by the manufacturing industry in the EU. Combining the manufacturing industrial composition of the EU and the United States together with R&D intensity by type of manufacturing industry, gives the industrial composition of manufacturing R&D expenditure and its overall level in the EU and the United States.

A larger and more research-intensive high-tech industry in the United States explains a large part of the R&D gap between the EU and the United States in manufacturing industry

In manufacturing industry, R&D intensity — measured as R&D expenditure as a % of value added — varies greatly across sectors. The manufacturing sectors are usually grouped into four types of industry by decreasing order of R&D intensity[77]: high-tech, medium high-tech, medium low-tech and low-tech.

Figure I.5.11 (b) shows the average R&D intensity by type of industry for both the EU and the United States. The difference in R&D intensity across the four types of industry is clear-cut: in both economies, going from high-tech to low-tech, each industry type is several times less research-intensive than the one above and the research intensity is of a comparable order of magnitude (although not identical) on both sides of the Atlantic. Figure I.5.11 (b) therefore highlights how strong an influence the research intensity in high-tech and medium high-tech industries has on the overall level of business R&D intensity in an economy

The following observations can be made from Figure I.5.11:

- In both the EU and the United States, high-tech and medium high-tech sectors alone make up about 90 % of all manufacturing R&D (Panel c).
- Manufacturing R&D is largely dominated by high-tech sectors in the United States, while in the EU, the high-tech and medium high-tech sectors contribute to the same extent to total manufacturing R&D (Panel c).
- Relative to GDP, high-tech sectors perform R&D almost twice as much in the United States (0.87 % of GDP) as in the EU (0.46 % of GDP) (Panel c).
- This is because (i) the share of high-tech sectors in the US manufacturing industry is more than 40 % larger than the share of high-tech sectors in the EU manufacturing industry (17.7 % against 12.4 %, Panel a) and (ii) high-tech sectors are 60 % more research-intensive in the United States than in the EU (Panel b).

[77] Sectors included in each of these four types of industry are listed in the Methodological annex.

- The medium high-tech and low-tech sectors are also more research-intensive in the United States than in the EU (Panel b). Quantitatively, the higher research intensity of low-tech sectors in the United States has a limited impact on the overall level of business R&D expenditure. However, this may have important consequences on the innovative capacity and the productivity gains in low-tech sectors.

Among high-tech sectors, Information and Communication Technology (ICT) plays a central role in the EU business R&D deficit (see section I.5.5 below).

Figure I.5.11 (a) Manufacturing value added - % distribution by type of industry (1), 2006

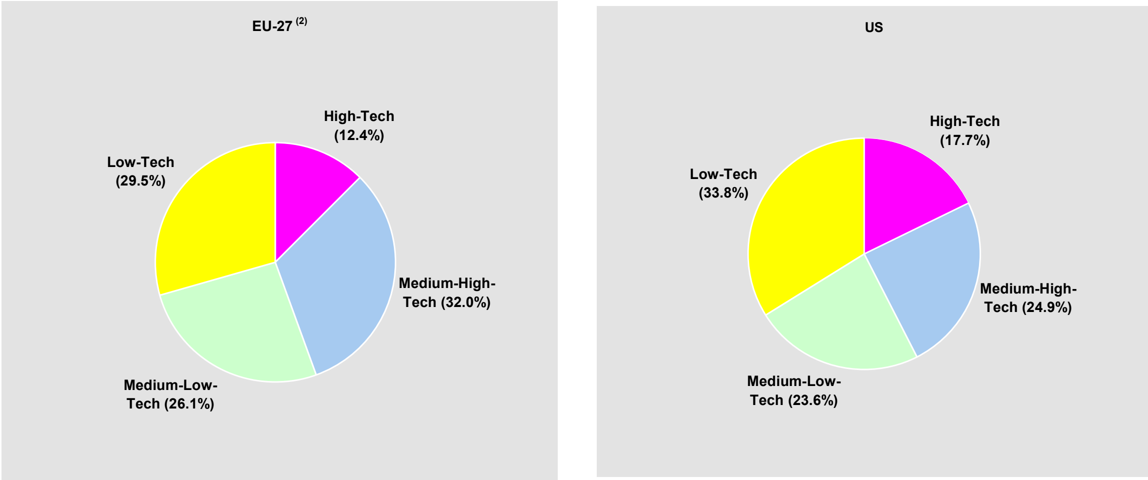


Figure I.5.11 (b) Manufacturing BERD (3) as % of manufacturing value added by type of industry (1), 2006

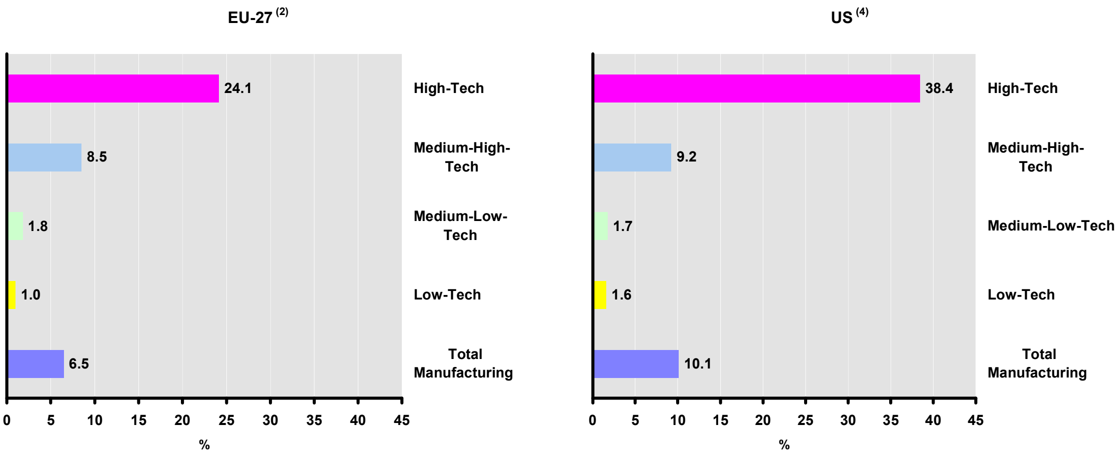
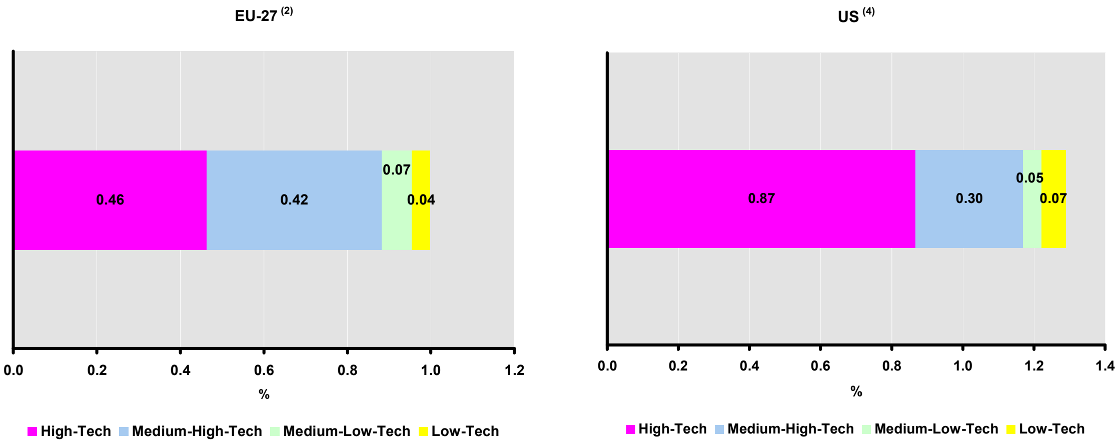


Figure I.5.11 (c) Manufacturing BERD (3) by type of industry (1) as % of total GDP, 2006



Source: DG Research and Innovation

Innovation Union Competitiveness Report 2011

Data: Eurostat, OECD

Notes: (1) See Methodological Annex for the list of sectors included in each type of industry.

(2) EU-27 does not include BG, EE, IE, EL, CY, LV, LT, LU, MT, PT, RO and SK. The 15 Member States included in the EU-27 aggregate account for more than 90% of Manufacturing Value Added and Manufacturing BERD in the EU.

(3) The Manufacturing BERD data for BE, FR, FI, SE, UK were classified by product field; the data for all other countries were classified by main activity.

(4) US: Building and repairing of ships and boats was included in medium high-tech rather than medium-low-tech.

Box I.5.3 - The role of 'young' innovative firms in research-intensive sectors

The 2010 EU Industrial R&D Investment Scoreboard (referred to as the Scoreboard in this section) presents information on the world's top 1 400 companies (1 000 non-EU and 400 EU) ranked by their investment in R&D. The Scoreboard finds that the sectoral composition of EU and US companies explains the R&D intensity gap between EU and US companies[78]. In addition, it highlights the role played by 'young' companies (created after 1975) in the gap:

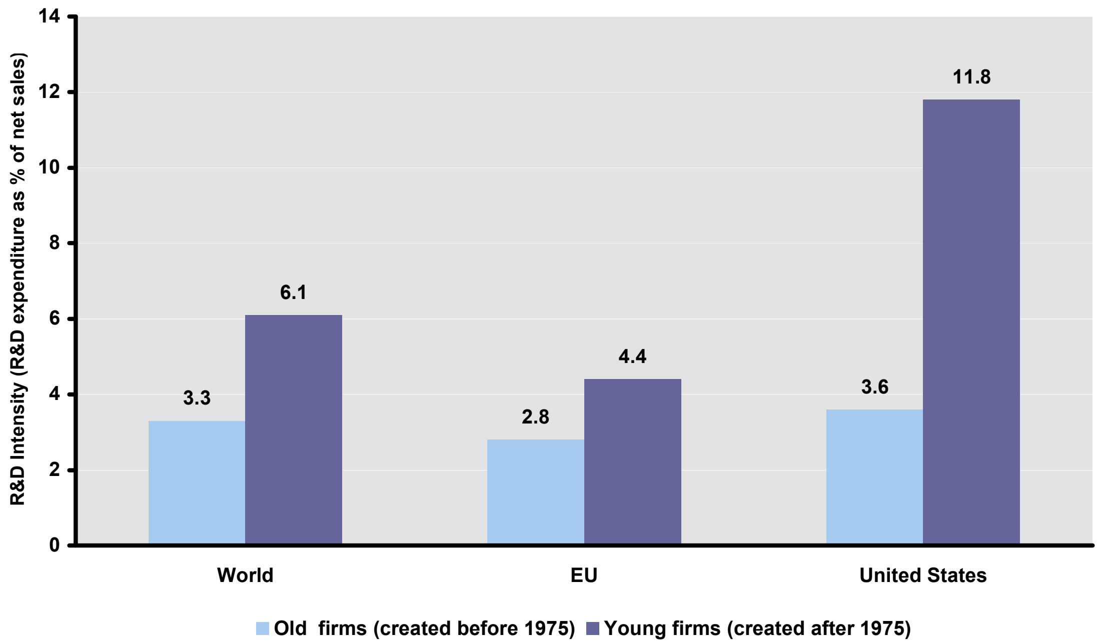
- Young companies on the Scoreboard are on average almost twice as research-intensive as old companies (3.3 % *vs* 6.1 % respectively, figure below). This suggests that young companies are more likely to be found in research-intensive sectors.

- Young companies on the Scoreboard represent 17.8 % of EU companies, while they represents 54.4 % of US companies (Figure I.5.13). This difference matters because young firms are more research-intensive than old firms.

- The EU-based young companies are much less research-intensive than their US counterparts (4.4 % vs 11.8 %, Figure I.5.12). This suggests that young companies are more concentrated in research-intensive sectors in the US.

Altogether, a large part of the business R&D intensity gap between EU and US companies comes from a smaller number of young innovative companies in the most research-intensive sectors. The EU business R&D gap is a consequence of its industrial structure, in which new firms fail to play a significant role in the dynamics of the industry, in particular in high-tech sectors.

Figure I.5.12 R&D Intensity of the EU and US *Scoreboard* companies by age of company

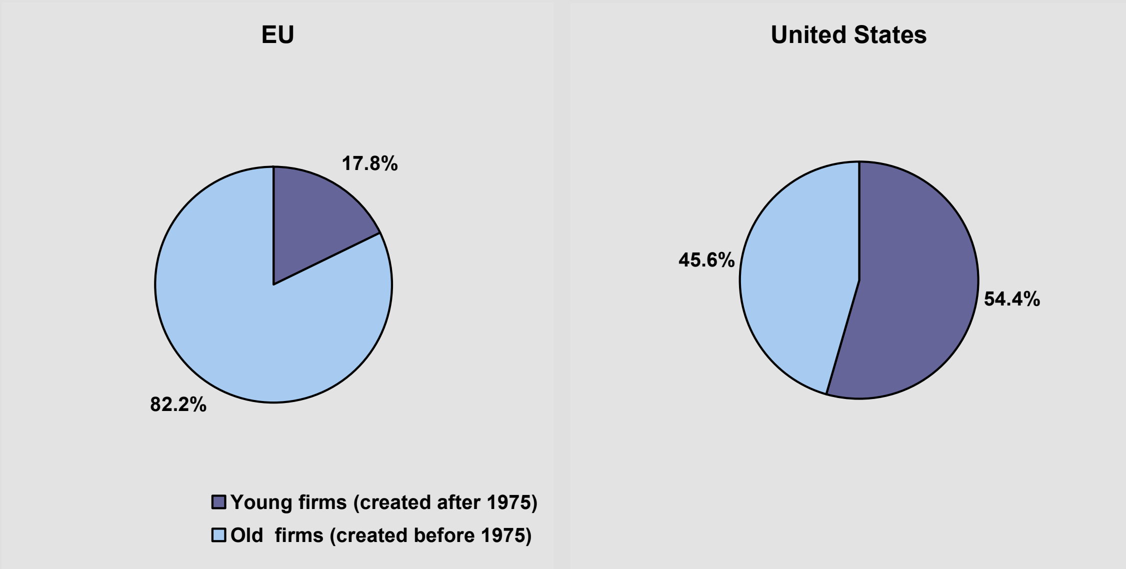


Source: DG Research and Innovation
Data: The 2010 EU Industrial R&D Investment Scoreboard

Innovation Union Competitiveness Report 2011

[78] The *Scoreboard* analyses R&D investments by top R&D-investing EU-based firms and US-based firms whatever the location of these investments. It therefore demonstrates the R&D intensity gap between top R&D-investing companies based on both sides of the Atlantic, which is not exactly the business R&D intensity gap between the EU and the US (which is about the R&D performed in the business sector on the territories of the EU and the US, whatever the nationality of the companies).

Figure I.5.13 Shares of young and old *Scoreboard* companies



Source: DG Research and Innovation
Data: The 2010 EU Industrial R&D Investment Scoreboard
Innovation Union Competitiveness Report 2011

The evolution of overall business R&D intensity and structural change were very much tied together in the three largest Member States between 1995 and 2006

The business R&D intensity is to a large extent determined by the structure of the economy. Statistically, an increase in value on this indicator can be caused by two possible phenomena: the weight of the research-intensive sectors grows in the economy (structural change) and/or the research intensity of individual economic sectors grows.

In Germany, France and the United Kingdom, 79%, 73% and 70% of total BERD in 2001–2006 was performed in the high-tech and medium high-tech sectors respectively. Between the two periods 1995–2000 and 2001–2006, business R&D intensity increased in the only country where these sectors gained some weight in the economy, namely Germany (Table I.5.1). This increased weight of high-tech and medium high-tech sectors in Germany's economy even out-weighted a general decline in research intensity of these sectors (Table I.5.2).

Table I.5.1 Evolution of structural change and business R&D Intensity in Germany, France and the United Kingdom, 1995-2006

	High-Tech Value Added as % of total Value Added (1)		High-Tech + Medium-High-Tech (2) Value Added as % of total Value Added (1)		BERD as % of GDP	
	1995-2000	2001-2006	1995-2000	2001-2006	1995-2000	2001-2006
Germany	2.2	2.5	11.7	12.4	1.6	1.7
France	2.2	2.0	6.5	5.7	1.4	1.4
United Kingdom (3)	2.6	2.2	7.5	5.6	1.2	1.1

Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Rindicate consortium, based on the OECD ANBERD and STAN databases
Notes: (1) The total value added of the economy.
(2) Medium-high-tech does not include 'Manufacture of other transport equipment'.
(3) UK: 'Office machinery and computers' is not included in high-tech (0.2% and 0.1% of total value added in DE and FR respectively.

Colour code: green = increase, red = decrease between 1995-2000 and 2001-2006.

In contrast, increased research-intensity in a number of individual high-tech and medium high-tech sectors did not allow France and the United Kingdom to compensate for the decrease in economic weight of these sectors. This observation highlights the close link between the evolution of overall business R&D intensity and structural change in the three large Member States since 1995[79].

Table I.5.2 Evolution of the R&D Intensity of high-tech and medium-high-tech (1) industrial sectors in Germany, France and the United Kingdom, 1995-2006

	NACE code	Industry	Germany		France		United Kingdom (2)	
			1995-2000	2001-2006	1995-2000	2001-2006	1995-2000	2001-2006
High-Tech	24.4	Pharmaceuticals, medicinal chemicals and botanical products	24,2	22,2	32,9	32,2	45,5	45,0
High-Tech	30	Office machinery and computers	18,3	15,0	32,7	23,1	: (2)	: (2)
High-Tech	32	Radio, television and communication equipment and apparatus	37,2	32,0	35,3	44,9	12,8	23,4
High-Tech	33	Medical, precision and optical instruments, watches and clocks	11,7	14,1	21,1	17,6	8,2	9,3
High-Tech	35.3	Aircraft and spacecraft	54,2	31,2	44,4	41,1	21,9	29,8
Medium-High-Tech	24 less 24.4	Chemicals and chemical products, excluding pharmaceuticals	11,4	10,0	9,4	12,0	6,7	6,5
Medium-High-Tech	29	Machinery and equipment	5,7	5,8	5,0	5,9	4,9	6,0
Medium-High-Tech	31	Electrical machinery and apparatus	4,1	3,6	7,5	9,9	8,2	8,2
Medium-High-Tech	34	Motor vehicles, trailers and semi-trailers	16,6	18,2	13,4	22,0	10,2	9,9

Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Rindicate consortium, based on the OECD ANBERD and STAN databases
Notes: (1) Medium-high-tech does not include 'Manufacture of other transport equipment'.
(2) UK: 'Office machinery and computers' is not among the top R&D performing sectors in the UK.

Colour code: green = increase, red = decrease between 1995-2000 and 2001-2006,
grey = no significant change between 1995-2000 and 2001-2006

[79] The R&D intensity of an economy is mathematically related to the share of research-intensive sectors in the economy. Structural change can be driven by many factors, including R&D activities themselves.

5.4. Which are the top ten performing economic sectors in R&D?[80]

This section gives an overview of the main features that characterise the evolution of business R&D intensity in the EU and its main competitors, in terms of the evolution of both the research intensity of the different economic sectors and their respective weights in the economy.

The two tables below show the research intensity and the weight in terms of value added (VA) of the 7 to 10 main R&D performing sectors in each economy (the EU, the United States, Japan, South Korea). These 7 to 10 sectors make 70 % to 80 % of total BERD in each economy. These sectors are almost exclusively manufacturing high-tech and medium high-tech sectors, but some are services sectors whose importance in an economy's BERD — despite their low R&D intensity — comes from their large size in the economy.

Comparability of BERD data at industry level across countries is not fully ensured, as methods and practices to allocate business R&D expenditures to the different sectors differ across countries. Therefore, it is preferable to compare the parallel evolutions (of the sectoral research intensities and of the sectoral composition) over time in each economy rather than the actual values of sectoral R&D intensities in the different economies.

The research intensity of most of the main R&D performing sectors, in particular the manufacturing high-tech sectors, grew between 1995 and 2006 in the EU, United States, Japan and South Korea

Table I.5.3 shows that 8 out of the 10 sectors that make the bulk of EU BERD have become more research intensive (green) over the decade 1995–2006. In particular, the manufacturing high-tech and medium high-tech sectors, which are the most R&D-intensive in the economy, have become more research-intensive, apart from Aerospace and Chemicals (red).

In comparison, in the United States the high-tech sectors have seen a much more dramatic increase of their R&D intensity than in Europe, apart from Aerospace, whose R&D intensity declined even more sharply than in Europe. The R&D intensity of high-tech sectors is markedly higher in the United States than in the EU over the period 2001–2006.[81] Particularly astonishing is the difference in R&D intensity of the sector Medical, precision and optical instruments which is almost three times more research intensive in the United States.

In South Korea, research intensity increased in all the main high-tech and medium high-tech sectors of that country, but the different high-tech sectors remain markedly less research-intensive than in the EU and the United States, while the medium high-tech sectors are of comparable research intensity. What makes the difference in the case of South Korea is that high-tech and medium high-tech sectors have a significantly higher weight in the economy than in the case of the EU and the United States (see Table I.5.4), especially 'radio, TV and communication equipment' (one of the high-tech sectors) and 'motor vehicles' (one of the medium high-tech sectors). Due to their size in the economy, these two sectors together concentrate about 60 % of total BERD in South Korea.

[80] This section is based on the study '*Sectoral analysis of the long-term dynamics of business R&D intensity*', commissioned by DG Research and conducted by the Rindicate consortium in 2009.

[81] It is to be noted that the fact that the intensity of the services sectors in the United States is markedly higher than the EU is partly due to the method used in the US to classify R&D expenditures into sectors.

In Japan, the high-tech sector ‘office machinery and computers’ is exceptionally research-intensive, on the order of four to five times more research-intensive than the other high-tech sectors in Japan, the United States or the EU. The medium high-tech sectors in Japan are substantially more research-intensive than in the EU and the United States (up to four times more), in particular ‘chemicals’ and ‘electrical machinery’. Research intensity increased in all the main R&D performing high-tech and medium high-tech sectors in Japan, apart from ‘radio, TV and communication equipment’ which very slightly decreased.

Research intensity of high-tech and medium high-tech sectors in China are clearly lower but they refer to the year 2000 and are therefore largely outdated. Therefore, China is not included in Table I.5.3 below.

Table I.5.3 Evolution of the R&D intensity of the most important R&D performing industries in each country [(1)]
EU: The top 10 R&D performing industries make up 80% of BERD.
United States: The top 7 R&D perfoming industries make up 70% of BERD.
Japan: The top 7 R&D perfoming industries make up more than 75% of BERD.
South Korea: The top 8 R&D perfoming industries make up 80% of BERD.

	NACE code	Industry	EU		United States		South Korea		Japan		Highest value
			1995-2000	2001-2006	1995-2000	2001-2006	1995-2000	2001-2006	1995-2000	2001-2006	
		Total BERD intensity (expenditure / value added)	1,36	1,41	1,93	1,86	1,92	2,44	1,99	2,34	2.44 (KR)
Manufacturing – High-Tech	24.4	Pharmaceuticals, medicinal chemicals and botanical products	25,4	26,4	25,3	31,9	3,1	5,3	20,5	27,5	45.0 (UK)
Manufacturing – High-Tech	30	Office machinery and computers	:	:	:	:	10,6	11,4	36,0	115,6	115.6 (JP)
Manufacturing – High-Tech	32	Radio, television and communication equipment and apparatus	27,8	31,3	22,8	39,8	17,6	22,7	16,8	16,4	44.9 (FR)
Manufacturing – High-Tech	33	Medical, precision and optical instruments, watches and clocks	12,2	13,0	39,9	48,9	:	:	:	:	48.9 (US)
Manufacturing – High-Tech	35.3	Aircraft and spacecraft	37,3	33,4	32,8	22,4	:	:	:	:	41.1 (FR)
Manufacturing – Medium-High-Tech	24 less 24.4	Chemicals and chemical products excluding pharmaceuticals	7,8	7,4	:	:	4,7	6,2	14,8	16,8	16.8 (JP)
Manufacturing – Medium-High-Tech	29	Machinery and equipment	5,0	5,4	:	:	3,6	5,1	7,8	8,8	8.8 (JP)
Manufacturing – Medium-High-Tech	31	Electrical machinery and apparatus	5,0	5,0	:	:			18,1	21,0	21.0 (JP)
Manufacturing – Medium-High-Tech	34	Motor vehicles, trailers and semi-trailers	13,7	16,0	15,2	14,9	16,0	14,5	13,1	15,5	22.0 (FR)
Services	60-64	Transport, storage and communications	0,6	0,7	:	:	1,7	0,6	:	:	:
Services	72	Software services	2,8	3,8	12,5	14,7	:	:	:	:	:
Services	50-52	Wholesale and retail trade	:	:	1,5	1,0	:	:	:	:	:
	45	Construction	:	:	:	:	0,8	0,9	:	:	:

Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Rindicate consortium, based on the OECD ANBERD and STAN databases and on the EU KLEMS database
Note: (1) Only the top R&D performing sectors that account for more than 70% of R&D are considered for each country.

Colour code: green = increase, red = decrease between 1995-2000 and 2001-2006.

The economic weight of most of the main R&D-performing sectors declined between 1995 and 2006 in the EU, United States and Japan but increased in South Korea

Table I.5.4 shows that, with the exception of Pharmaceuticals and the two services sectors, all the sectors that perform most of the BERD in the EU saw a decline or a stagnation of their weight in the EU economy in terms of VA. The same holds in the United States. The decrease of the weight of high-tech sectors is more marked in the United States than in the EU, although it remains higher[82].

What is remarkable is that the main R&D performing high-tech and medium high-tech sectors in South Korea account for 14% of total VA in the economy, while the main R&D performing high-tech and medium high-tech sectors in the EU account for 7.8% of total VA in the EU. Compared to the 1995–2000 period, this weight of high-tech and medium high-

[82] See also the analysis of structural change in the EU in Part III, chapter 3.

tech sectors in South Korea even increased (from 12.8% of total VA). Although smaller than in South Korea, the share of the main R&D performing high-tech and medium high-tech sectors in Japan (9.6% of total VA) is also higher than in the EU (7.8% of total VA). However, this weight has slightly declined between 1995 and 2006, as in the EU. In South Korea, and to a lesser extent in Japan, the very high weight of high-tech sectors in the economy plays a determinant role in the high overall level of business R&D.

Table I.5.4 Evolution of the share in value added (1) of the most important R&D performing industries in each country (2)

EU: The top 10 R&D performing industries make up slightly less than 17% of value added.
United States: The top 9 R&D performing industries make up slightly more than 19% of value added.
Japan: The top 8 R&D performing industries make up slightly less than 10% of value added.
South Korea: The top 9 R&D performing industries make up slightly more than 30% of value added.

		NACE code	Industry	EU		United States		South Korea		Japan		Highest value
				1995-2000	2001-2006	1995-2000	2001-2006	1995-2000	2001-2006	1995-2000	2001-2006	
Manufacturing	High-Tech	24.4	Pharmaceuticals, medicinal chemicals and botanical products	0,60	0,68	0,54	0,66	0,89	0,91	0,63	0,68	0.91 (KR)
		30	Office machinery and computers	:	:	:	:	0,63	0,46	0,56	0,26	0.46 (KR)
		32	Radio, television and communication equipment and apparatus	0,63	0,52	1,07	0,61	3,85	4,90	2,04	1,92	4.90 (KR)
		33	Medical, precision and optical instruments, watches and clocks	0,60	0,61	0,44	0,36	:	:	0,33	0,31	0.90 (DE)
		35.3	Aircraft and spacecraft	0,28	0,28	0,53	0,49	:	:	:	:	0.60 (UK)
			Total High-Tech manufacturing	2,11	2,09	2,58	2,12	5,37	6,27	3,56	3,17	6.27 (KR)
	Medium-High-Tech	24 less 24.4	Chemicals and chemical product, excluding pharmaceuticals	1,49	1,28	1,21	1,00	2,14	2,03	1,19	1,00	2.03 (KR)
		29	Machinery and equipment	2,24	2,06	1,18	0,91	2,05	2,27	2,26	2,17	3.40 (DE)
		31	Electrical machinery and apparatus	0,99	0,85	:	:	0,98	1,07	1,14	0,94	1.07 (KR)
		34	Motor vehicles, trailers and semi-trailers	1,58	1,50	1,25	0,94	2,22	2,36	1,91	2,30	3.20 (DE)
			Total Medium-High-Tech manufacturing	6,30	5,69	3,64	2,85	7,39	7,73	6,50	6,41	7.73 (KR)
Services		60-64	Transport, storage and communications	6,68	6,85	:	:	6,86	7,35	:	:	:
		72	Software services	1,53	1,98	1,37	1,62	:	:	:	:	:
		50-52	Wholesale and retail trade	:	:	13,07	12,60	:	:	:	:	:
			Total Services	:	:	:	:	:	:	:	:	:
			Construction	:	:	:	:	10,54	9,06	:	:	:

Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Rindicate consortium, based on the OECD ANBERD and STAN databases and on the EU KLEMS database
Notes: (1) Share in the total value added of the economy.
(2) Only the top R&D performing sectors that account for more than 70% of R&D are considered for each country.

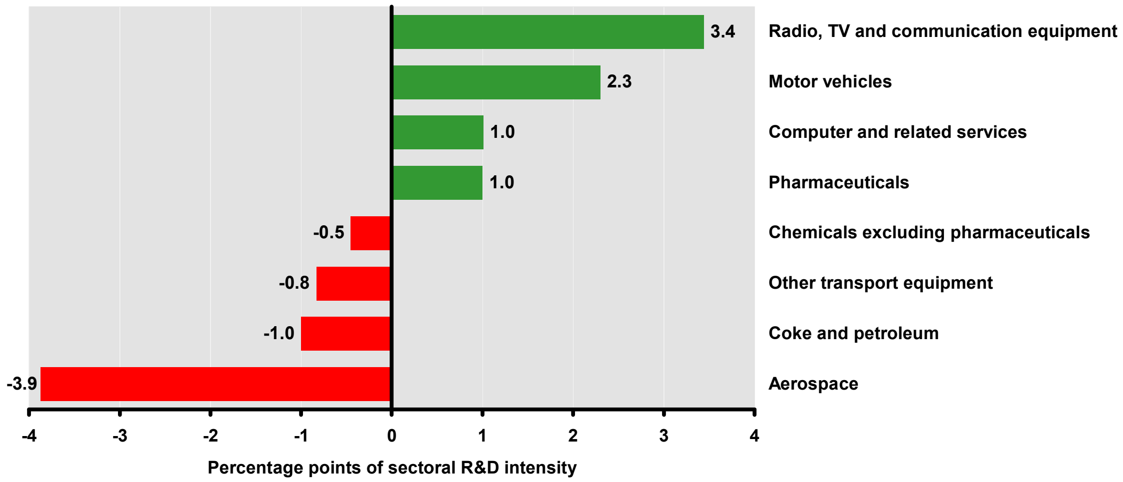
Colour code: green = increase, red = decrease, grey = no change between 1995-2000 and 2001-2006.

Several of the sectors with the largest R&D intensity gains and losses are the same in the EU and the United States

Figure I.5.14 presents the four sectors whose R&D intensity grew the fastest between the two periods 1995–2000 and 2001–2006 in the EU[83]. Two of them, 'Radio, TV and communication equipment and apparatus' and 'Pharmaceuticals', are high-tech sectors whose R&D intensity (R&D expenditures over value added) reached 31.2% and 26.4% respectively on average over the period 2001–2006 (from 27.8% and 25.4% respectively over 1995–2000). The medium high-tech sector 'Motor vehicles' progressed from 13.7% to 16%, while the service sector 'Computer and related services' progressed from 2.8% to 3.8%. The sector which experienced the largest fall in R&D intensity in the EU is the high-tech sector 'Aerospace' from 37.3% to 33.4%.

[83] The EU includes 11 Member States covering more than 90% of EU BERD: Germany, France, the United Kingdom, Italy, Sweden, Spain, the Netherlands, Belgium, Finland, Denmark and Ireland.

Figure I.5.14 R&D Intensity gains and losses in the EU (1) - sectors with the most significant gains and losses, 1995-2006 (2)



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Rindicate consortium, based on OECD ANBERD and STAN databases and EU KLEMS database.
Notes: (1) EU includes 11 Member States covering more than 90% of EU BERD: BE, DK, DE, IE, ES, FR, IT, NL, FI, SE, UK.
(2) The difference in average R&D Intensity between the two periods 2001-2006 and 1995-2000, in percentage points.

The trends in sectoral R&D intensity in the United States are similar to those of the EU, with 'Radio, TV and communication equipment and apparatus' and 'Pharmaceuticals' as top winners in R&D intensity, while 'Aerospace' and 'Chemicals (excluding "Pharmaceuticals")' saw their R&D intensity decline significantly between 1995 and 2006.

In Japan, an extraordinary increase in R&D intensity occurred in the high-tech sector 'Office machinery and computers' between the two periods 1995–2000 and 2001–2006. The atypical evolution of this sector is responsible for a large part of the overall increase in business R&D intensity in Japan. The R&D intensity of 'Pharmaceuticals' is also among the top winners in R&D intensity in Japan. However, in contrast to the EU and the United States, no economic sector experienced a decline in R&D intensity in Japan between 1995 and 2006.

Overall, the slight increase in business R&D intensity in the EU in 2001–2006 compared to 1995–2000 is linked to a research intensification of most of the sectors that perform the vast majority (80 %) of the EU BERD, in particular the high-tech sectors, while the weight of these sectors in the economy tended to decrease

The above tables show that the slight increase in business R&D intensity overall in the EU in the period 2001–2006 compared to 1995–2000 is due to a research *intensification* of most of the sectors that perform the vast majority (80 %) of the EU BERD, in particular the high-tech sectors, while the *weight* of these sectors in the economy tended to decrease, with the notable exception of 'Pharmaceuticals'.

In the United States, the same decline in the weight of high-tech and medium high-tech sectors is observed, while the increase in research intensity of the high-tech sectors is much larger than in the EU. However, in the United States in total, the decline in weight slightly over-compensates the gain in research intensity so that the overall business R&D intensity slightly declined in the United States.

The high business R&D intensity of South Korea comes from its economy's composition, which is clearly less dominated by services than the EU or the United States, with the main South Korean high-tech and medium high-tech sectors being almost twice as important in the South Korean economy as in the EU or US economy. In contrast, high-tech sectors in South Korea are clearly less research-intensive than in the EU or the United States.

The high business R&D intensity of Japan (and its growth) comes from the exceptionally high and growing research intensity of the high-tech sector 'Office machinery and computers' and from very research-intensive medium high-tech sectors. In addition, the weight of high-tech sectors in Japan's economy is one third larger than in the EU's economy, although it suffered from a decline between 1995 and 2006 as in the EU and the United States. In total, the high growth in research intensity of the above-mentioned sectors in Japan largely overcompensates their decline in economic weight.

Altogether, in the four economies of the EU, the United States, South Korea, and Japan, the main R&D performing sectors are manufacturing high-tech and medium high-tech sectors that make more than 70 % of total BERD in each economy. The research intensity of these sectors generally grew in the four economies between 1995 and 2006, while their weight in the economy declined, except in Korea where their already high weight grew still greater. This increase in sectoral research intensity is more pronounced in the high-tech and medium high-tech of Japan and in the high-tech sectors of the United States than in the EU.

Among high-tech sectors, 'manufacture of office machinery and computers' (hereafter 'IT equipment'), 'manufacture of radio, television and communication equipment' (hereafter ' IT components, telecom and multimedia equipment') and 'manufacture of medical, precision and optical instruments, watches and clocks' (hereafter 'measurement instruments')[84] play a particularly important role in the EU business R&D deficit. Together with the two services sectors 'post and telecommunications' and 'computer and related activities'[85], they form what is called the 'Information and Communication Technologies' (ICT) industry. Section 5.5 offers a further insight in the R&D dynamics of that industry.

5.5. What is the role of the ICT industry in the European research landscape[86]?

The ICT industry, and the ICT-enabled innovation in non-ICT industries and services, makes an important contribution to the economic growth of advanced economies. The ICT sector was highlighted in the EU Lisbon Objectives, and has retained its prominence in the Europe 2020 Strategy. The ICT sector is a significant contributor to the ambition of achieving the target of investing 3 % of GDP in R&D in the EU. This section presents an analysis of ICT R&D over the period 2002-2007[87], i.e. the period of ICT sector growth that took place between two important financial events (the 'dot.com' crisis and the current financial and economic crisis).

[84] Codes 30, 32 and 33 in NACE Rev.1.1.
[85] Codes 64 and 72 in NACE Rev. 1.1.
[86] In this section, ICT industry includes economic activities with codes 30, 32, 33, 64 and 72 of NACE Rev. 1.1.
[87] This analysis was carried out by the JRC-IPTS in the context of PREDICT, a research project co-financed by JRC-IPTS and the Information Society & Media Directorate General of the European Commission. Further information, including details on the study methodology can be found at http://is.jrc.ec.europa.eu/pages/ISG/PREDICT.html.

The ICT sector is by far the largest R&D investing sector of the economy

ICT technologies are highly pervasive technologies and the ICT sector underpins growth in all sectors of the economy. In the EU, the US and Japan, the ICT sector is by far the largest R&D-investing sector of the economy. In 2007, while the ICT sector represented 4.8 % of GDP and 3 % of total employment in the EU (6.1 million employees), it accounted for 25 % of overall business expenditure in R&D (BERD)[88] and employed 32.4 % of all business-sector researchers.

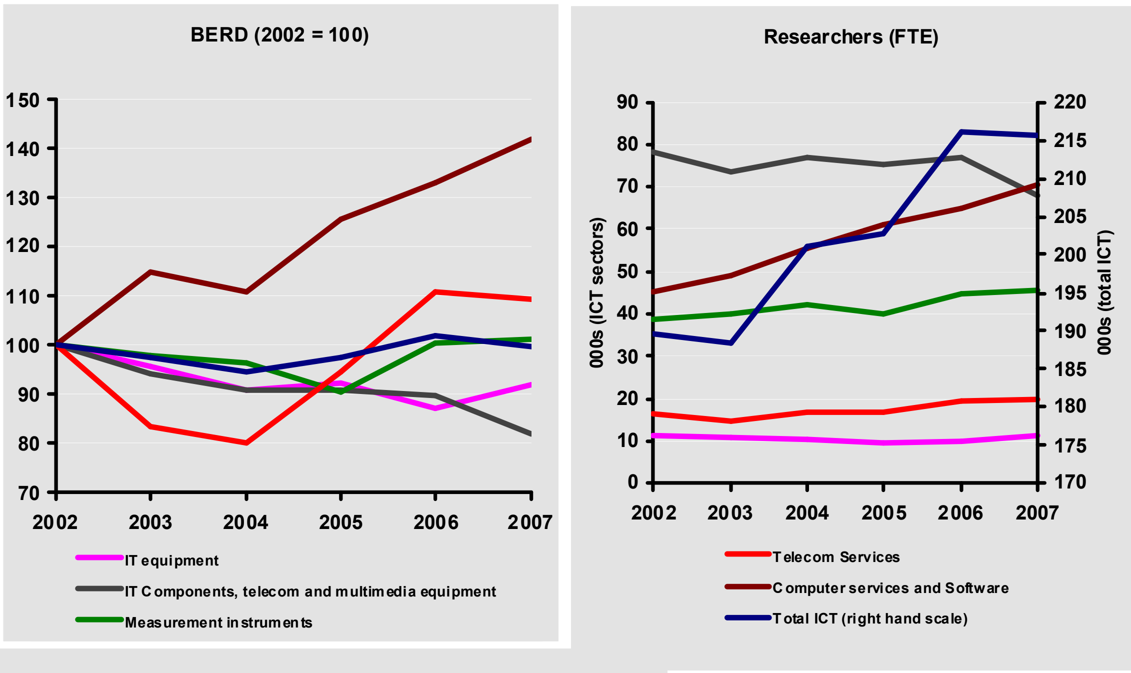
The EU ICT BERD remained stable during the period of analysis (see blue line in Figure I.5.15[89], left) with an ICT BERD intensity between 6 and 6.5 % of ICT sector value added, well below US ICT BERD intensity (see Table I.5.5). It does, however, demonstrate the importance of the sector when it comes to observing and understanding R&D expenditure, dynamics and performance in the EU. Not only does the ICT sector lead other economic sectors in terms of BERD, it also provides them with productivity-enhancing technology. Hence it contributes directly and indirectly to increasing labour productivity and overall EU competitiveness.[90]

Between two economic crises, the dynamics of the ICT sector was underpinned by structural change towards ICT services

In 2007, total ICT sector employment exceeded for the first time its previous peak level in 2001, accompanied by an important redistribution of jobs from ICT manufacturing to ICT services sub-sectors. In 2007, the share of ICT services employment reached 68 % of the total ICT sector. ICT Services accounted for more than 75 % of total ICT value added (42 % in the 'computer services and software' sub-sector alone). The 'computer services and software' sub-sector is also the only EU ICT sub-sector with a strong and sustained increase in both BERD and the employment of researchers: from 2002–2007, BERD increased by 40 % (see brown line in Figure I.5.15, left) and employment of researchers by 56 %. In 2007, the 'computer services and software' sub-sector became for the first time the leading ICT sub-sector in terms of employment of researchers (see brown line in Figure I.5.15, right).

[88] Followed by 'automotive' (16 %) and 'pharmaceutical/biotechnology' (13.3 %) in 2007.
[89] Source: JRC-IPTS estimates, based on data from Eurostat, OECD, EU KLEMS and national statistics.
[90] See the March 2009 European Commission Communication: 'A Strategy for ICT R&D and Innovation in Europe: Raising the Game', COM(2009)116, available at:
http://ec.europa.eu/information_society/tl/research/documents/ict-rdi-strategy.pdf.

Figure I.5.15 EU - evolution of BERD [(1)] and researchers (FTE) by ICT sub-sector, 2002-2007



Source: DG Research and Innovation, JRC-IPTS
Data: The 2010 report on R&D in ICT in the European Union
Note: (1) Real growth.

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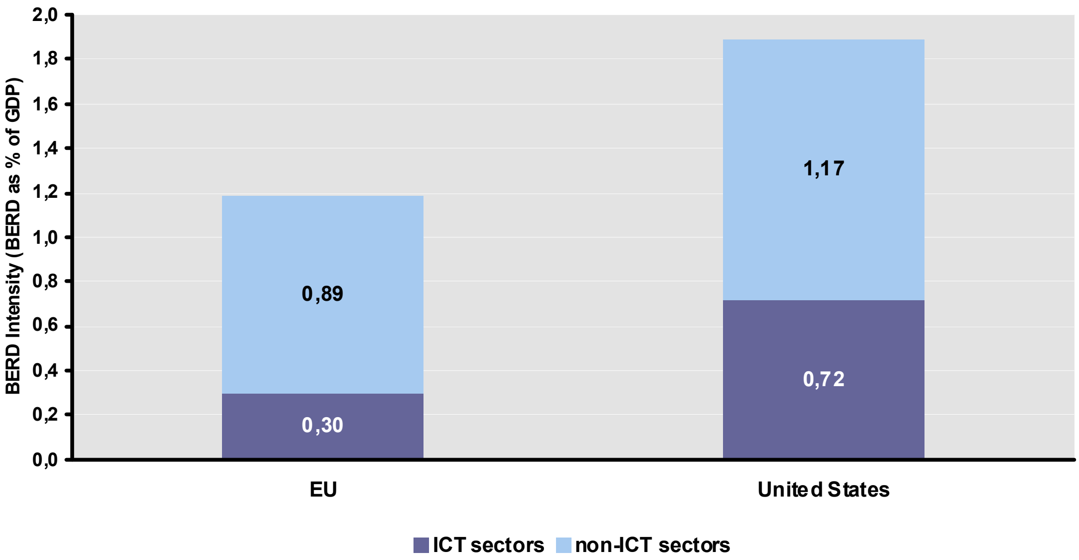
In 2007, ICT accounted for 63 % of the business R&D intensity gap between the United States and the EU

Although impressive, the contribution of the European ICT industry to total BERD (24.9 %) is much lower than in Japan and the United States, where ICT drives 32.4 % and 39.2 % of total R&D, respectively. As shown in the figure below, ICT explains most (63 %) of the business R&D gap between the United States and the EU: in 2007, the ICT business R&D intensity gap explained 0.44 out of the 0.7 percentage points of GDP that constitute the total EU–US business R&D intensity gap (Figure I.5.16).

Figure I.5.16 Contribution of ICT and non-ICT sectors to total BERD Intensity, 2007



Source: DG Research and Innovation, JRC-IPTS
Data: The 2010 report on R&D in ICT in the European Union

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The weight and research intensity of ICT industry in the EU economy are smaller than in its main competitors

The United States, Japan, Taiwan and South Korea are investing significantly more in ICT R&D than the EU (when comparing ICT R&D business expenditure over GDP ratios). Although the EU and the US have roughly equivalent GDPs, the US levels of both business ICT R&D expenditure (ICT BERD) and public ICT R&D funding are twice as large as those of the EU.

Table I.5.5 ICT BERD as % of GDP, size of the ICT sector in the economy and ICT R&D Intensity, 2007

	ICT BERD as % of total GDP 2007	ICT value added as % of total GDP 2007	ICT R&D Intensity (ICT BERD as % of ICT value added) 2007
EU	0,30	4,8	6,2
United States	0,72	6,4	11,2
Japan	0,87	6,8	12,8
South Korea	1,30	7,9	16,5
Chinese Taipei	1,31	10,6	12,3

Source: DG Research and Innovation, JRC-IPTS
Data: The 2010 report on R&D in ICT in the European Union

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These points can be further elaborated from three perspectives:

- In 2007, ICT BERD intensity was 0.30 % of GDP for the EU, compared to 0.72 % for the United States. This difference can be attributed to both a smaller relative size of the ICT sector in the economy and to a lower R&D intensity of the ICT sector (Table I.5.5). This difference is even bigger when comparing the EU to Japan, South Korea and Taiwan. Company-level data analysis of global R&D investments of the 2008 ICT Scoreboard companies[91] produces similar results.
- Public funding figures also indicate that, compared to the United States, EU governments fund a smaller share of ICT R&D in relation to total public funding for R&D. In 2007, EU ICT GBOARD represented 6 % of total public funding for R&D in the EU, while it was close to 9 % in the United States. In addition, available (incomplete) data indicates a substantial 'gap' between the EU and the United States in terms of ICT R&D public procurement[92] and dual-use research[93].
- R&D output, proxied by patenting activity also appears to be notably more specialised in ICT in the United States than it is in the EU. In 2006, 50 % of all patents applied for by US-based inventors[94] were in ICT technologies, compared to only 20 % of all patents applied for by EU-based inventors.

Further company-level data analysis of R&D, invested in ICT sub-sectors for the period 2004–2007 by ICT Scoreboard companies, shows that R&D investment by EU companies has been growing, in some cases strongly, in all ICT sub-sectors[95]. At the same time, the *ICT Scoreboard* shows that US companies clearly outperform the EU ones in several ICT sub-sectors that are key to the competitiveness of the EU industry, notably 'computer services and software' (Figure I.5.17).

[91] The JRC-IPTS *ICT Scoreboard* includes the 453 ICT companies with the largest R&D budgets globally. It is extracted from the *EU Industrial R&D Investment Scoreboard*, (http://iri.jrc.ec.europa.eu/research/scoreboard_2008.htm). In the *Scoreboard*, the term 'EU company' concerns companies whose ultimate parent has its registered office in a Member State of the EU. For more methodological details, see: http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=3239.

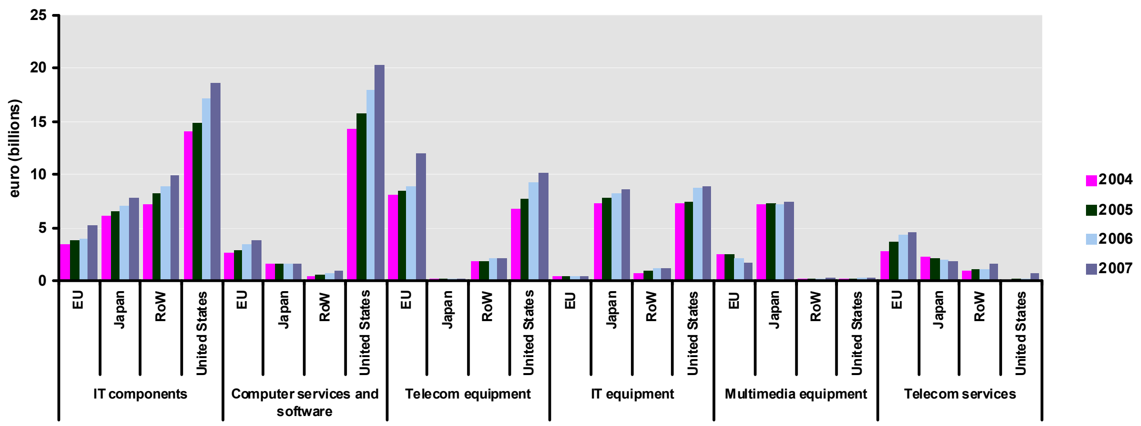
[92] See December 2007 EC Communication on pre-commercial procurement, COM(2007) 799, available at: http://ec.europa.eu/information_society/tl/research/priv_invest/pcp/documents/pcp_brochure_en.pdf .

[93] Dual-use research refers to tools or techniques, developed originally for military or related purposes, which are sufficiently commercially viable to support adaptation and production for industrial or consumer uses. The United States Department of Defense (DOD) has an important dual-use research program. Adapted from: http://www.answers.com/topic/dual-use-technology.

[94] Patent priority applications by inventors physically based (residing) in the US.

[95] With the unique exception of Multimedia Equipment.

Figure I.5.17 R&D investment in ICT sub-sectors by *ICT Scoreboard* companies, 2004-2007



Source: DG Research and Innovation, JRC-IPTS
Data: The 2010 report on R&D in ICT in the European Union

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Company data analysis also indicates that the EU does not generate as many large new and innovative ICT companies as the United States (and may additionally be threatened by emerging competitors from China and India). This appears particularly true in a key growth segment: 'computer services and software'. The lack of large innovation clusters in the EU may partly explain these difficulties, but market fragmentation, difficult access to financial capital, and other market rigidities are often cited[96] as other possible causes. The lack of large ICT companies in high-growth sectors and slower industrial growth clearly has a negative impact on the R&D investment indicators.

A cross-country comparison also needs to take into account the fact that ICT R&D is increasingly distributed globally. Analyses of a combination of indicators (global distribution of corporate R&D sites of major ICT companies,[97] and international patents in ICT technologies[98]) indicate that the EU remains an important location for ICT R&D — for both EU and non-EU companies — but it is also observed that Asia is gaining importance in this respect. Such analysis further indicates that US companies have taken a 'first mover' advantage in developing ICT R&D collaborations with Asia. For example, the share of the ICT inventions developed in Asia and owned by US patent applicants grew from almost zero in the early 1990s to 1.5 % in 2006, while the share owned by EU patent applicants merely started growing in the late 1990s and reached only 0.5 % in 2006.

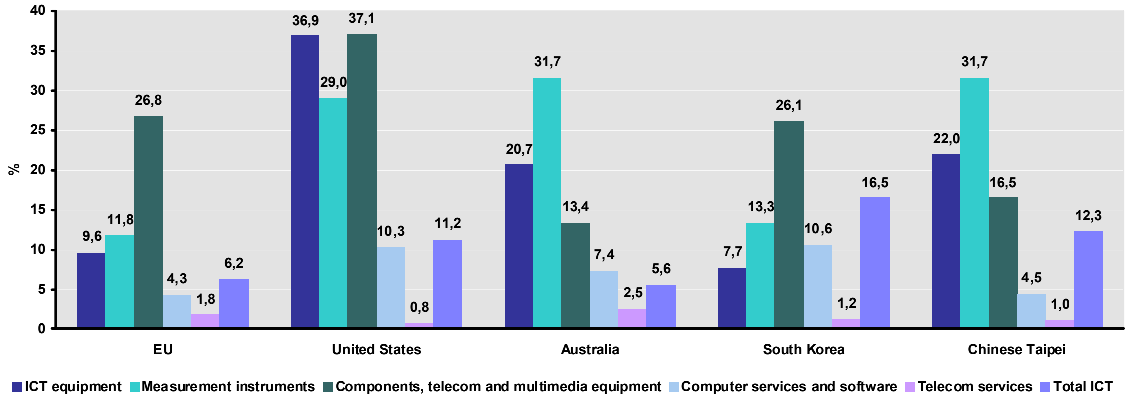
ICT sub-sectors are less research intensive in the EU than in its main competitors, with the exception of 'Post and telecommunications'

Figure I.5.18 shows the R&D intensity (BERD/value added) of the ICT sub-sectors in an international perspective,[99] and indicates that the overall lower R&D intensity of the ICT

[96] See also: Information and Communication Technologies, Market Rigidities and Growth: Implications for EU Policies at http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=1508.
[97] Based on the JRC-*IPTS ICT R&D Location Database.* This dataset includes location information for over 1 800 R&D sites that, in 2007 and 2008, belonged to 80 major multinational companies.
[98] Based on priority applications analysis from the PATSTAT database of EPO.
[99] The sectoral disaggregation presented in this chapter does not include data for Canada and Japan due to the unavailability of comparable data at this level of disaggregation.

sector in the EU relative to the United States is reflected in all the sub-sectors, except the Telecom Services.

Figure I.5.18 R&D Intensity (BERD as % of value added) by ICT sub-sector, 2007



Source: DG Research and Innovation, JRC-IPTS
Data: The 2010 report on R&D in ICT in the European Union
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The comparative analysis of R&D intensities reveals different patterns of R&D specialisation. The EU's highest R&D intensity is in 'components, telecom and multimedia equipment', at the same value as South Korea. The US ICT manufacturing sector seems the least specialised in terms of R&D investments/value added. From the countries in our sample, the fast-growing 'computer services and software' sector is most R&D intensive in South Korea and the United States.

The best performing countries in ICT R&D in the EU are the Nordic countries

In absolute terms, quite expectably, the EU's three largest economies (Germany, France and the United Kingdom), and to some extent the next two (Italy and Spain), dominate and set the average EU trend. When the size of the respective economies is taken into account, the best relative performers in ICT are the Nordic countries. In 2007, Germany, France, the United Kingdom, Italy and Spain accounted for more than 70% of total ICT sector value added and two thirds of its employment. In ICT manufacturing, Germany alone contributed 27% of EU employment and 30% of value added. In ICT services, the United Kingdom remains the leading country for employment (19% of EU employment) and a clear leader in value-added terms (25% of EU value added). These five countries together contribute more than two thirds of EU ICT BERD, and they generate more than 75% of all ICT patents (Germany generates almost 45% of these).

Finland and Sweden invest the largest amount in ICT BERD in relation to their GDP (and above the US level). In 2007, Finland and Sweden were also (with Spain) the countries with highest levels of ICT R&D public funding in relation to their GDP (comparable to US level). Finland, Germany, the Netherlands and Sweden are the only four Member States with ratios of ICT patent applications in relation to GDP either above or close to the US ratio. The Member States that have experienced the largest increases in ICT BERD in recent years are the new EU Member States along with Portugal and Spain. In spite of strong ICT BERD increase, however, the new EU Member States still have very low ICT BERD in relation to their GDP. They also have very low ratios of ICT GBAORD to GDP. Although several new Member States, such as Hungary, the Czech Republic and Poland, recorded spectacular increases in ICT manufacturing employment, deeper analysis shows that these countries are still hosting rather low-value-added activities.

A lot of ICT R&D is also performed in non-ICT sectors of the economy

Substantial ICT R&D is carried out in other sectors of the economy (for example, automotive or aeronautics). The size of this additional ICT R&D expenditure cannot be readily measured with current statistics. However, OECD has estimated that the magnitude of ICT R&D carried out outside of the ICT sector could be as large as an additional one third of the R&D carried out in the ICT sector itself.[100] After further statistical analysis and estimation, taking this additional R&D into account may eventually deepen our understanding of the nature of the EU–US gap in R&D investment. More importantly, it may also provide further evidence of the pervasive impact of ICT and ICT R&D investment on the overall economy.

[100] Estimated by OECD in a sample of countries: Czech Republic, Denmark, Norway, Finland and Japan (OECD, 2008 b).

6. Outputs and efficiency of science and technology in Europe

Highlights

In 2009, the EU produced 33.4% of world's total scientific publications, the largest scientific centre in the world. However, the capacity of the EU to produce high-impact scientific publications, a proxy for scientific quality, is lower than that of the United States. Among the scientific publications in 2007, the ratio of EU's contribution to the 10% most cited scientific publications in 2007-2009 was 1.16, which is well above the ratio for Japan, South Korea and China, but behind the ratio of 1.53 for the United States. However, since 2001, the EU has improved its scientific quality from 1.04 to 1.16, while the United States has stagnated. In Europe, it is Denmark the Netherlands, Iceland, Belgium and Switzerland, which have achieved the highest quality in their scientific publications according to this indicator. In absolute and quantitative terms the United Kingdom, Germany, France and Italy are the countries with the highest number of scientific publications.

Concerning technological output, the latest available data is from 2007. Contrary to the strong European scientific production, the technological production in the EU is less competitive. In 2007, the EU Member States only accounted for 43% of the EPO patent applications. In other words, more than 50% of all EPO patent applications were generated outside the EU. Relative to GDP, the inventing activity of EPO patents in the EU has decreased since 2000, while it increased dramatically in South Korea and Japan. About half of the Member States do not produce high-tech EPO patents. Evidence at regional level shows a strong concentration of patents in a few of Europe’s regions.

The divergence between scientific publications and technological production in Europe is an indication of a weakness in the European research and innovation system. However, estimating efficiency of the European R&I system is more complex, relating input to output, while analysing the impact of scientific output on innovation. This report presents some experimental and preliminary evidence on the efficiency of public research systems. In the EU, the ratio of quantity and quality of scientific production to the number of researchers is clearly below that of the United States. On average, a researcher in the public sector in the United States produces 2.25 articles among the 10% most cited articles worldwide, compared to 0.79 highly-cited articles per average researcher in the public sector in the EU. One of many explanations of this large difference is that public researchers in the United States benefit from total funding over 2 times higher per researcher than their colleagues in the EU. Further downstream, for almost all EU Member States and Associated countries, there is a positive relation between high-quality scientific output in the public sector and business sector investment in R&D. A growth of business sector R&D investment is in turn positively related to a growing patenting activity. Improving the efficiency producing high quality public research thus has potentially a positive impact on innovation. However, this relation is not linear or automatic, but depends on many dimensions of the public research system and its interaction with private actors, which will be further analysed in Part II of this report, capitalising on the emerging European Research Area.

6.1. Where does Europe stand in terms of scientific excellence?

Bibliometric indicators and patents are currently the most easily available and widely used proxies for measuring scientific and technological output. Bibliometric indicators give information on the codified knowledge produced by universities, research institutes and private firms. They also allow comparison of the scientific performance of different countries and regions. Patents, on the other hand, provide a valuable measure of the exploitation of research results and of inventiveness of countries, regions and firms. Both publications and patents play a role in the diffusion and exploitation of knowledge.

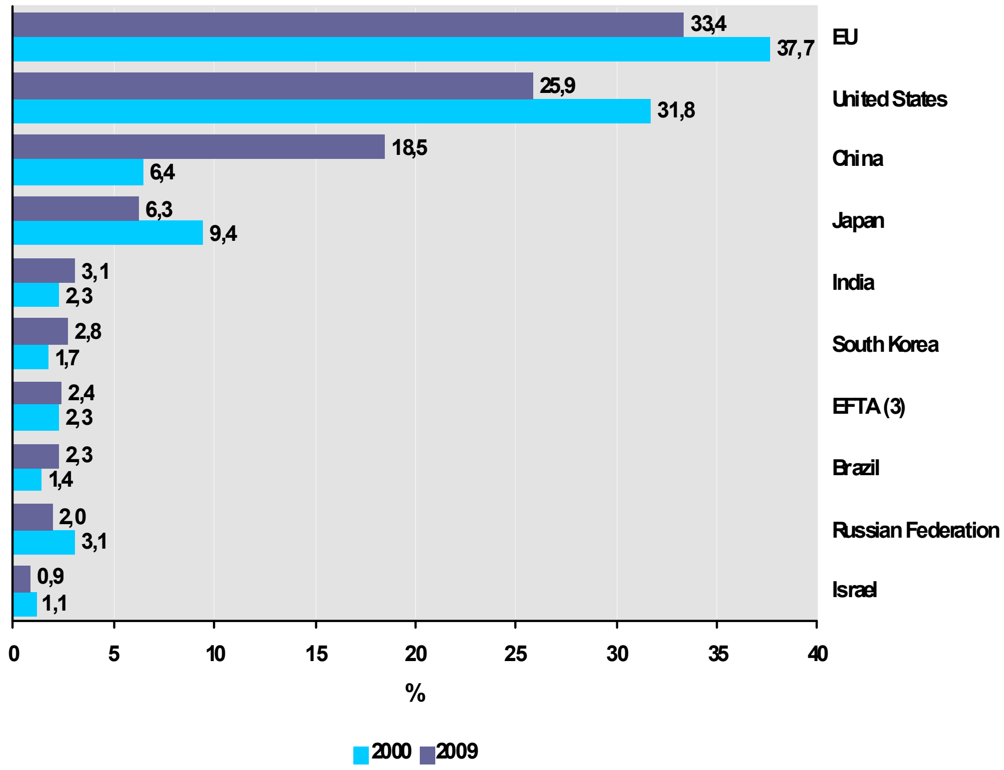
All the indicators and data on publications below refer to internationally peer-reviewed scientific publications which are indexed in Scopus (one of the largest abstract and citation database of peer-reviewed literature) [101].

The EU remains the largest producer of scientific publications in the world, followed by the United States. However both the shares of the EU and the United States worldwide are decreasing, whereas China is catching up rapidly

In 2008, 33.4% of the world's peer-reviewed publications were signed by EU authors, compared to 25.9% in the United States (figure I.6.1). Both shares have considerably decreased between 2000 and 2009 as a result of the increasing scientific capacity of Asia. China is catching up fast, from 6.4% of world publications in the Scopus database to 18.5% in 2008. The average annual real growth of peer-reviewed scientific publications between 2000 and 2008 was 6.9% in the EU, 5.6% in the United States and 28.2% in China.

[101] http://www.scopus.com/home.url

Figure I.6.1 World shares of scientific publications (%) (1), 2000 and 2009 (2)



Source: DG Research and Innovation
Data: Science Metrix / Scopus (Elsevier)
Notes (1) Full counting method.
(2) Data for 2009 are provisional.
(3) EFTA: Liechtenstein is not included.

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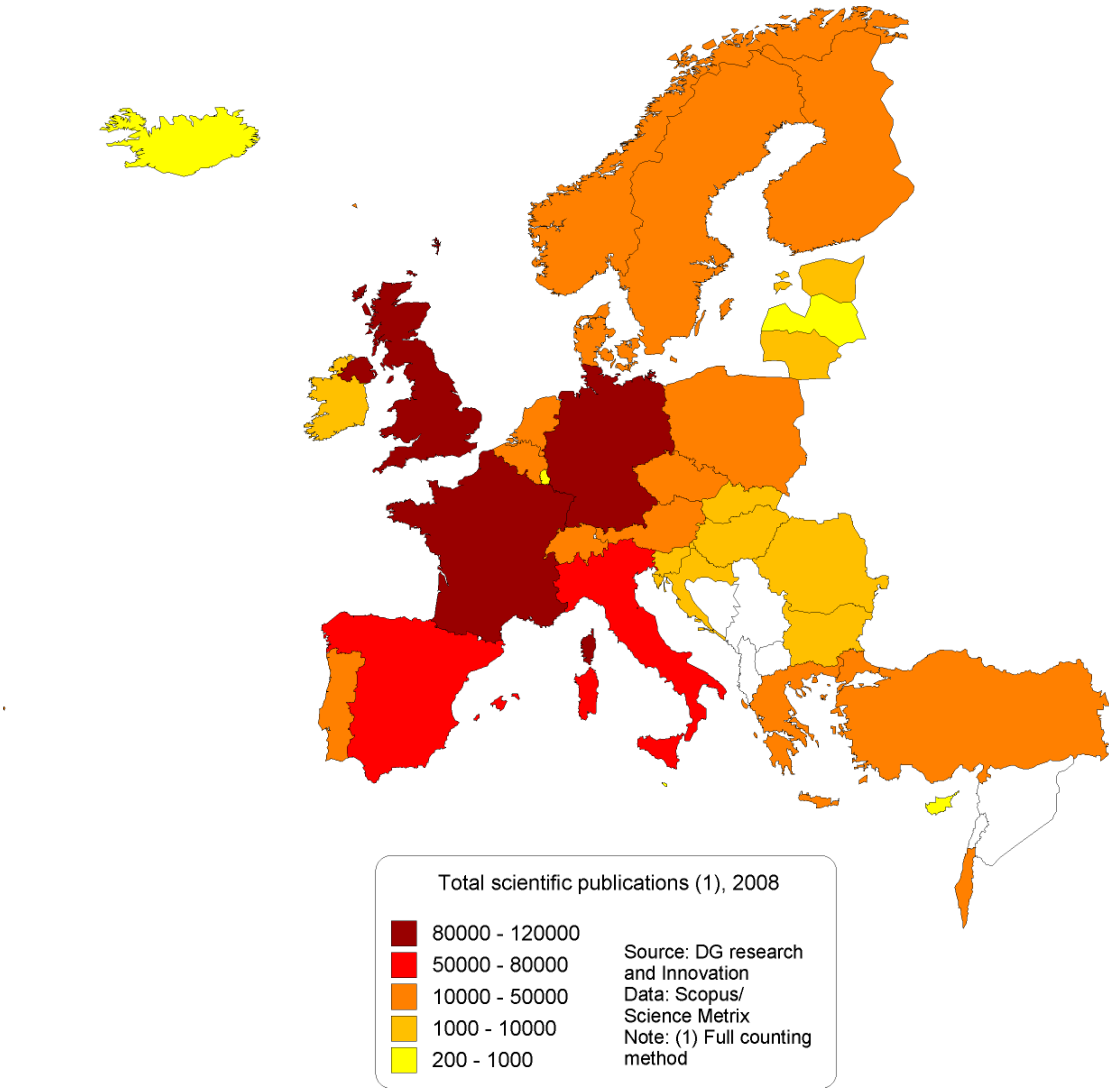
The United Kingdom, Germany, France and Italy, followed by Spain and the Netherlands, remain the countries with most scientific publications in Europe in the last decade. Small countries register the highest growth rates in terms of number of publications between 2000 and 2008.

In 2008, the EU Member States with the highest number of scientific publications are the United Kingdom (21.9% of the total EU-27 publications), Germany (20.8%), France (15.1%), Italy (11.3%), and Spain (8.7%). Figure I.6.2 below provide an overview of the absolute values.

Figure I.6.2.: Number of scientific publications of the EU Member States and Associated Countries, 2008



The smallest countries (Luxembourg, Malta, and Cyprus) are leading in terms of growth rates between 2000 and 2008, both for the total number of publications and for the highly cited publications (see table I.6.1 below). Remarkable growth rates on publications are shown also by Lithuania (16.4%), Turkey (15.6%), Portugal and Romania (each with 13.9%), whereas highly cited publications have increased spectacularly in Turkey (24.1%), Croatia (18.5%), Estonia (18.2%), Portugal (16.9%), and Greece (16%).

Table I.6.1 Scientific publications

	Total scientific publications [1]			Scientific publications within the 10% most cited scientific publications worldwide [1]		
	2000	2008	Average annual growth (%) 2000-2008	2000	2007	Average annual growth (%) 2000-2007
Belgium	11820	20285	7.0	1401	2787	10.3
Bulgaria	1925	2896	5.2	95	165	8.2
Czech Republic	5781	11894	9.4	353	743	11.2
Denmark	8896	13260	5.1	1327	2092	6.7
Germany	77958	111288	4.5	9085	13576	5.9
Estonia	603	1392	11.0	41	132	18.2
Ireland	3178	7799	11.9	345	904	14.8
Greece	5924	13855	11.2	459	1299	16.0
Spain	27089	52664	8.7	2347	5317	12.4
France	57081	81911	4.6	6049	9030	5.9
Italy	38708	63408	6.4	3816	6858	8.7
Cyprus	197	801	19.2	10	66	30.9
Latvia	359	613	6.9	18	16	-1.8
Lithuania	612	2065	16.4	42	96	12.6
Luxembourg	90	503	24.0	5	38	33.7
Hungary	5164	7419	4.6	335	560	7.6
Malta	50	223	20.5	3	15	25.6
Netherlands	22181	35425	6.0	3207	5383	7.7
Austria	7967	14225	7.5	946	1754	9.2
Poland	13022	24121	8.0	609	1210	10.3
Portugal	3804	10781	13.9	317	949	16.9
Romania	2456	6967	13.9	120	278	12.7
Slovenia	1926	3701	8.5	102	284	15.8
Slovakia	2405	3968	6.5	90	204	12.4
Finland	8358	12606	5.3	1028	1471	5.2
Sweden	17409	22976	3.5	2259	3117	4.7
United Kingdom	84422	117742	4.2	10512	15691	5.9
EU	367207	546837	5.1	37150	55557	5.9
Iceland	322	759	11.3	47	106	12.4
Norway	5978	10963	7.9	674	1368	10.6
Switzerland	16027	26009	6.2	2563	4236	7.4
Croatia	1884	3882	9.5	52	170	18.5
Turkey	7246	23092	15.6	326	1475	24.1
Israel	10709	15279	4.5	1207	1862	6.4

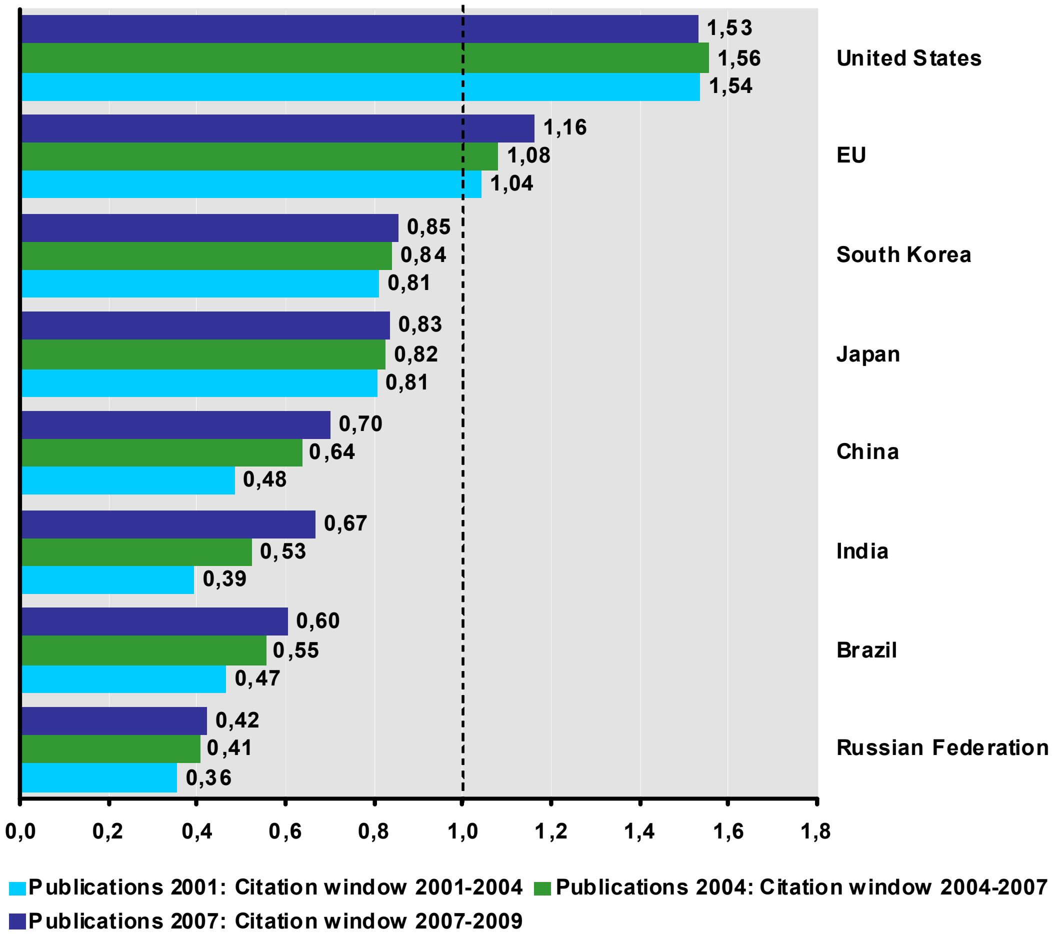
Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Science Metrix / Scopus (Elsevier)
Note: (1) Full counting method.

The EU's capacity to produce high-impact scientific publications is well above other world regions and on increasing trend since 2000, but it remains substantially lower than that of the United States despite the stagnation of American high-impact scientific publication numbers

The number of citations that a scientific publication receives is an indication of the use of this publication in subsequent scientific works. It is therefore an indication of the impact of this publication on science. In each scientific field, one can assume that the top 10% most-cited scientific publications are among the most influential publications in that field. The values reported in the figure below concern publications of 2001 with a 2001–2004 citation window, publications of 2004 with a 2004–2007 citation window and publications of 2007 with a 2007–2009 citation window.

On average, a country is expected to have 10% of its publications among the top 10% most cited ones worldwide. A higher value means that this country produces highly cited publications more often than expected. This is the case of the United States and the EU as a whole and for a number of European countries, led by Switzerland, Iceland, Denmark, the Netherlands and Belgium. The EU has progressed since 2000 and so has the EU average, which reached 11.6% in 2009 (from 10.4% in 2001), while the United States has stagnated overall at 15.3%. The EU–US gap in highly cited publications has therefore decreased since 2000, but it remains considerable. Japan, South Korea and China perform relatively lowly on this indicator, which is probably partly due to its English-language bias. However, China's performance increased significantly between 2000 and 2007, as well as those of India, Brazil and Russia. According to this indicator, a substantially smaller proportion of EU publications than US publications have a high impact. In absolute terms, the United States produces about 5% more high-impact publications than the EU. This observation points to a difference in the efficiency of the research systems in both economies. The issue for the EU may not be only a deficit in translating excellent science into innovative products and processes - it may also be that the EU is actually producing excellent science less often than the United States.

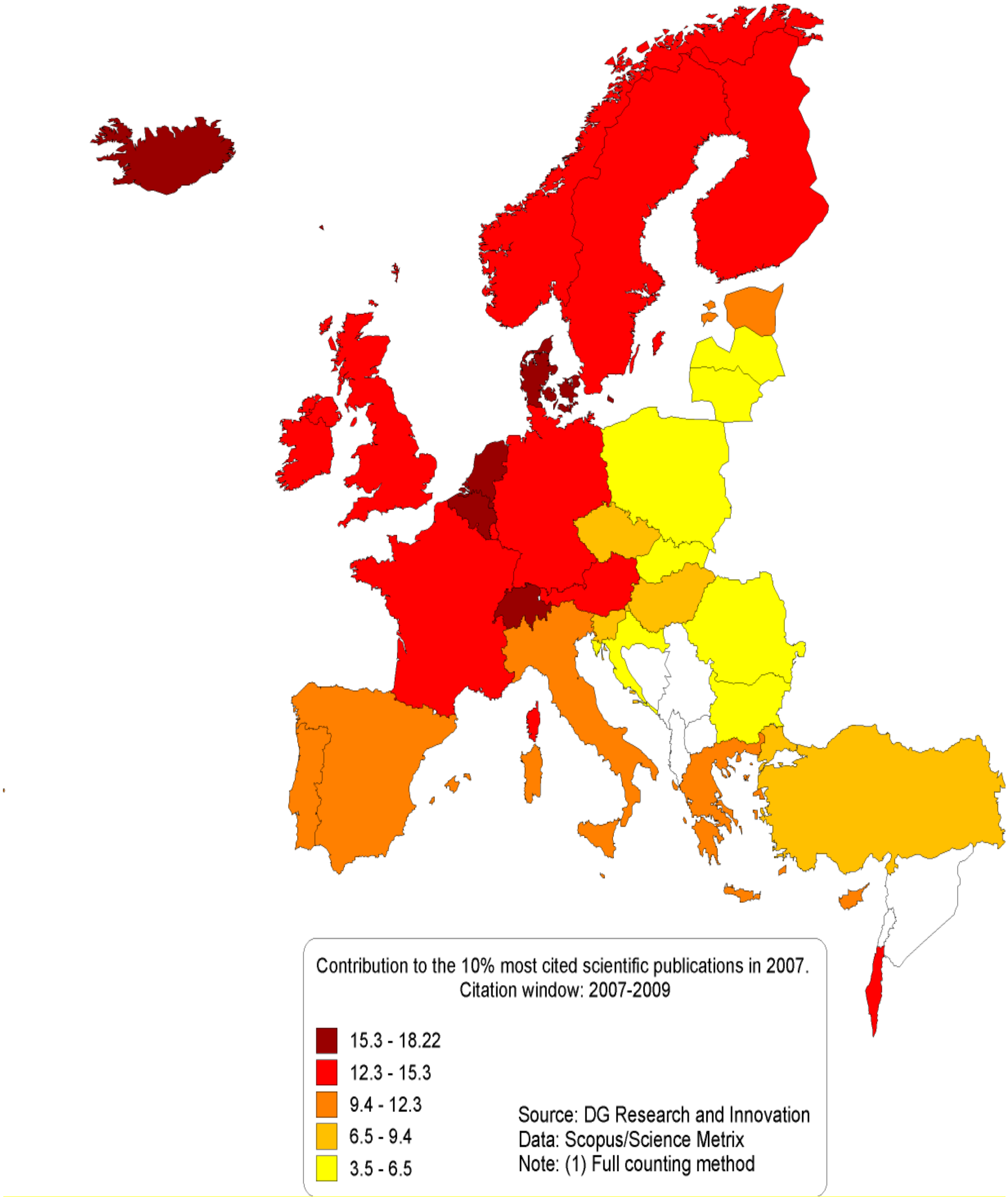
Figure I.6.3 Contribution to the 10% most cited scientific publications [(1)], 2001-2004, 2004-2007 and 2007-2009



Source: DG Research and Innovation Innovation Union Competitiveness Report 2011
Data: Science Metrix / Scopus (Elsevier)
Note: (1) The 'contribution to the 10% most cited scientific publications' indicator is the ratio of the share in the total number of the 10% most frequently cited scientific publications worldwide to the share in the total number of scientific publications worldwide. The numerators are calculated from the total number of citations per publication for the publications published in 2001 and cited between 2001 and 2004, from the total number of citations per publication for the publications published in 2004 and cited between 2004 and 2007 and from the total number of citations per publication from the publications published in 2007 and cited between 2007 and 2009. A ratio above 1.0 means that the country contributes more to highly-cited high-impact publications than would be expected from it's share in total scientific publications worldwide.

The European countries with the highest ratio of highly cited publications out of the total number of publications are Denmark, the Netherlands, Belgium, Iceland, and Switzerland. EU-12 Member States have low ratio of their publications among the 10% most-cited publications worldwide (figure I.6.4). However in terms of growth rates between 2000 and 2008 the leading countries are Turkey, Croatia, Estonia, Portugal and Greece (table I.6.1).

Figure I.6.4. Contribution to the 10% most cited scientific publications, 2007

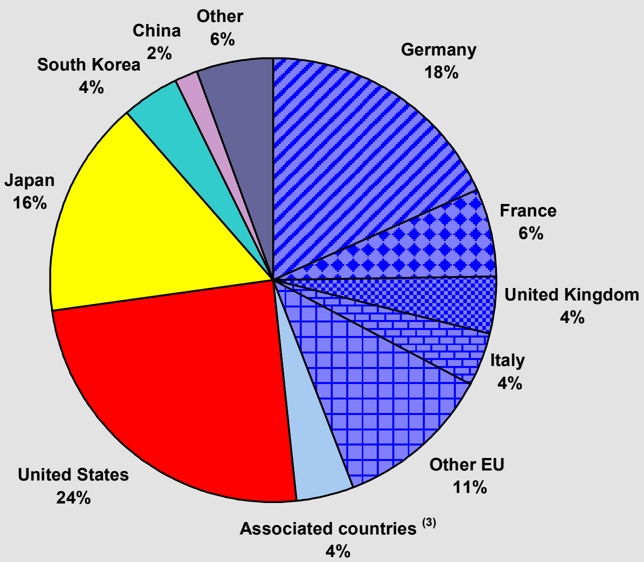


6.2. How large is Europe's technological output?

The EU Member States only accounted for 43 % of all EPO patent applications in 2007

Figure I.6.5 below shows the countries of invention of EPO patent applications. 47% of all EPO patent applications in 2007 were invented in Europe. In comparison, 24% of them were invented in the United States and 16% in Japan. The number of EPO patents invented in South Korea is about the same as the number of EPO patents invented in the United Kingdom or in Italy. Germany is by far the leading country in Europe in invention of EPO patent applications. Germany, France, the United Kingdom and Italy account for about one third of inventions of EPO patent applications.

Figure I.6.5 EPO patent applications (1) by inventor's country of residence, 2007 (2)



Source: DG Research and Innovation
Data: Eurostat
Notes: (1) Estimated values.
(2) Fractional counting; priority year.
(3) IS, LI, NO, CH, HR, TR, IL.

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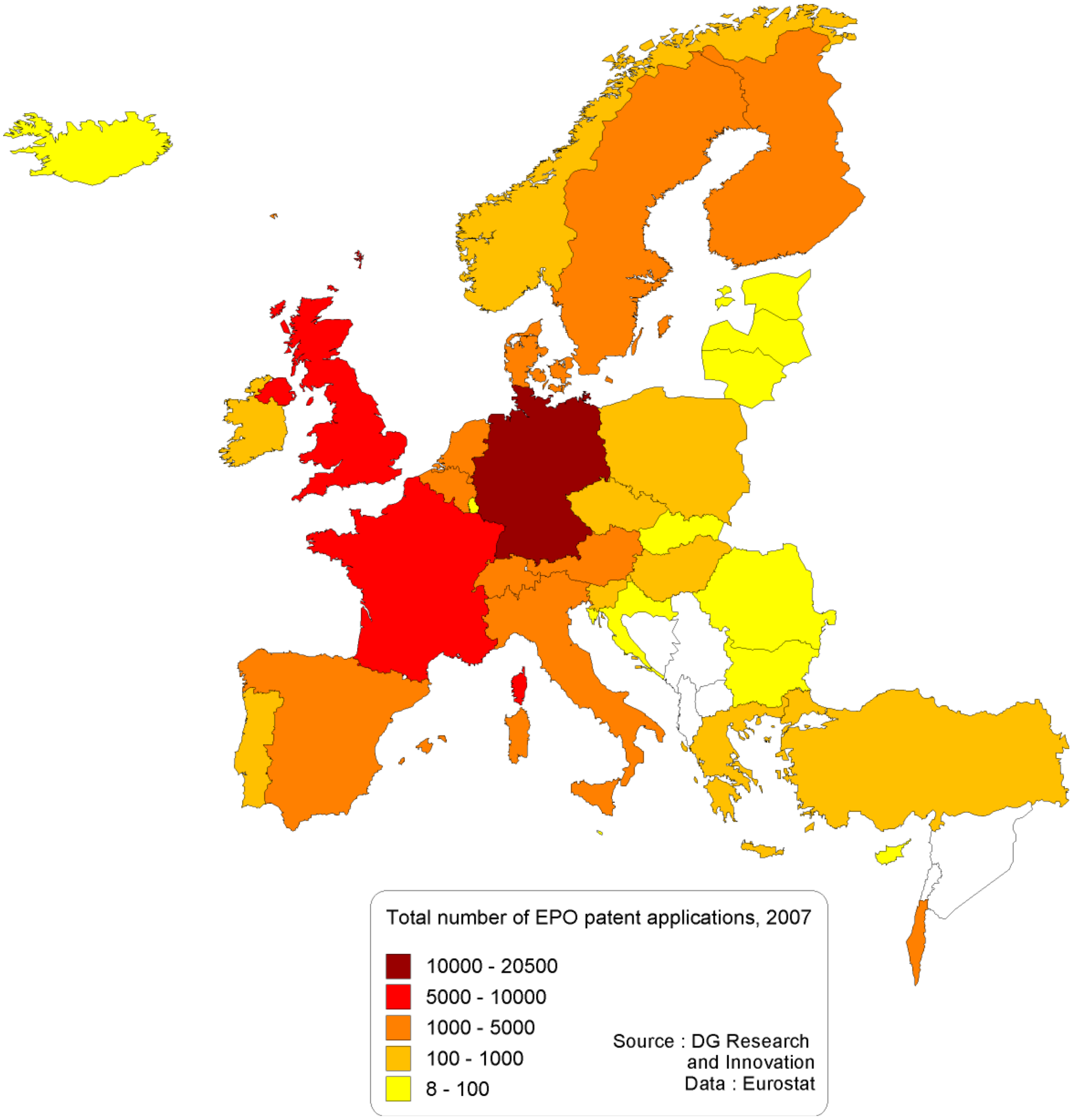
Figure I.6.6: EPO patents applications, 2007



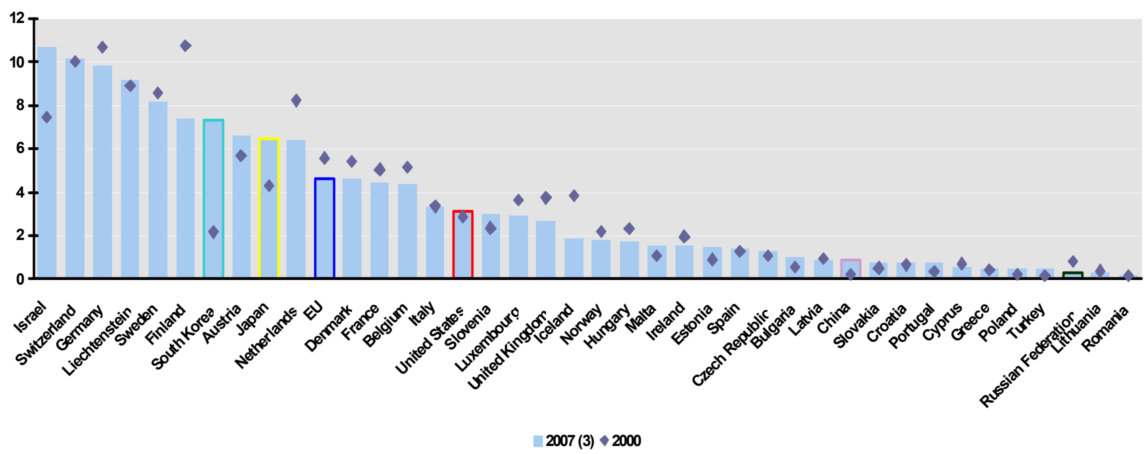
Relative to GDP, the inventing activity of EPO patents in Europe and associated countries is highest in Israel, Switzerland and Germany. South Korea and Japan have dramatically increased their EPO patenting since 2000

Normalising the number of EPO patent inventions by GDP allows correction for the size of the country, as does the normalisation by population. It also allows assessment of the role of inventing activity in the economy of the country. Switzerland, Germany, Sweden, Finland, Austria and the Netherlands are the European countries where the EPO patent invention activity is the most intensive. The trend however has been sharply negative in Finland and the Netherlands since 2000, while it was more stable in the four other countries. With sharp progress since 2000, Israel has now become the best performing country.

Among the medium and medium-low patenting European countries (Denmark, France, Belgium, Italy, Slovenia, Luxembourg and the United Kingdom), the trend has been negative since 2000, except in Slovenia. The number of EPO patents invented per GDP in these countries has been decreasing. In all other European countries, the situation did not change much between 2000 and 2007, with very few inventions of EPO patents. Altogether, relative to GDP, there were fewer inventions of EPO patents in EU in 2008 than in 2000.

In the majority of cases, inventions are applied in the country where they were invented, hence a home bias in favour of European countries when considering inventions of EPO patent applications. The latter are therefore less suited to comparing European countries to non-European countries. However, the most striking observation in the figure below is the outstanding progress observed in South Korea and to a lesser extent in Japan. These two countries have by far overtaken the United States in inventing EPO patents, relative to the size of their economy. Inventions of EPO patents per GDP in China have been multiplied by almost four since 2000 but remain at a relatively low level.

Figure I.6.7 EPO patent applications (1) by inventor's country of residence (2) per billion GDP, 2000 and 2007 (3)



Source: DG Research and Innovation
Data: Eurostat
Notes: (1) The values for 2007 are estimates.
(2) Fractional counting; priority year.
(3) LI: 2006.

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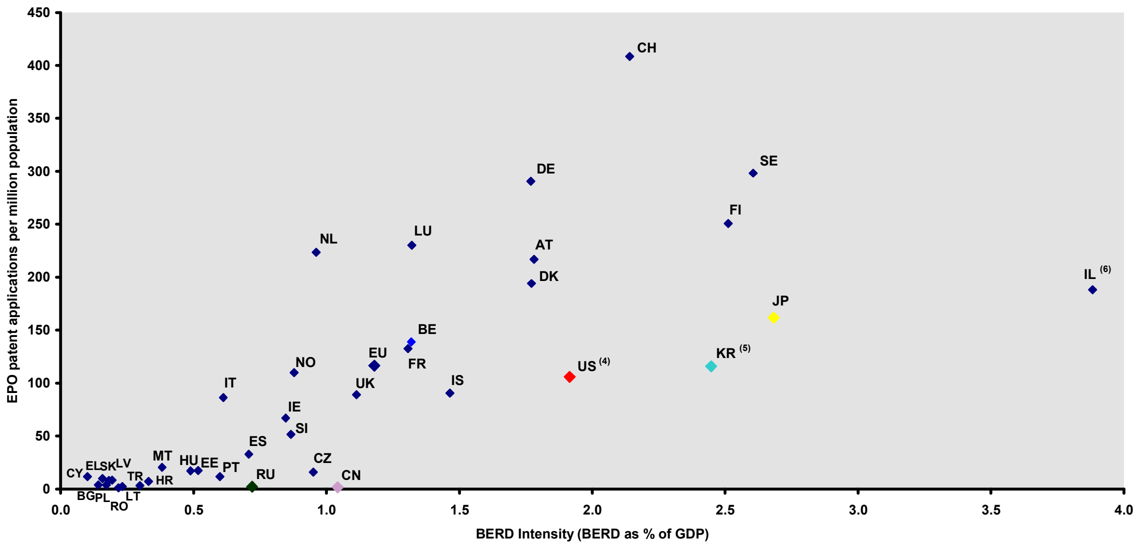
The level of patenting activity is positively correlated to the level of business investments in R&D

Unsurprisingly, Figure I.6.8 below shows that countries that have high levels of patenting activity are countries with high levels of business R&D expenditure. However, the ratio between the two differs widely across countries. This ratio is an indication of the efficiency of business R&D in producing patents in a country[102]. The Netherlands, Luxembourg, Germany, Italy and Norway are the European countries inventing the most EPO patents relative to their

[102] Of course, this is only a first approximation. Many factors influence the level of patenting activity in a country. One prominent factor is the country's degree of specialisation in technology areas which are intensive in patents.

business R&D expenditure. In contrast, Central and Eastern European countries are those which invent the fewest EPO patents per euro of business R&D expenditure.

Figure I.6.8 EPO patent applications (1) by inventor's country of residence (2) per million population and BERD as % of GDP, 2007 (3)



Source: DG Research and Innovation
Data: Eurostat
Notes: (1) The values for 2007 are estimates.
(2) Fractional counting; priority year.
(3) CH:2004
(4) US: BERD does not include most or all capital expenditure.
(5) KR: BERD does not include R&D in the social sciences and humanities.
(6) IL: BERD does not include defence.

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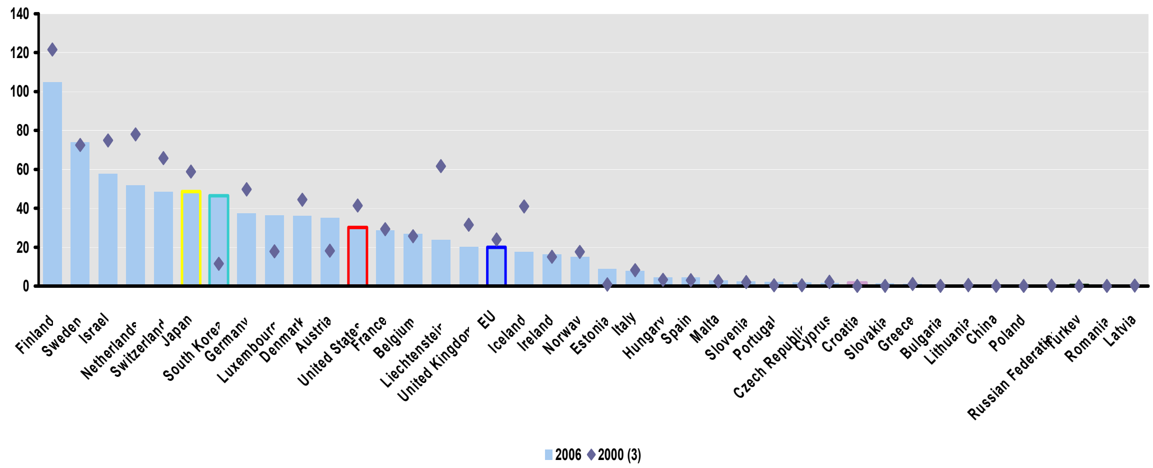
About half of European countries do not invent high-tech EPO patents

The best performing countries in terms of high-tech EPO patents[103] are the same as for all EPO patents. However, Finland and Sweden are now ahead of Israel and Switzerland. The Netherlands, Japan and South Korea also go up the ranking, ahead of Germany. This indicates a higher concentration of patents in high-technology areas in these countries. Similarly, the United States is ahead of the EU in terms of inventions of high-tech patents per population, contrary to what happens when all EPO patents are considered (see Figure I.6.7 above). Germany invents fewer high-tech patents than its overall level of patenting activity would predict, indicating a concentration of patenting activity in medium technology areas. It is to be noted that half of the European countries produce virtually no high-tech EPO patents.

Surprisingly, in all countries, the number of high-tech EPO patent inventions decreased or remained unchanged relative to the population between 2000 and 2006, except in South Korea, Austria and Luxembourg. The progress observed in these three countries is larger than the one observed with all patents[104], suggesting an increasing concentration of patenting activity in high-technology areas in these countries.

[103] High-tech patents are patents in the following technology areas: Computer, Aviation, Semi-conductors, Micro-organisms and genetic engineering, Communication technology, Laser.
[104] In the case of Luxembourg, one even observes a decrease in global patenting activity.

Figure I.6.9 High-Tech (1) EPO patent applications by inventor's country of residence (2) per million population, 2000 and 2006 (3)



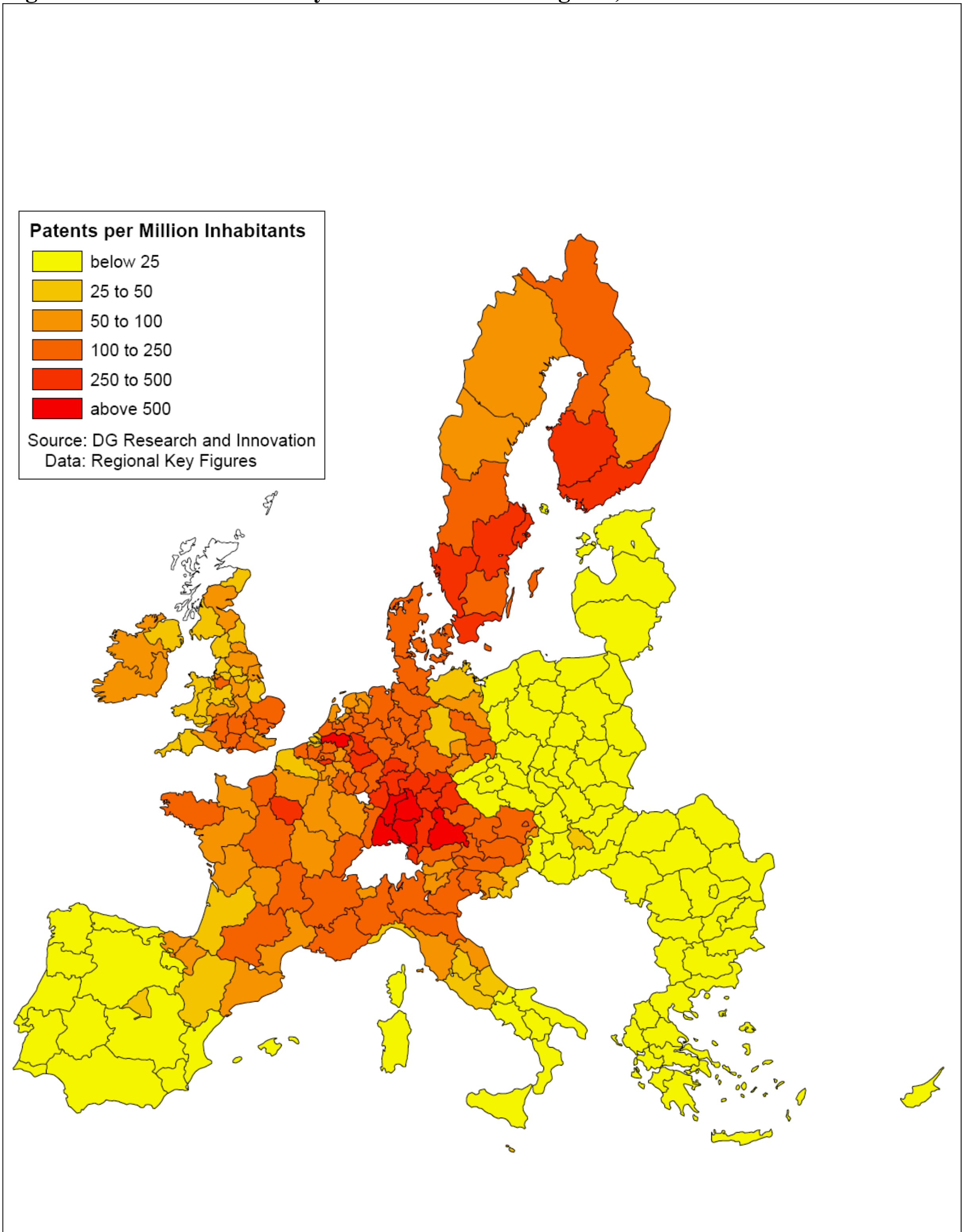
Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat
Notes: (1) High-Tech: Computer and automated business equipment; Semi-conductors; Aviation; Communication technology; Laser; Micro-organism and genetic engineering.
(2) Fractional counting; priority year.
(3) MT: 2002.

Patent applications in the EU are concentrated in a few regions

The figure below shows the intensity of patent applications at the EPO, by residence of inventor, in the EU Nuts 2 Regions, by million inhabitants. For most of the countries, patent activity is concentrated in a few regions and these regions tend to be geographically close, independently of whether they belong to the same country or not. This is the case for the north of Italy, the south of Germany and the south east of France - the darker parts of the map. The Nordic countries are also very active regions in terms of patent applications, with more than 100 patents per million inhabitants.

Patent activity varies strongly inside a single country from region to region, and strong disparities can be observed. Significant disparities were observed in Germany between the leading region of Stuttgart in the south, and the lowest-ranked region of Mecklenburg-Vorpommern in the east. Regional discrepancies are even larger in the Netherlands, between the regions of Noord-Brabant and Zealand. In contrast, discrepancies between regions are much lower in Finland and Sweden.

Figure I.6.10: Patent intensity in the EU NUTS 2 regions, 2007



6.3. Estimating efficiency: what is the return on investments?

The public sector in the EU has a lower scientific output per researcher than the United States

In an innovation ecosystem, the public sector is in charge of delivering the cutting-edge knowledge and well-trained researchers which are needed to feed business inventiveness in the long run, but would be too costly for the private sector to train. Keeping in mind the importance of cutting-edge knowledge production by the public sector, one has to compare quantity and quality of public research in the EU and the United States.

The analysis can first measure the quantity of output of the public research sector. In this area, the publication output per researcher provides a rough measure of productivity of researchers in the public domain in both economies[105]. Taking the data relating to the number of publications in 2007[106], one can see that the average number of publications per year per researcher in the public sector is 1.54 in the United States versus 0.70 in the EU[107]. Researchers in the EU public sector appear significantly less productive in terms of publication output compared to their US counterparts. However, it should be noted that research institutions in Europe have multiple "missions", which are not all oriented towards scientific publications.[108]

Concerning the relative quality of publications produced in a country, the best proxy available is the share of a country's scientific publications which counts among the 10 % most-cited publications worldwide. As presented in chapter 6.1 in Part I, the contributions of the United States and the EU to the 10 % most-cited scientific publications in the citation window 2007-2009 are 1.53 for the United States and 1.16 for the EU.

To compare both quantity and quality of output per public researcher, one can calculate the Average Publication Quantity and Impact-10 that is publication per researcher x 10 % most-cited publication ratio (APQI-10)[109]. As a result, the APQI-10 /researcher is 2.35 in the United States versus 0.81 in the EU. Hence the APQI-10 per researcher in the United States is almost three times higher than in Europe (see figure below). This finding - with all its limitations - is very telling about the difference in output of public research in the United States and the EU. Taking the figures of 2007, we find that with just 38 % of the number of researchers (FTE) of the EU, researchers of the public sector in the United States produce a Total Publication Impact (TPI, equal to APQI-10 x number of researchers) higher than the total TPI of the EU (663 000 in the United States versus 619 000 in the EU).

[105] Though there might be slight differences between the United States and the EU in the share of private-sector researchers publishing, it is fair to approach the activity of the public sector via the number of publications produced.

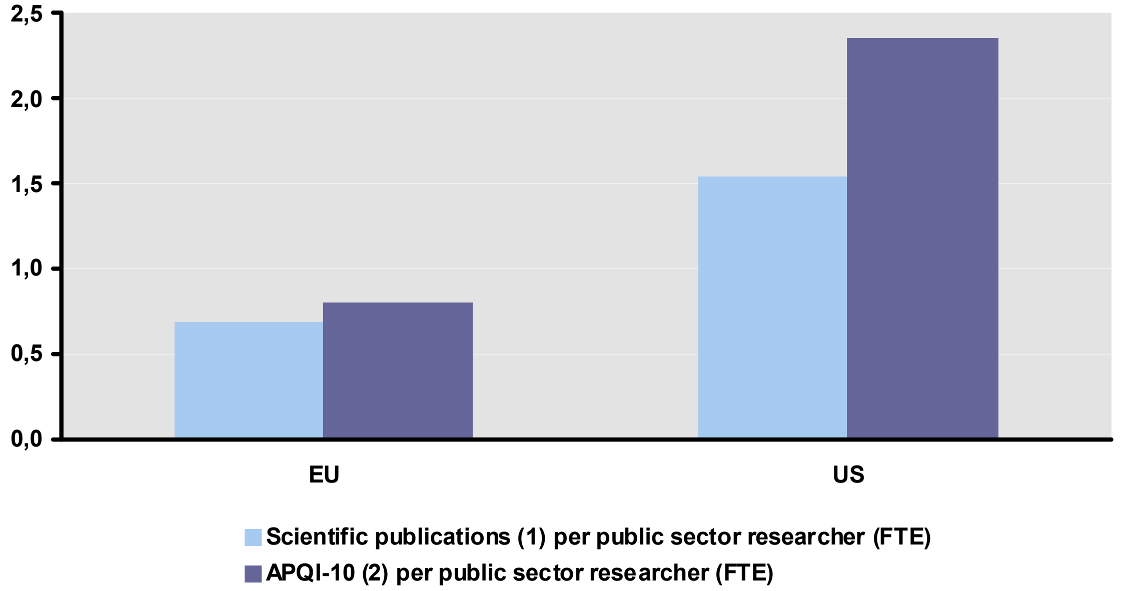
[106] For a more comprehensive review of scientific publication, see Part I, chapter 6.1.

[107] Eurostat data on number of researchers FTE; Data from the CWTS-Leiden University/Web of Science (Thomson Reuters Scientific).

[108] See Part II, Chapter 1.

[109] One could also construct a APQI-1 –Value- the Average Publication Quantity and Impact that is publication per researcher x **1 % most cited** paper. However, taking the analysis of Giovanni Dosi et al. in 'European Science and Technology Policy: Towards Integration or Fragmentation?' by Henri Delanghe, Ugur Muldur, Luc Soete, 2009, the results would turn much more to the disadvantage of Europe.

Figure I.6.11 Scientific publications [1] and APQI-10 [2] per public sector researcher (FTE), 2007



Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat, OECD, Science Metrix / Scopus (Elsevier)
Notes: (1) Full counting method.
(2) APQI: Average Publication Quantity and Impact.

A better understanding of this difference in both quality and quantity of output in the public domain requires a correlation with the financial resources available per researcher. If we look for the capital endowment per researcher, the tremendous difference between European researchers and US researchers in the public domain becomes obvious: on average a researcher in the public domain in the United States has financial resources more than two times higher than their colleagues in Europe have at their disposal. Put differently: the public research sector in the United States provides few, but excellently equipped research capacities. Funding per researcher (including remuneration schemes) in the public sector of the United States is higher than in the private sector - but limited to a number of researchers much smaller than in Europe.

Table I.6.2 R&D expenditure (euro) per researcher (FTE) in the public and private sectors

	EU 2008	US 2007
Public sector expenditure on R&D per researcher	107614	231424
Private sector expenditure on R&D per researcher	217584	183050
Total expenditure on R&D per researcher	159328	192711

Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat, OECD

This difference in the efficiency of public research to produce high quality output has impacts on the capacity of European business to build on the knowledge, ideas, and skills provided by the European public research sector. The following considerations apply:

1. The race for innovation is a winner-takes-all game. The first inventor usually takes the major profit from an innovation. Expected financial returns are higher, the greater the distance ahead of the nearest competitor (it takes longer for the competitors to come up with a similar innovation). The data presented above, and other specific analysis[110] suggest that public-sector research in Europe - even under assumption of perfect and frictionless knowledge transfer into the private sector - provides insufficient cutting-edge input to the private sector to be a winner in a completely new field of technology.

2. The outstanding achievements of top researchers attract young talents. The bigger the fame of a top researcher, the more she or he will attract young researchers with high potential from elsewhere. Moreover, many of these talents will not stay in public (academic) research, and will subsequently move - with all their talent and knowledge - to the business sector close to the location of the top researchers. As indicated by the recent MORE study, the issue of working with a leading expert in the field is a far lesser motivation for American researchers to come to Europe than vice versa. In contrast, an important motivation for European researchers to leave Europe for the US is to work with leading experts in their field[111].

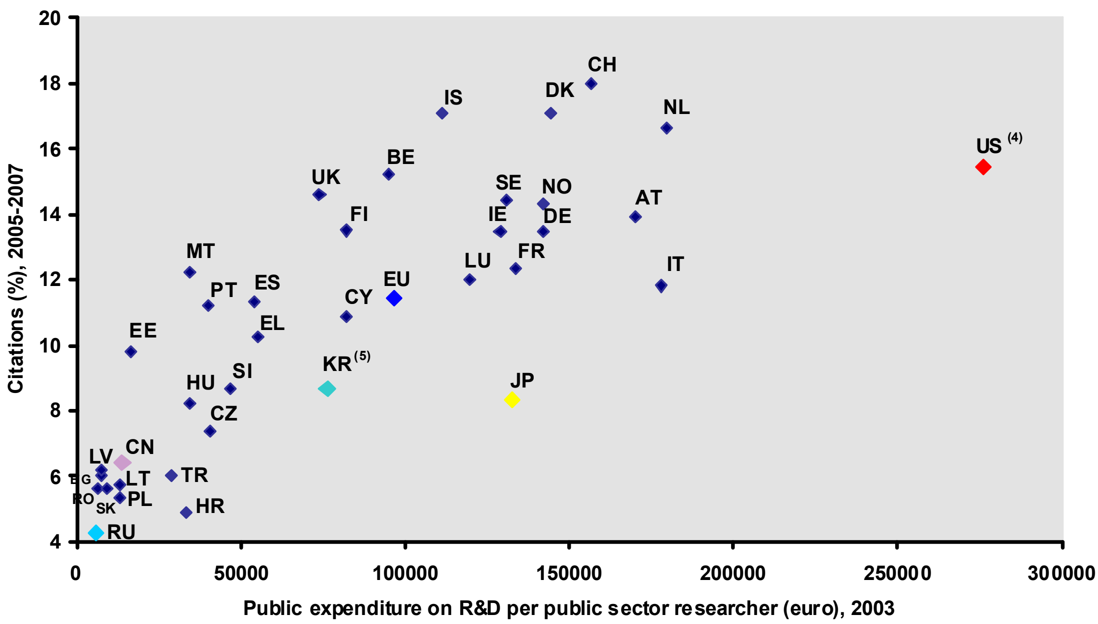
3. The relatively high level of concentration of high quality research in the public sector in certain States in the US facilitates the networking between researchers in the public sector and the business sector, in particular when it concerns matching venture capital, researchers and inventors. Europe also has pockets of excellent public research with ideas and knowledge which could be highly relevant for the private sector, but to find these outstanding ideas would take much more effort for venture capitalist and R&D intensive firms. These large transaction costs in turn reduce the profitability of private investment into cutting-edge innovations in the EU.

The reasoning presented here is not entirely new. Earlier work provided evidence that excellent public research generates additional business R&D, which is critical for innovation and ultimate productivity and economic growth as well as other societal benefits. Several authors have argued that private investment in R&D and its localisation is likely to be stimulated by the quality and size of academic research. To give two examples: Dosi, Llerena and Sylos Labini (2009) presented cross-country comparisons showing that industry-financed R&D appears positively related with both the per capita number of highly cited researchers and expenditure on higher-education R&D.[112] Abramovsky, Harrison and Simpson (2007) investigated the relationship between the location of private sector R&D labs and university research departments in Great Britain and found that private R&D investment first of all co-locates with outstanding research departments of universities.[113]

[110] Please see, for instance: 'Linking industrial competitiveness, R&D specialisation and the dynamics of knowledge in science: A look at remote influences', Andrea Bonaccorsi, in 'The Question of R&D Specialisation: Perspectives and policy implications', IPTS, 2009.
[111] See MORE Study 2010 - Report 3: Extra-EU mobility.
[112] Dosi, G., P. Llerena and M. Sylos Labini (2009), 'Does the "European Paradox" still hold? Did it ever?' in: H. Delanghe, U. Muldur and L. Soete (Eds) European Science and Technology Policy: Towards Integration or Fragmentation?, Cheltenham, UK, Northampton, USA: Edward Elgar, 214-236.
[113] Abramovsky, L., R. Harrison and H. Simpson (2007), 'University Research and the Location of Business R&D', Economic Journal, 117 (519), 114-41.

Given the importance of the production of cutting-edge knowledge in the public sector for seeding high-tech industries in the private sector, the next pages provide some reflections on European research funding. Figure I.6.12 presents the relationship between public investment per researcher in 2003 and the share of highly cited publications in the period from 2005–2007 (under the assumption that an investment into research in year X produce cited papers 2-4 years later). The relationship is quite straightforward - with the interesting exception of Italy: the more resources are available per researcher the more likely research results are produced that are regarded as seminal and cited accordingly. It is also interesting to note the large differences between European countries, where several countries (such as Switzerland, Denmark, the Netherlands and Iceland) present a higher number of highly-cited publications for less funding per researchers than the United States as a whole.

Figure I.6.12 Public [(1)] expenditure on R&D per public sector researcher (euro), 2003 [(2)] and scientific publications in the 10% most cited scientific publications worldwide as % of total scientific publications, 2005-2007 [(3)]

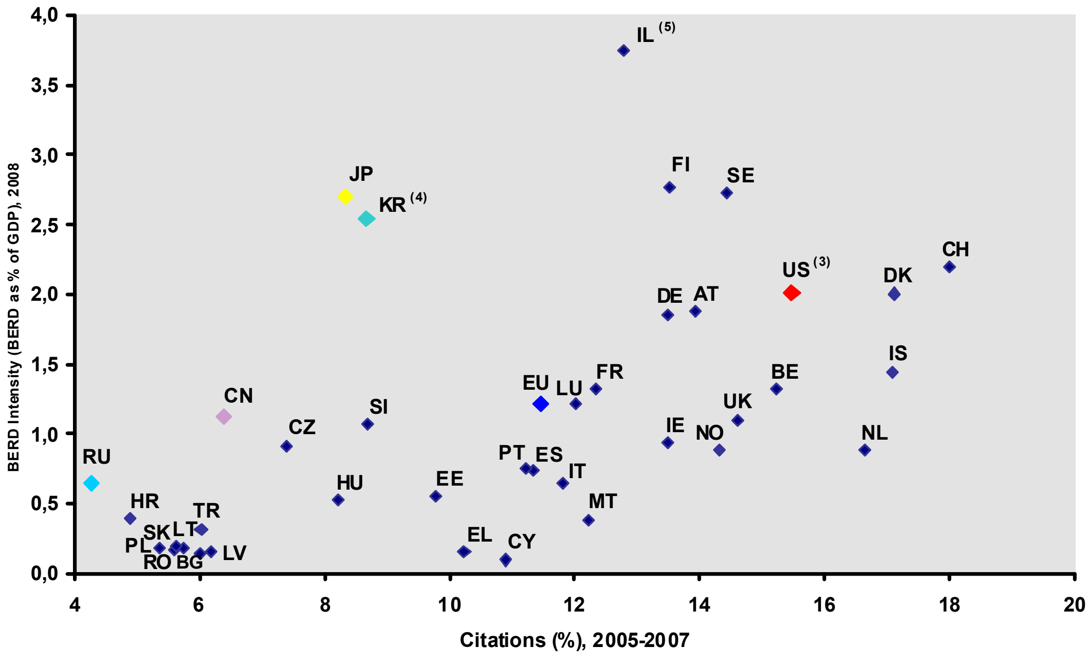


Source: DG Research and Innovation Innovation Union Competitiveness Report 2011
Data: Eurostat, OECD, Science Metrix / Scopus (Elsevier)
Notes: (1) For this graph the public sector refers to the Government, Higher Education and Private non-Profit Sectors. Public expenditure on R&D excludes R&D financed by business enterprise.
(2) MT, AT, FI, CH: 2004; UK: 2005.
(3) Full counting method.
(4) US: R&D expenditure does not include most or all capital expenditure.
(5) South Korea: R&D expenditure does not include R&D in the social sciences and humanities.

A higher scientific output in the public sector is positively related to a higher business sector R&D investment and innovation

Figure I.6.13 follows this logic further downstream: The more cutting-edge knowledge has been produced, the more likely it is that such knowledge should spill over into new products and services and hence private R&D activities. Therefore, figure I.6.13 presents the relationship between the quality of public research in the period 2005-2007 (measured in the share of highly quoted papers) and the private R&D intensity in 2008. Quality of public research relates positively with private R&D activities.

Figure I.6.13 BERD Intensity, 2008 (1) and scientific publications in the 10% most cited scientific publications worldwide as % of total scientific publications, 2005-2007 (2)



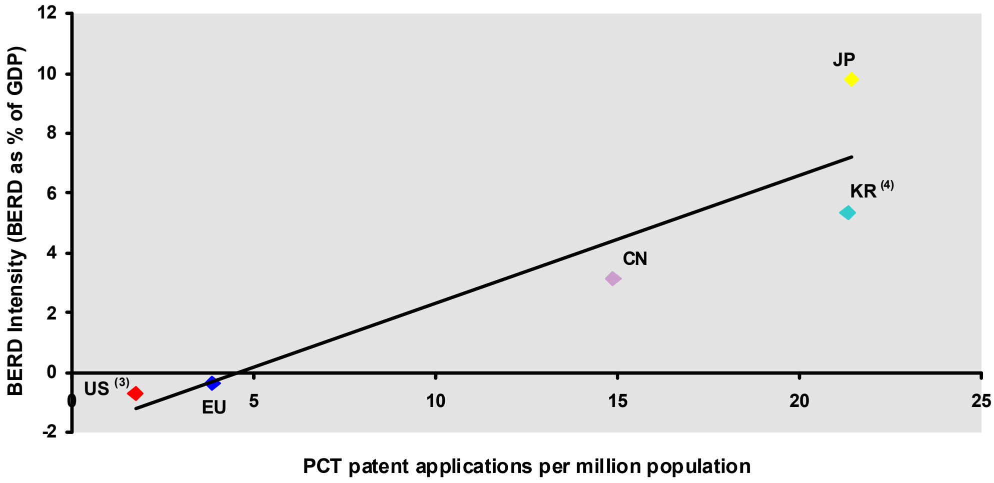
Source: DG Research and Innovation — Innovation Union Competitiveness Report 2011
Data: Eurostat, OECD, Science Metrix / Scopus (Elsevier)
Notes: (1) EL: 2007.
(2) Full counting method.
(3) US: BERD does not include most or all capital expenditure.
(4) KR: BERD does not include R&D in the social sciences and humanities.
(5) IL: BERD does not include defence.

Of course, quality of public research is not the only factor behind private R&D investments. A lack of adequate IPR protection and fragmented internal markets are also important determinants, and are detrimental to private R&D intensity.[114] But the capacities of the public-research sector of Europe to deliver cutting-edge knowledge, ideas and discoveries might be an issue in helping high-tech industries flourish still further in Europe.

Figure I.6.14 shows that those countries which have increased their private research efforts the most have also achieved higher technological outputs, measured by the increase rate in the number of patents. The same positive correlation is visible for EPO patent applications.[115]

[114] For a more comprehensive review of the framework conditions for business R&D, see Part III, Chapter 2 in this report.
[115] See Part I, Chapter 6.2, Figure I.6.8.

Figure I.6.14 PCT patent applications [1] per million population and BERD Intensity, average annual growth 2000-2007 [2]



Source: DG Research and Innovation

Innovation Union Competitiveness Report 2011

Data: Eurostat, DG ECFIN, 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) KR: 2000-2006.

(3) US: BERD does not include most or all capital expenditure.

(4) KR: BERD does not include R&D in the social sciences and humanities.