CHAPTER 1.3

INVESTMENT IN R&I AND OTHER INTANGIBLE ASSETS

Financial and human resource investments in research and innovation (R&I) and other intangible assets such as information and communication technologies (ICT); education and skills development; or organisational, management capacity, and marketing are crucial to support knowledge creation and diffusion that can be transformed into higher-value-added innovations. There is an increasing understanding that innovation, and notably reaping the full benefits of innovation, can require investment in different types of intangible assets that are highly complementary. For example, many of the benefits that digitalisation has brought about to increase firms' productivity require investment in R&I and ICT to develop and adopt the enabling technologies, as well as the reorganisation and adjustment of production or distribution activities to benefit from these technological innovations.

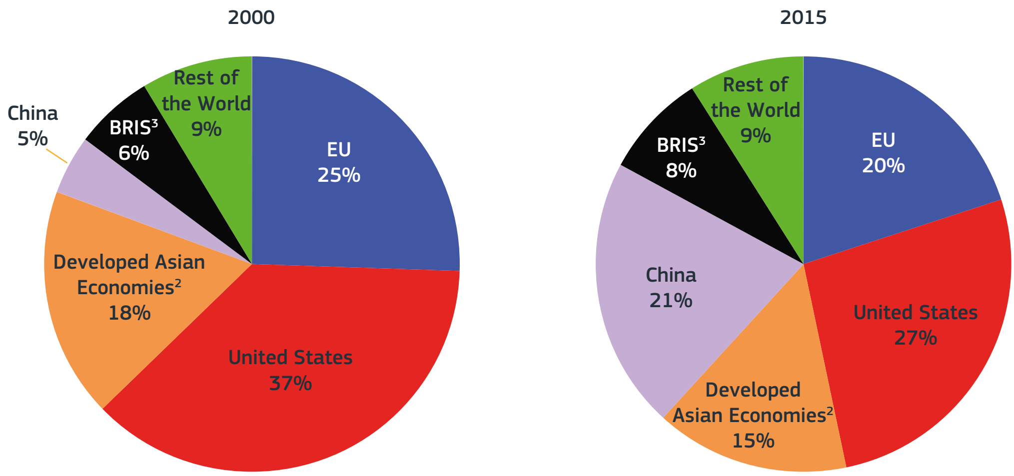
Against this background, this chapter assesses investment trends in R&I and other intangible assets in the EU and third countries, highlighting differences between the private and the public sectors. Using this analysis, the chapter aims to knock down persistent silos in the analysis of different sources of innovation, highlighting the complementarity and synergies across innovation-driving assets.

CHAPTER I.3-A: R&D INVESTMENT

The EU is a global research powerhouse responsible for one-fifth of all R&D investment worldwide, a share that has nonetheless decreased over time due to the globalisation of research and the rise of China as a major global research competitor.

China's share of world R&D expenditure increased from 5% in 2000 to 21% in 2015 while over the same period the United States' share declined by 10 percentage points from 37% to 27% and the EU's share fell from 25% to 20%. These changes reflect a new broader international distribution of R&D investment and show a shift from 'East' to 'West' in the global R&D compass. This is underlined by the fact that, between 2000 and 2015, R&D intensity in South Korea rose from 2.18% to 4.23% of GDP, in China from 0.89% to 2.07% and in Japan from 2.91% to 3.29%.

Figure I.3-A.1 World expenditure on R&D -% distribution[1], 2000 and 2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD, UNESCO

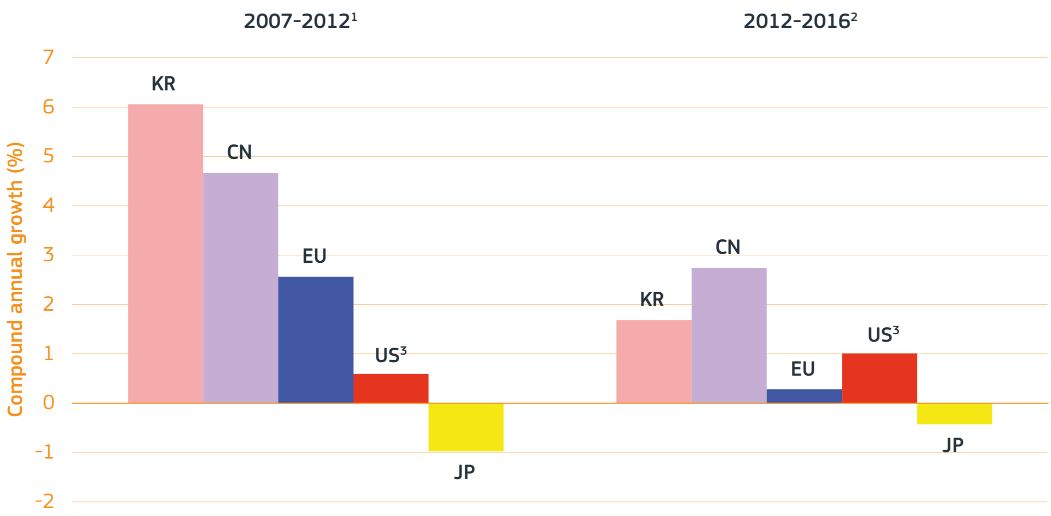
Notes: [1]The % shares were calculated from estimated values for total GERD in current PPS€. [2]Japan+South Korea+Singapore+Chinese Taipei. [3]Brazil+Russian Federation+India+South Africa.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f1_world_expend_on_total_rd.xlsx

Over the past decade, R&D investment in China has outpaced most other economies, notably the EU, the United States and Japan, all of which experienced much lower growth rates than China for the period 2012-2015.

In the case of the EU, the compound annual growth of R&D intensity declined from 2.6 % for the period 2007-2012 to 0.3% for the period 2012-2016 (Figure I.3-A.2), a significantly lower growth rate than the corresponding one over the period 2012-2015 for China (2.7 %), South Korea (1.7 %) and the United States (1.0 %).

Figure I.3-A.2 R&D intensity - compound annual growth, 2007-2012 and 2012-2016

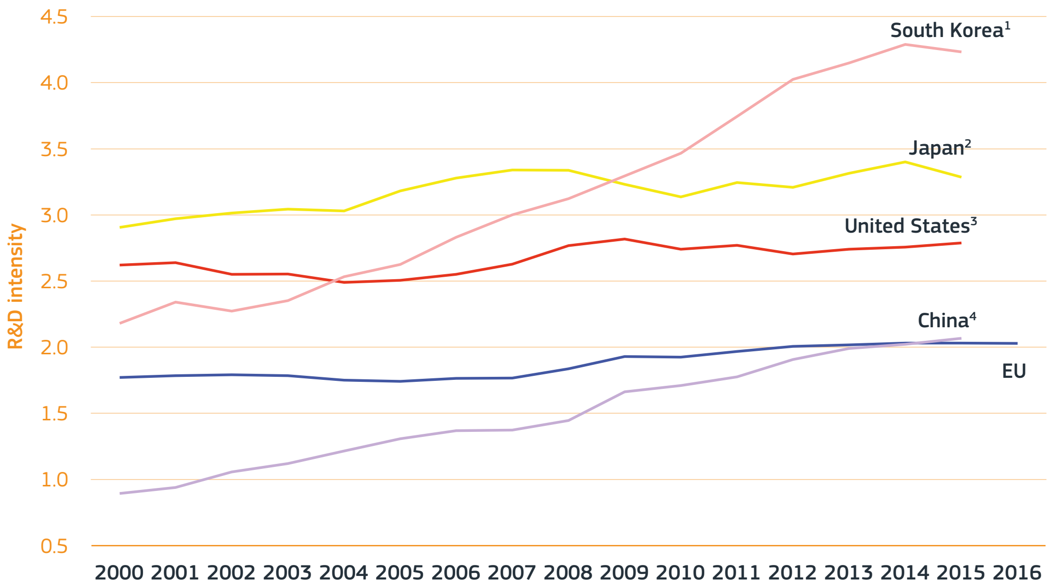


Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, OECD
Notes: [1]JP: 2008-2012; CN: 2009-2012. [2]US, CN, KR: 2012-2015; JP: 2013-2015. [3]US: R&D expenditure does not include most or all capital expenditure.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f2_rd_intensity_cagr.xlsx

This enabled China to overtake the EU in R&D investment, both in relative and in absolute terms.

South Korea, Japan and the United States continue to achieve significantly higher R&D intensities than the EU, although the gap between Japan and the EU narrowed slightly between 2014 and 2015.

Figure I.3-A.3 Evolution of R&D intensity, 2000-2016



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, OECD
Notes: [1]KR: There is a break in series between 2007 and the previous years. [2]JP: There is a break in series between 2008 and the previous years and between 2013 and the previous years. [3]US: (i) R&D expenditure does not include most or all capital expenditure; (ii) There is a break in series between 2003 and the previous years. [4]CN: There is a break in series between 2009 and the previous years.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f3_rd_intensity.xlsx

R&D investment in the EU is not growing fast enough to achieve its target of investing 3% of GDP in R&D by 2020, even though some Member States have met or are close to meeting their national R&D intensity targets[1].

The R&D intensity target is one of the EU's five headline targets aimed at creating a smarter, greener, more inclusive economy and society. In order to reach the 3% target, R&D intensity in the EU as a whole would have to grow at a compound annual growth rate of 10.3% per annum between 2016 and 2020. Cyprus has already reached its 2020 R&D intensity target, and Germany and Denmark will almost certainly reach their targets before 2020. Belgium, Greece, Italy, the Netherlands, Austria and Sweden will reach their R&D intensity targets if their R&D intensities grow at a rate of between 4.5% and 5.5% per annum. However, it will be difficult for the other Member States to meet their targets (Figure I.3-A.4).

1 R&D investment intensity values for BG, CZ, EE, HR, LV, LT, HU, MT, PL, RO, SI and SK refer to 2015 rather than 2016. Provisional R&D expenditure data are available for these Member States for 2016. However, in many cases these data show a relatively important decrease. An investigation into the causes of this decline is under way. Early indications suggest that changes to the programming period of the European Structural and Investment Fund, a main source of funding for R&D in these Member States, may largely explain this situation. These decreases should, therefore, be considered as temporary with the expectation of a full recovery in the coming years. As a result, R&D investment intensities for these Member States in 2016 may not accurately reflect R&D trends.

Figure I.3-A.4 Situation of each Member State with regard to its R&D intensity target

	R&D intensity 2016[1]	R&D intensity target 2020	R&D intensity compound annual growth (%) 2000-2016[2]	R&D intensity compound annual growth (%) 2007-2016[3]	R&D intensity compound annual growth (%) required to meet the 2020 target 2016-2020[4]
Belgium	*2.49*	*3.00*	*+1.6*	*+3.4*	*4.8*
Bulgaria	0.96	*1.50*	+4.5	+10.6	*9.3*
Czech Republic	1.93	:[5]	+3.7	+5.0	:
Denmark	*2.87*	*3.00*	*+1.5*	*+1.5*	*1.1*
Germany	2.94	*3.00*	*+1.3*	*+2.1*	*0.5*
Estonia	1.49	*3.00*	+6.2	+4.2	*15.1*
Ireland	*1.18*	*2.00*[6]	*+0.5*	*-0.5*	*14.2*
Greece	*0.99*	*1.21*	*+3.9*	*+5.2*	*5.0*
Spain	*1.19*	*2.00*	*+1.9*	*-0.4*	*13.9*
France	*2.22*	*3.00*	*+0.7*	*+1.6*	*6.2*
Croatia	0.84	*1.40*	-0.9	+0.8	*10.7*
Italy	*1.29*	*1.53*	*+1.5*	*+1.4*	*4.4*
Cyprus	*0.50*	*0.50*	*+5.1*	*+2.6*	*Target reached*
Latvia	0.62	*1.50*	+2.4	+1.5	*19.1*
Lithuania	1.04	1.90	+3.9	+3.3	*12.8*
Luxembourg	*1.24*	*2.30 - 2.60*[7]	*-1.1*	*-1.3*	*18.5*
Hungary	1.36	*1.80*	*+4.5*	+4.5	*5.7*
Malta	0.77	*2.00*	+4.1	+4.3	*21.0*
Netherlands	*2.03*	*2.50*	*+0.01*	*+1.0*	*5.3*
Austria	*3.09*	*3.76*	*+3.1*	*+2.7*	*5.1*
Poland	1.00	*1.70*	+3.0	+7.5	*11.1*
Portugal	*1.27*	*2.70 - 3.30*[8]	*+2.1*	*-1.6*	*24.0*
Romania	0.49	*2.00*	*+1.5*	*-2.1*	*32.6*
Slovenia	2.20	*3.00*	*+1.4*	*+2.3*	*6.4*
Slovakia	1.18	*1.20*	+4.1	+12.8	*0.4*
Finland	2.75	*4.00*	-1.0	-2.2	*9.8*
Sweden	*3.25*	*4.00*	*-0.9*	-0.01	*5.3*
United Kingdom	*1.69*	:	*+0.2*	*+0.4*	:
EU	*2.03*	*3.00*	*+0.8*	*+1.5*	10.3

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, Member States

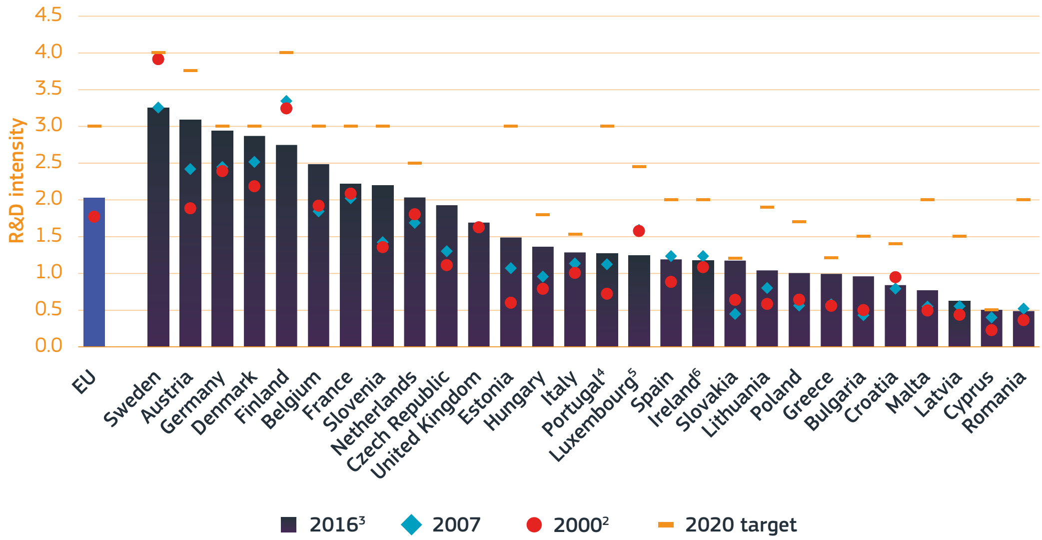
Notes: [1]BG, CZ, EE, FR, HR, LV, LT, HU, MT, PL, RO, SI, SK: 2015. [2]BG, CZ, EE, FR, LV, LT, HU, PL, RO, SI, SK: 2000-2015; HR: 2002-2015; EL, LU, SE: 2003-2016; MT: 2004-2015. [3]BG, CZ, EE, FR, HR, LV, LT, HU, MT, PL, RO, SK: 2007-2015; SI: 2008-2015; EL, PT: 2008-2016. [4]BG, EE, FR, HR, LV, LT, HU, MT, PL, RO, SI, SK: 2015-2020. [5]CZ: a target (of 1%) is available only for the public sector. [6]IE: The national target of 2.5% of GNP has been estimated to equal 2.0% of GDP. [7]LU: a 2020 target of 2.45% was assumed. [8]PT: a 2020 target of 3.0% was assumed. [9]DK, EL, FR, LU, NL, PT, RO, SI, SE, UK: Breaks in series occur between 2000 and 2016; when there is a break in series the growth calculation takes into account annual growth before the break in series and annual growth after the break in series. [10]Values in italics are estimated or provisional.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f4_progress_to_rd_targets.xlsx

Undoubtedly, the economic crisis has put an important upper limit on the progress made by many Member States towards their R&D intensity targets. Nevertheless, the R&D intensities of most EU Member States were significantly higher in 2016 than in 2007 (with Finland and Sweden being notable exceptions).

In some Member States (Bulgaria, the Czech Republic, Poland and Slovakia) R&D intensity grew at more than 5 % per annum between 2007 and 2015. Greece had an R&D intensity growth rate of 5.2 % per annum between 2008 and 2016[2]. Belgium, Germany, France, Austria and Slovenia all had R&D intensities higher than the EU average in 2016 and also had R&D intensity growth rates that were higher than the EU average over the period 2007-2016[3].

Figure I.3-A.5 R&D intensity 2000, 2007, 2016 and 2020 target[1]



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, Member States
Notes: [1]CZ, UK: R&D intensity targets are not available. [2]EL, SE: 2001; HR: 2002; MT: 2004. [3]BG, CZ, EE, FR, LV, LT, HU, PL, RO, SI, SK: 2015. [4]PT: The R&D intensity target is between 2.70% and 3.30% (3.00% was assumed). [5]LU: The R&D intensity target is between 2.30% and 2.60% (2.45% was assumed). [6]IE: The R&D intensity target is 2.5% of GNP which is estimated to be equivalent to 2.0% of GDP. [7]DK, EL, FR, LU, HU, NL, PT, RO, SI, SE, UK: Breaks in series occur between 2000 and 2016.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f5_rd_intensities_ms.xlsx

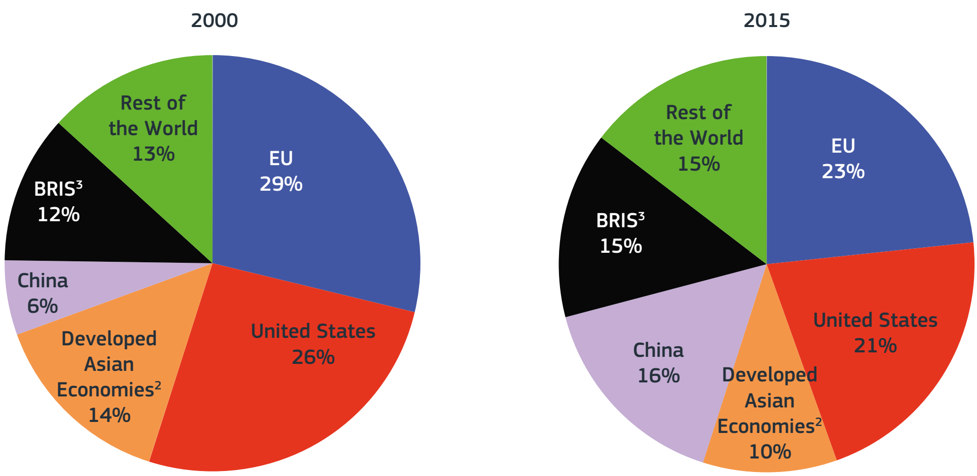
2 It should be noted that, during this period, GDP in Greece fell, which affected the denominator of the R&D intensity; therefore, growth rates should be analysed against this general economic backdrop.

3 The data for France and Slovenia refer to 2015 and 2007-2015.

A breakdown of R&D investment by sector shows that the EU remains the major global public investor in R&D.

Europe's high public sector investment in R&D contributes to nurturing and improving a research capacity that benefits both the public and private sectors. The United States has the second highest global share of public investment in R&D after the EU. Most public sector R&D in both the EU and the United States is performed by higher education institutions. Higher education expenditure on R&D was around 30% higher in the EU than in the United States in both 2000 and 2015.

Figure I.3-A.6 World public expenditure on R&D - % distribution[1], 2000 and 2015

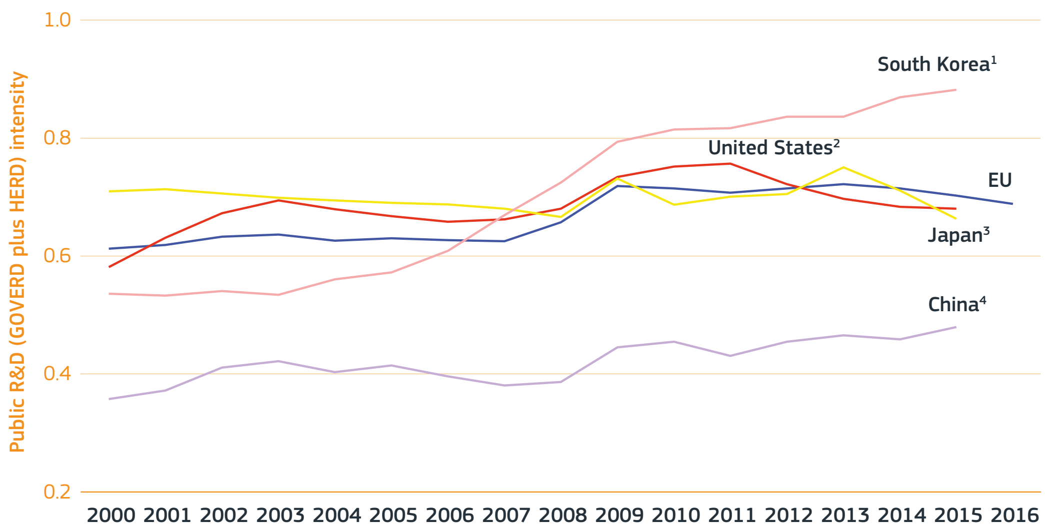


Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, OECD, UNESCO
Notes: [1]The % shares were calculated from estimated values for GOVERD+HERD in current PPS€.
[2]Japan+South Korea+Singapore+Chinese Taipei. [3]Brazil+Russian Federation+India+South Africa.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f6_world_expend_on_public_rd.xlsx

The EU has one of the highest public R&D intensities worldwide with a value of 0.69% of GDP in 2016, progressing from 0.61% in 2000.

Public R&D intensity is now higher in the EU than in the United States, Japan and China.

Figure I.3-A.7 Evolution of public R&D intensity, 2000-2016

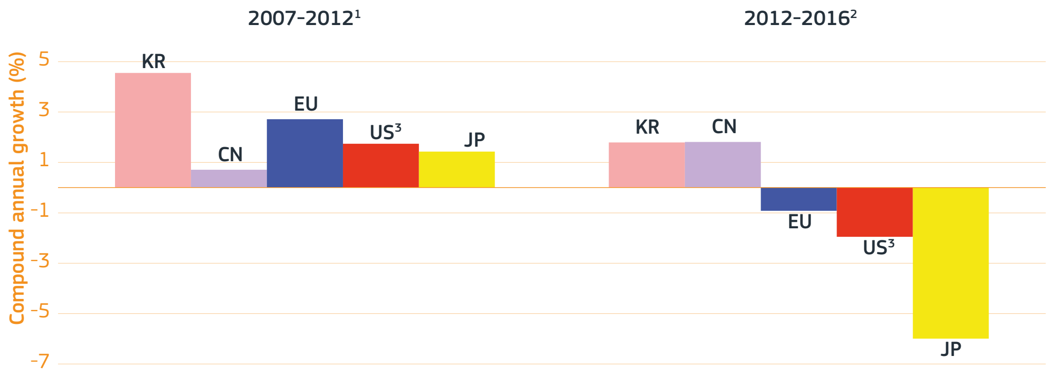


Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, OECD
Notes: [1]KR: There is a break in series between 2007 and the previous years. [2]US: (i) Public R&D expenditure does not include most or all capital expenditure; (ii) There is a break in series between 2003 and the previous years. [3]JP: There is a break in series between 2008 and the previous years and between 2013 and the previous years. [4]CN: There is a break in series between 2009 and the previous years.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f7_public_rd_intensity.xlsx

Public R&D intensity growth in the EU, although decreasing over recent years, has not declined to the same extent as in the United States and Japan.

In fact, total public R&D expenditure in the EU increased every year from 2007 to 2015 and the total of national government budgets for R&D increased every year from 2012 to 2015 (Figure I.3-A.8).

Figure I.3-A.8 Public R&D intensity - compound annual growth, 2007-2012 and 2012-2016



EU
million euro

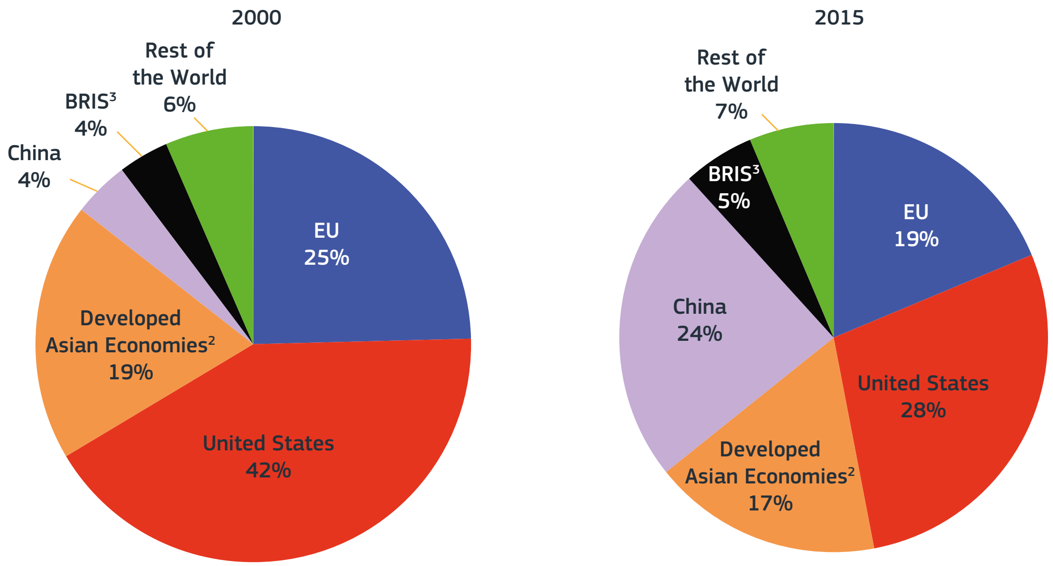
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Public expenditure on R&D (GOVERD plus HERD)	81197	85908	88462	91651	93365	96183	98015	100346	103900	*102612*
Government budget allocations for R&D (GBARD)	*85360*	89883	92112	92846	92702	90927	92548	93869	96083	*94991*

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, OECD
Notes: [1]JP: 2008-2012; CN: 2009-2012. [2]US, CN, KR: 2012-2015; JP: 2013-2015. [3]US: Public R&D expenditure does not include most or all capital expenditure. [4]Values in italics are estimated or provisional.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f8_public_rd_intensity_cagr.xlsx

In terms of business R&D, the EU also maintains a strong position in the global research landscape, accounting for nearly one fifth of all research investment, although this share has declined due to the sharp rise of China which now accounts for almost one quarter of global business R&D expenditure.

China's share of global business R&D expenditure increased exponentially from 4% in 2000 to 24% in 2015. This increase was mirrored by a decline of 14 percentage points in the United States' share, from 42% to 28%, and by a much less dramatic fall of six percentage points in the EU's share, from 25% to 19%.

Figure I.3-A.9 World business enterprise expenditure on R&D -% distribution[1], 2000 and 2015

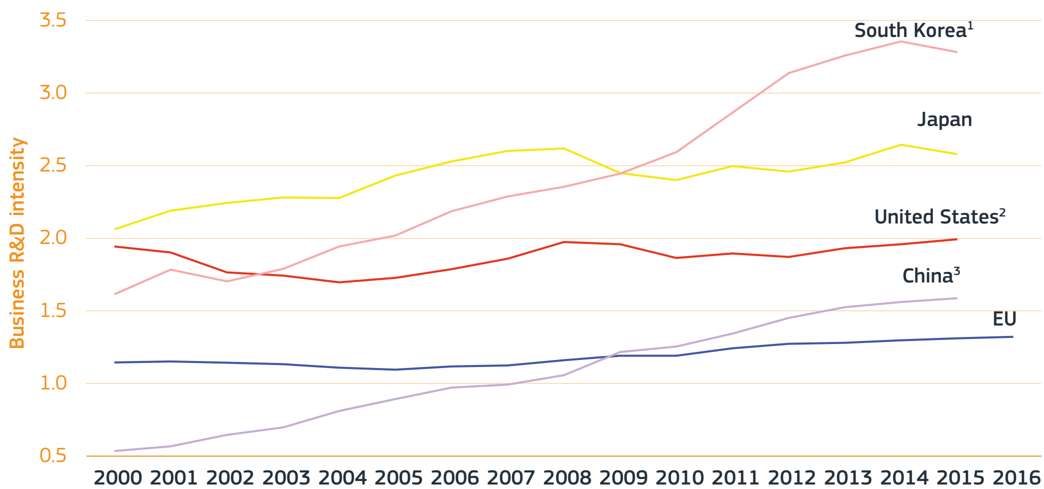


Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, OECD, UNESCO
Notes: [1]The % shares were calculated from estimated values for total BERD in current PPS€.
[2]Japan+South Korea+Singapore+Chinese Taipei. [3]Brazil+Russian Federation+India+South Africa.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f9_world_expend_on_business_rd.xlsx

China has nearly tripled its business R&D intensity since 2000, progress that is rivalled only by South Korea, whose business R&D intensity is approaching 3.5 %.

Business R&D intensity is significantly higher in South Korea (3.28 % of GDP) than in Japan (2.58 %), the United States (1.99 %), China (1.59 %) and the EU (1.32 %). The rapid growth of business R&D intensity in South Korea, China and to a lesser extent Japan over the last decade and a half is in sharp contrast to the moderate evolution of business R&D intensity in the EU and the United States and is reflected in the increasing business R&D intensity gap between the EU and its main competitors.

Figure I.3-A.10 Evolution of business R&D intensity, 2000-2016



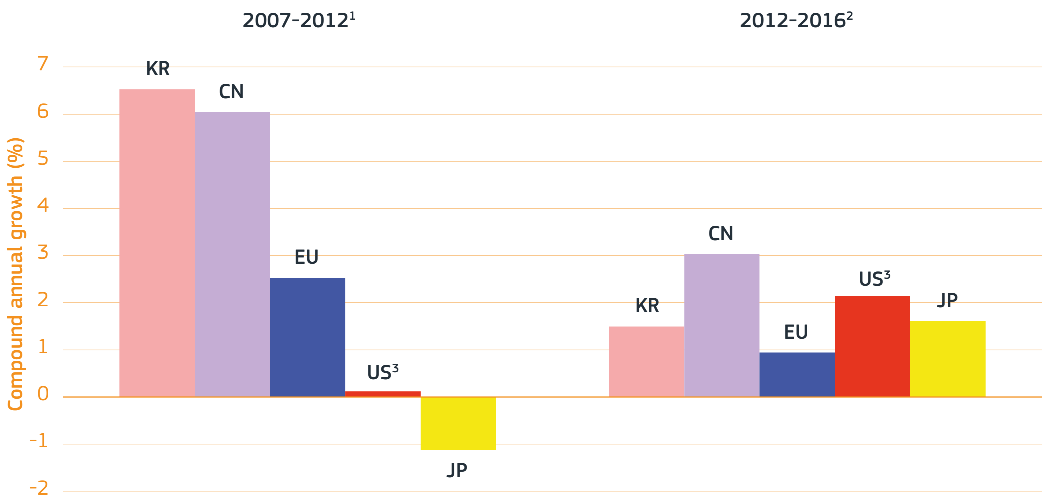
Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, OECD
Notes: [1]KR: There is a break in series between 2007 and the previous years. [2]US: Business enterprise expenditure on R&D (BERD) does not contain most or all capital expenditure. [3]CN: There is a break in series between 2009 and the previous years.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f10_business_rd_intensity.xlsx

Business R&D intensity in the EU proved to be quite resilient over the first period of the economic crisis and grew at a compound annual growth rate of 2.5% over 2007-2012. This was a much higher level of growth than that experienced in the United States (0.1%) and Japan (-1.1%).

However, over the period 2012-2016, business R&D intensity growth slowed in the EU to 0.9% per annum, a growth rate that was less than half that of China and the United States, and well below the growth rates of Japan and South Korea (Figure 1.3-A.11). Nevertheless, there are now clear signs of economic recovery in the EU and it is expected that this will lead to increasing business investment in R&D and to higher business R&D intensities.

Figure I.3-A.11 Business R&D intensity - compound annual growth, 2007-2012 and 2012-2016



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: [1]CN: 2009-2012. [2]US, JP, CN, KR: 2012-2015. [3]US: Business R&D expenditure does not inlcude most or all capital expenditure.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f11_berd_int_cagr.xlsx

The analysis of R&D investment at the aggregate level masks large differences across EU Member States.

Overall, there is a large dispersion in terms of R&D investment levels, as well as in their dynamics, with some low investors stagnating, some high investors accelerating, and several, but not all, Central and Eastern European countries sharply increasing their R&D levels, thereby initiating a process of upwards convergence (Figure I.3-A.12). The highest EU R&D intensity growth rates over 2007-2015 occurred in Bulgaria, Poland and Slovakia, all of which had growth rates at least four times higher than the EU average. The Czech Republic, Estonia, Greece, Malta and Hungary also had growth rates that were significantly higher than the EU average. Although the R&D intensities of all of these eight Member States were below the EU average in 2015, the gap with the EU average has narrowed considerably since 2007 for all of them with the exception of Malta. The process of convergence has been facilitated by the increased use of European Structural and Investment Funds available for R&I activities. Greater national efforts will be required to ensure the sustainability of this trend.

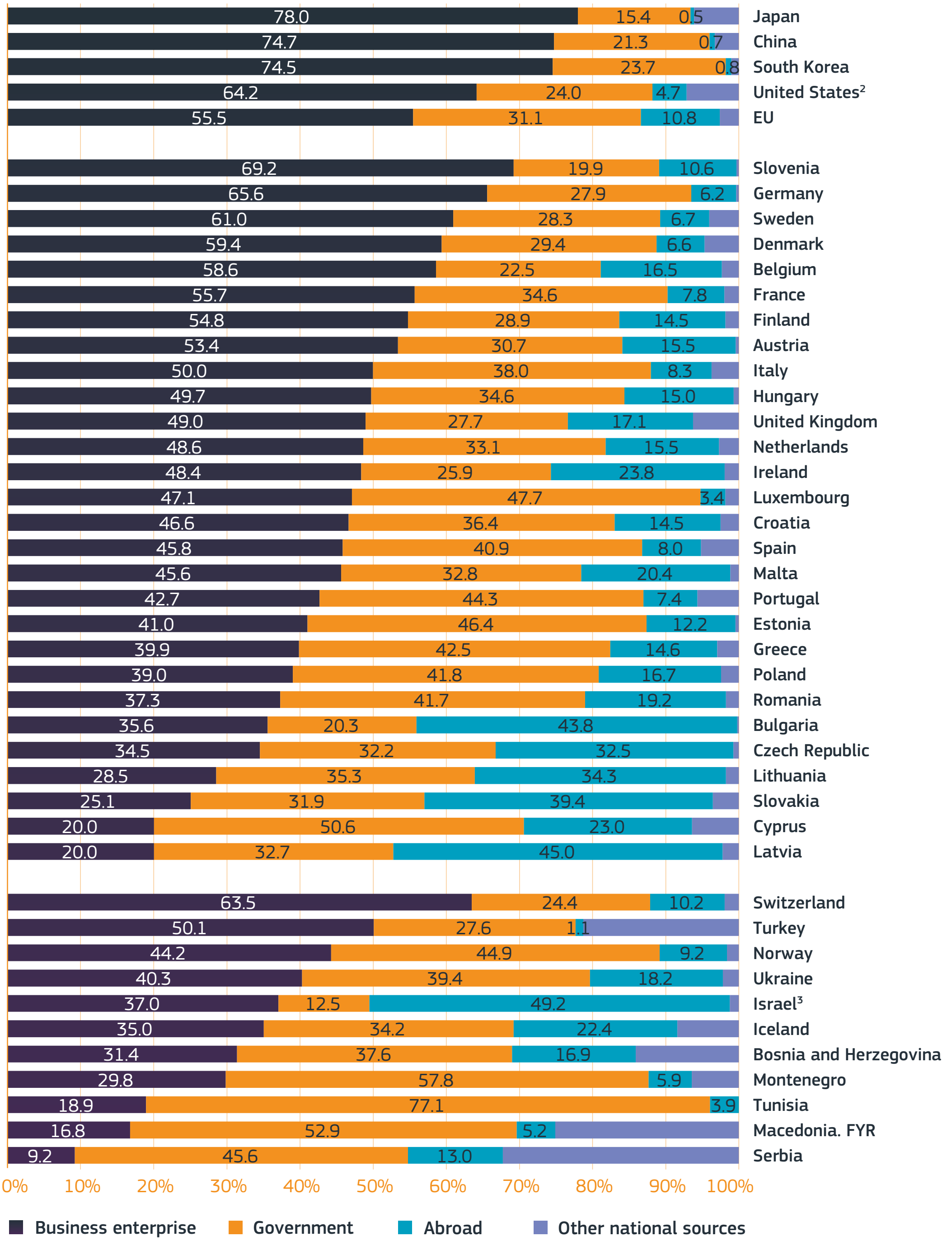
Figure I.3-A.12 R&D intensity, 2016 and compound annual growth, 2007-2016

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, OECD, UNESCO
Notes: [1]BG, CZ, EE, FR, HR, LV, LT, HU, MT, RO, SI, SK, CH, ME, MK, TR, BA, MD, UA, TN, IL, US, JP, CN, KR: 2015. [2]BG, CZ, EE, FR, HR, LV, LT, HU, MT, PL, RO, SK, MK, TR, MD, UA, TN, IL, US, CN, KR: 2007-2015; SI, CH, JP: 2008-2015; EL, PT, SI: 2008-2016; RS: 2009-2016; ME: 2011-2015; BA: 2012-2015; IS: 2013-2016. [3]US: R&D expenditure does not include most or all capital expenditure. [4]FR, LU, NL, RO, SI, UK, JP, CN: Breaks in series occur between 2007 and 2016; when there is a break in series the growth calculation takes into account annual growth before the break in series and annual growth after the break in series.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f12_rd_intensity_2007-2015.xlsx

In the EU as a whole, 31.1 % of R&D is financed by government.

This share is much higher than the corresponding shares for the United States (24.0 %), South Korea (23.7 %), China (21.3 %) and Japan (15.4 %). This reflects the higher reliance and stronger role of public research in many EU Member States. In fact, there are only nine Member States where the share of R&D financed by government is lower than 30 %. These are: Denmark (29.4 %), Finland (28.9 %), Sweden (28.3 %), Germany (27.9 %), the UK (27.7 %), Ireland (25.9 %), Belgium (22.5 %), Bulgaria (20.3 %) and Slovenia (19.9 %). Eight Member States have shares that are higher than 40 %. In the EU, 55.5 % of R&D is financed by domestic business enterprise, and an additional 7 % of R&D is financed by business enterprise abroad. This still leaves the EU's share of R&D financed by business enterprise behind the United States (64.2 %), South Korea (74.5 %), China (74.7 %) and Japan (78.0 %), all of which have higher R&D intensities than the EU.

Figure I.3-A.13 GERD financed by sector (%), 2015[1]



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD, UNESCO

Notes: [1]SE, IL: 2013; FR: 2014; EL, AT, IS, RS: 2016. [2]US: R&D expenditure does not include most or all capital expenditure.

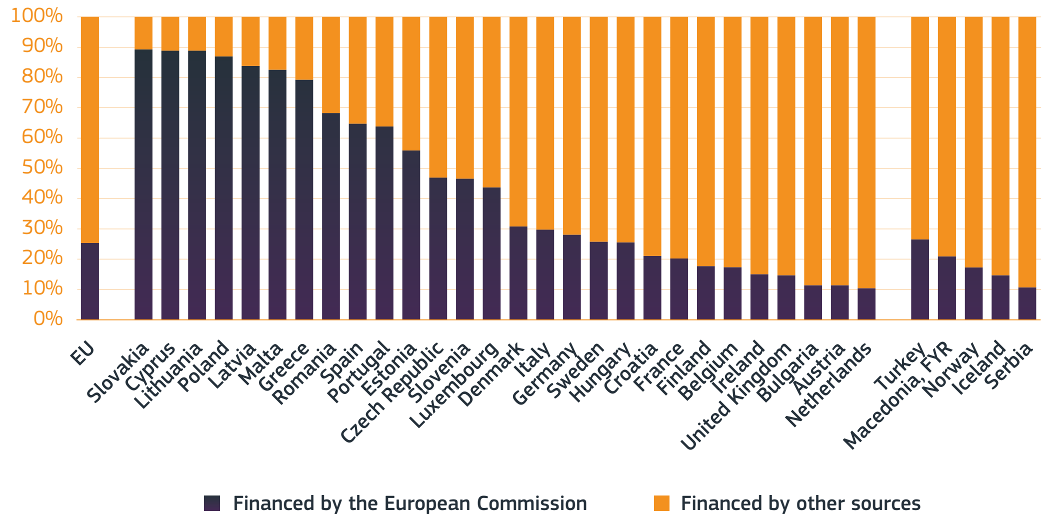
[3]IL: Defence (all or mostly) is not included.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f13_gerd_fin_by_sect.xlsx

R&D financing from abroad plays an important role in many countries.

R&D financing from abroad originates from public and private sources. The main public source of financing from abroad for EU Member States is the European Commission which funds R&D projects under the Horizon 2020 programme and the European Structural and Investment Funds. In 11 Member States, more than 50% of total R&D funding from abroad comes from the European Commission.

Figure I.3-A.14 R&D expenditure financed from abroad, 2015[1]



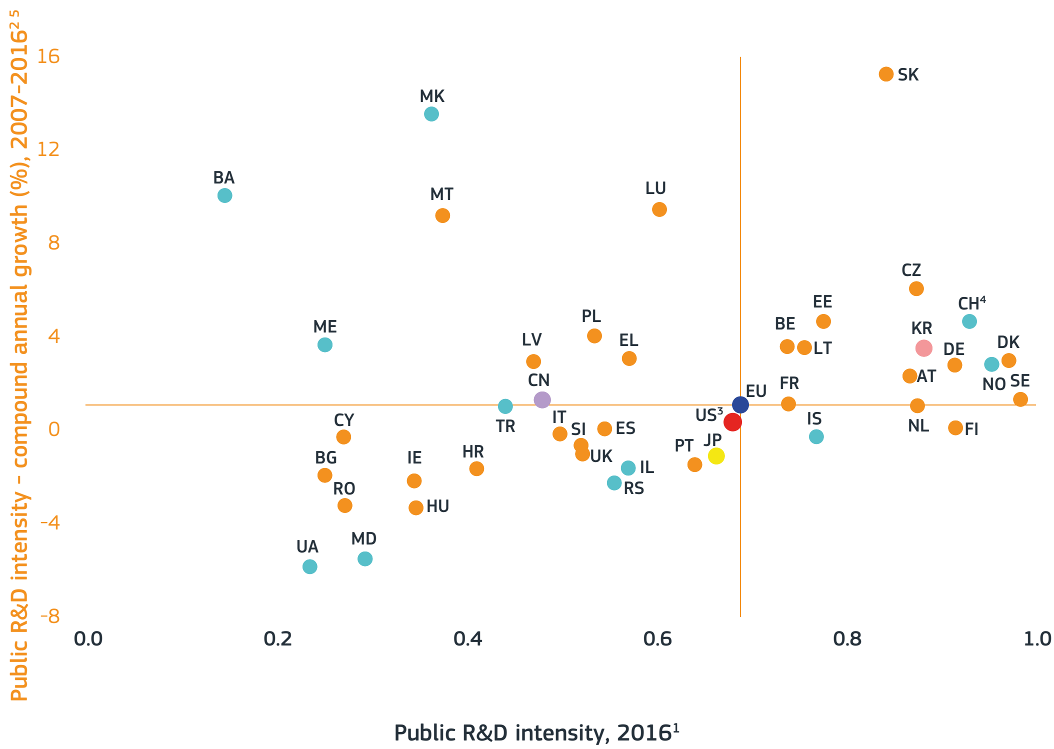
Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat
Note: [1]SE: 2013; FR: 2014; IS: 2016.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f14_financing_from_abroad.xlsx

R&D investment by the public sector has increased in several of the Member States where the European Commission is the main source of R&D funding from abroad.

In the Czech Republic, Lithuania and Slovakia, growth in public R&D intensity over the period 2007-2015 was significantly higher than the EU average with the result that their public R&D intensities were higher than the EU average in 2015 (Figure I.3-A.15). Eleven other Member States had public R&D intensity growth rates above the EU average. However, in several Member States, growth in public R&D intensity stagnated or even declined over the period 2007-2016, as was the case for Bulgaria, Ireland, Croatia, Italy, Cyprus, Hungary, Portugal, Romania, Slovenia and the UK.

Figure I.3-A.15 Public R&D intensity, 2016 and compound annual growth, 2007-2016



Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, OECD, UNESCO
Notes: [1]BG, CZ, DE, EE, FR, HR, LV, LT, HU, MT, PL, RO, SI, SK, CH, ME, MK, TR, BA, MD, UA, IL, US, JP, CN, KR: 2015. [2]BG, CZ, DE, EE, FR, HR, LV, LT, HU, MT, PL, RO, SI, SK, MK, TR, MD, UA, IL, US, CN, KR: 2007-2015; CH, JP: 2008-2015; EL, PT: 2008-2016; RS: 2009-2016; ME: 2011-2015; BA: 2012-2015; IS: 2013-2016. [3]US: Public expenditure on R&D does not include most or all capital expenditure. [4]CH: Government Intramural expenditure on R&D (GOVERD) refers to federal or central government only. [5]BE, DE, FR, LU, NL, PT, RO, SI, RS, JP, CN: Breaks in series occur between 2007 and 2016; when there is is a break in series the growth calculation takes into account annual growth before the break in series and annual growth after the break in series.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f15_pub_rd_intensity.xlsx

Business R&D intensity growth rates have been more modest.

Seven of the more R&D intensive EU Member States (Denmark, Germany, France, the Nether-lands, Finland, Sweden and the UK) reported business R&D intensity growth rates lower than the EU average over the period 2007-2016. Of the other EU Member States, Bulgaria, Hungary, Poland and Slovakia had very high business R&D intensity growth rates (above 8 %) over the period 2007-2015, and in Bulgaria and Hungary the business R&D intensity gap with the EU average narrowed considerably between 2007 and 2015. Business R&D intensity in Slovenia has grown significantly since 2007 and is now much higher than the EU average (Figure 1.3-A.16).

Figure I.3-A.16 Business R&D intensity, 2016 and compound annual growth, 2007-2016

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD, UNESCO

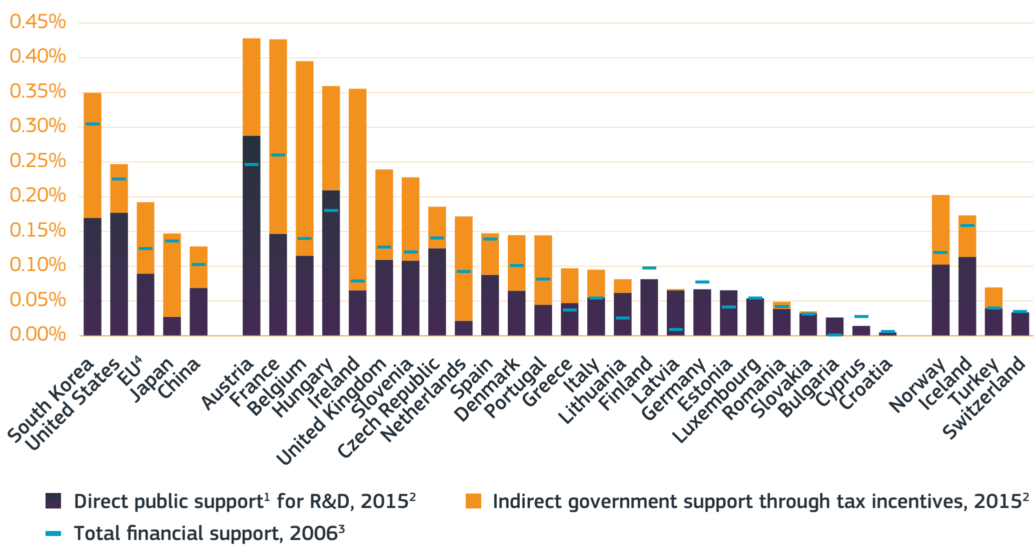
Notes: [1]BG, CZ, EE, FR, HR, LV, LT, HU, MT, PL, RO, SI, SK, CH, ME, MK, TR, MD, UA, IL, US, JP, CN, KR: 2015. [2]BG, CZ, EE, FR, HR, LV, LT, HU, MT, PL, RO, SK, MK, TR, MD, UA, IL, US, JP, CN, KR: 2007-2015; SI, CH: 2008-2015; EL, ES: 2008-2016; RS: 2009-2016; ME: 2011-2015; IS: 2013-2016. [3]US: Business enterprise expenditure on R&D (BERD) does not contain most or all capital expenditure. [4]LU, NL, RO, SI, UK, RS, CN: Breaks in series occur between 2007 and 2016; when there is a break in series the growth calculation takes into account annual growth before the break in series and annual growth after the break in series.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f16_berd_intensity.xlsx

In recent years, business R&D intensity has stagnated at the EU level. Public support for business R&D increased substantially from 0.13% of GDP in 2006 to 0.19% of GDP in 2015. While R&D tax incentives are effective in stimulating R&D investments, there is a lag between the introduction of an R&D tax incentive and an increase in R&D spending.

Public support for business R&D as a percentage of GDP increased in 21 Member States between 2006 and 2015, with a rise of more than 100 % in six of these countries. Much of this support came through the provision of tax incentives for R&D. In the EU as a whole, tax incentives for R&D now account for 53 % of all public support for business R&D. This share is greater than 50 % in the Netherlands (87 %), Ireland (82 %), Belgium (71 %), Portugal (69 %), France (66 %), Denmark (55 %), the UK (54 %), Slovenia (53 %) and Greece (51 %). Two of these economies, Denmark and Ireland, are the most high-tech-intensive economies in the EU. Germany and Finland, both of which have high business R&D intensities, either have no tax incentives for R&D. It should be noted that there is a lag between the introduction of an R&D tax incentive and an increase in R&D investment that would be contingent on how the incentive is designed and implemented, as well as on the structure of the economy in which it is implemented.

Figure I.3-A.17 Public support for business R&D as % of GDP, 2006 and 2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: OECD, Eurostat

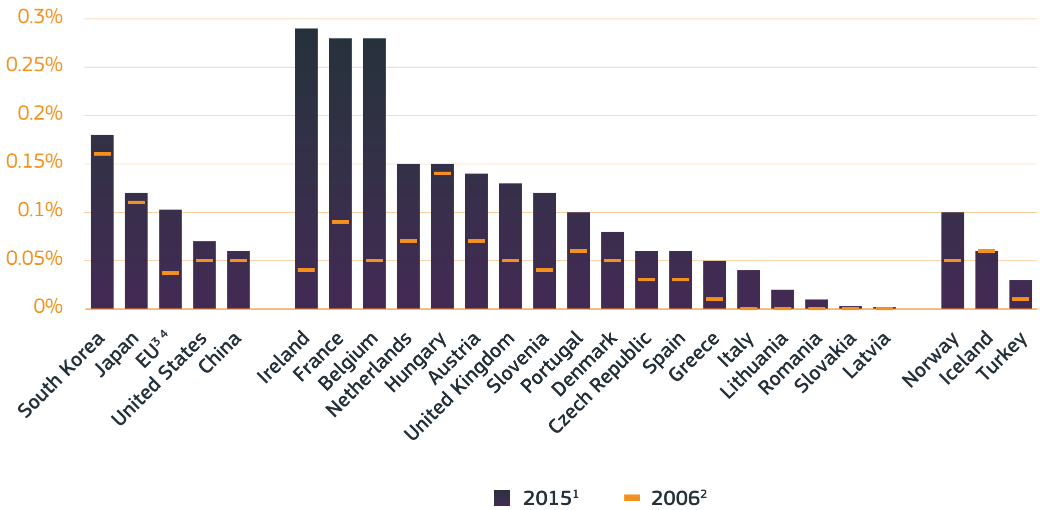
Notes: [1]Estimated direct public support for business R&D includes direct government funding, funding by higher education and public sector funding from abroad. Public sector funding from abroad is not included for DE, NL, IS, CH. [2]US, CN: 2013; BE, BG, FR, IE, EL, UK, IS, TR: 2014. [3]BE, DK, LU, SI, KR: 2007; CH, TR: 2008; RO, CN: 2009; SK: 2010; IS: 2011. [4]EU was estimated by DG Research and Innovation and does not include MT, PL, SE. Data on tax incentives for R&D are not available for MT, PL, SE. The following countries have no tax incenitves for R&D: BG, DE, EE, HR, CY, LU, FI. [5]Elements of estimation were involved in the compilation of the data.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f17_public_support_for_berd.xlsx

Tax incentives are now part of the R&D landscape in most EU Member States; in the EU as a whole, they increased from 0.04% of GDP in 2006 to 0.1% of GDP in 2015.

There is a much higher rate of increase in the use of tax incentives for R&D in Europe than in the United States, Japan, China and South Korea. Over the same period, tax incentives as a percentage of GDP increased by more than 100% in Belgium, Ireland, Greece, France, the Netherlands, Slovenia, the UK and Turkey. Although tax incentives for R&D are now higher than they have ever been, business R&D intensity in the EU did not increase very significantly between 2012 and 2016. The development of more effective public sector measures to stimulate business investment in R&D will depend on each EU Member State finding the right balance between direct public support for business R&D and tax incentives for R&D.

Figure I.3-A.18 Tax incentives for R&D as % of GDP, 2006 and 2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: OECD, Eurostat

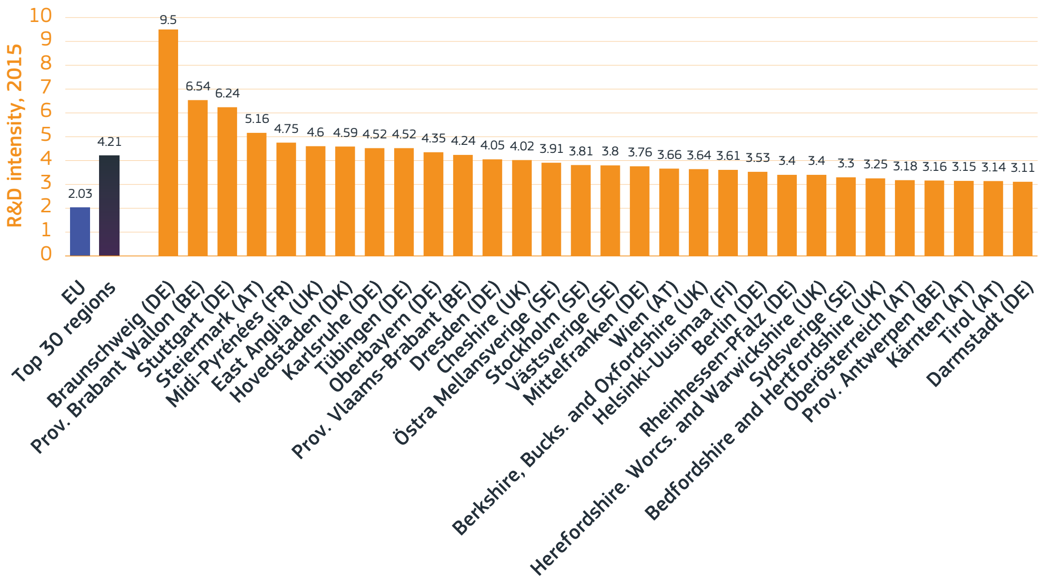
Notes: [1]US, CN: 2013; BE, IE, EL, FR, UK, IS, TR: 2014. [2]BE, DK, SI, KR: 2007; TR: 2008; RO, CN: 2009; SK: 2010; IS: 2011. [3]EU was estimated by DG Research and Innovation and does not include MT, PL, SE. Data on tax incentives for R&D are not available for MT, PL, SE. [4]BG, DE, EE, HR, CY, LU, FI, CH have no tax incentives for R&D.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/f18_tax_incentives.xlsx

A regional analysis of R&D investment shows that research is heavily concentrated in particular regions of the EU, notably in core Member States such as Germany, Sweden, Austria, Belgium and Finland.

The top 30 most R&D-intensive regions in the EU (out of a total of 272) accounted for 36 % of all EU R&D expenditure and had an average R&D intensity of 4.21 % of GDP in 2015. This is significantly higher than the EU R&D intensity of 2.03 %. The highest regional R&D intensity of 9.5 % in Braunschweig (DE) was more than four times higher than the EU average. The top 10 regions all had R&D intensities that were at least double the EU average and were also higher than the R&D intensities for the United States, Japan, China and South Korea.

Figure I.3-A.19 The 30 most R&D intensive regions[1] in the EU - R&D intensity, 2015[2]



Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat
Notes: [1]NUTS Level 2 regions. [2]FR: 2013.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/figure_19_top_30_regions.xlsx

The concentration of research activity in the most R&D intensive regions has not increased in recent years.

In 2007, the top 30 most R&D intensive regions at that time accounted for an estimated 42 % of all EU R&D expenditure and had an estimated R&D intensity of 3.65 % of GDP. There is some evidence to suggest that a regional 'catching-up' process may be taking place (Figure I.3-A.20). In 2015, the 30 regions ranked 31 to 60 in terms of R&D intensity had an aggregate R&D intensity of 2.60 % and accounted for 24 % of all EU R&D expenditure compared to an aggregate R&D intensity of 2.23 % and a 17 % share of total EU R&D expenditure in 2007. In 2015, the narrowing of the R&D expenditure gap between the top 30 regions and the regions ranked 31 to 60 is an indication of more widespread regional R&D activity, although a change in the Île-de-France's ranking from 28 in 2007 to 33 in 2015 had a big impact in this regard. It is noticeable that R&D intensities for the three categories of regions increased significantly between 2007 and 2015, with the highest rise of 17.3 % occurring in the least R&D intensive category of regions. The funding of R&D projects under the European Commission Framework and Horizon 2020 Programmes and the Structural Funds is a catalyst for this process. The Smart Specialisation Strategies approach, which was integrated into the reformed Cohesion Policy for 2014-2020, and which was designed to maximise the positive impact on growth and jobs, is already helping over 120 regions to identify their strengths and competitive advantages as a basis for prioritising R&I investment. Exploiting the full R&D potential of individual regions will lead to higher regional and national R&D intensities and reduce regional R&D intensive disparities.

Figure I.3-A.20 R&D intensity and % share of R&D expenditure by category of region[1], 2007 and 2015[2]

	R&D intensity			% share of total R&D expenditure	
	2007	2015	% change 2007-2015	2007	2015
Top 30 R&D intensive regions	3.65	4.21	15.3	42	36
Regions ranked 31 to 60 in terms of R&D intensity	2.23	2.60	16.7	17	24
Regions ranked higher than 60 in terms of R&D intensity	1.09	1.28	17.3	41	40
EU	1.77	2.03	15.0	100	100

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat
Notes: [1]NUTS Level 2 regions. [2]FR: 2013. [3]Some figures were estimated when the data were compiled.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-a_figures/figure_20_regional_table.xlsx

CHAPTER I.3-B: INVESTMENT IN INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT)

ICT is the driving force of the digital era and has the potential to spur innovation, job creation, productivity and economic growth[4].

ICT has profoundly shaped (and changed) the way businesses operate across all sectors of the economy and how individuals communicate and interact with each other. By creating opportunities to buy products and services online, engage in long-distance video calls, and store, exchange and share data, ICTs have also contributed to enhancing well-being. Investments in technologies, such as big data, high performance computing, the Internet-of-Things (IoT), artificial intelligence (AI) and cloud computing are also enabling productivity-enhancing processes and systems and contributing to ICT-driven innovation. In addition, ICTs are becoming increasingly relevant to create new and 'better' jobs. However, due to the disruptive nature of these technologies, it is important to ensure that the digital transition follows an inclusive approach whereby the access, adoption and uptake of digital technologies is widespread across individuals and firms. If not, the lack of ICT diffusion from frontier to laggard firms and among individuals could contribute to widening the digital divide and jeopardising the potential of ICTs to elevate living standards and generate inclusive and resilient growth in Europe. Investments in ICT coupled with investments in knowledge-based capital (see Section I.3-D) hold part of the solution to meet this ambition[5].

The contribution of ICT capital to economic growth has slowed down since the crisis.

The economic and financial crisis that followed the burst of the dot.com bubble had a negative impact on the contribution of ICT investments to economic growth (OECD, 2016b), which has slowed down substantially when comparing the period 2000-2007 with 2008-2015. Of the EU Member States with available data, the contribution of ICT investments declined the most in percentage points (-0.41) between both periods in Sweden, followed by Denmark (-0.31 percentage points) and Portugal (-0.28 percentage points). In South Korea, Japan and the United States, the contribution of ICT investments to GDP growth also slowed down significantly, with a fall of 0.33, 0.31 and 0.29 percentage points, respectively, between the two periods under consideration, despite the recent rise in digital technologies. When focusing only on the period 2008-2015, Belgium, the Netherlands and Austria were the EU Member States where ICT capital contributed the most to GDP growth (with increases of 0.28, 0.26 and 0.25 percentage points, respectively). While understanding the full reasons for this decline is complex, lower investment levels and returns on these investments may be behind this trend.

4 See, for instance, OECD (2016a) and Cardona, M., Kretschmer, T. and Strobel, T. (2013).

5 For example, IT is more effective when paired with good management. Bloom et al. (2012) found that "US IT-related productivity advantage is primarily due to its tougher people management practices". Haskel and Westlake (2017) also emphasise the growing dominance of the intangible economy to explain a firm's success.

Figure I.3-B.1 Contribution of ICT capital[1] to GDP growth (percentage points), average over 2000-2007 and 2008-2015

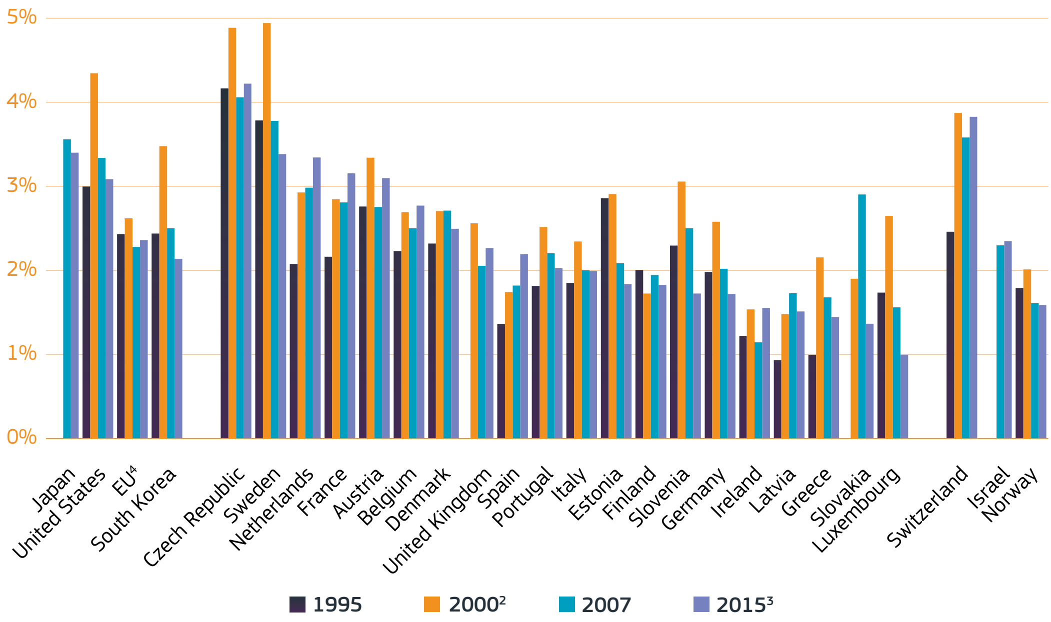
Science, Research and Innovation performance of the EU 2018
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: OECD Productivity Database
Note: [1]ICT capital: computer hardware, telecommunications equipment, and computer software and databases.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_1.xlsx

The EU still invests less in ICT than other third countries such as Japan and the United States.

ICT investments have an important role to play as catalysts of economic growth, through both the supply and the demand side (OECD, 2016a). On the supply side, investing in ICT fosters upwards convergence towards higher-value-added and productive activities. The widespread access and use of ICTs on the demand side can also contribute to efficiency gains across all sectors of the economy and to societal welfare. Through the "ICT dividend"[6], ICT investments generate a higher return on productivity growth than other types of capital investment.

After a generalised increase in ICT investments between 1995 and 2000, overall, investments contracted to a lower level in 2015 (in some countries even slipping back to 1995 levels). From 2000 to 2015, the share of ICT investments declined significantly in the United States and South Korea. Despite the recent increase of ICT investment in Europe, the EU continues to lag behind Japan and the United States, as investment rose slightly above 2% in 2015 against values above 3% in the United States and Japan. Some EU Member States, such as the Czech Republic, Sweden and the Netherlands, stand out as top investors in ICT as a percentage of GDP with shares equivalent to or even higher than those of the United States and Japan. Luxembourg, Slovakia and Greece were the EU Member States that registered the lowest shares of ICT investments relative to GDP in 2015, showing a decline since 2007.

Figure I.3-B.2 Investment in ICT[1] as % of GDP, 1995, 2000, 2007 and 2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: OECD Compendium of Productivity Indicators 2016, OECD National Accounts at a Glance, Eurostat

Notes: [1]For those countries for which data on total investment in ICT were not available, investment in ICT as % of GDP was derived from the ICT share in gross fixed capital formation (GFCF) and the share of GFCF in GDP. [2]DE, CH, KR: 2001. [3]SI: 2013; DE, DK, EE, IE, ES, LV, PT, SK, SE: 2014. [4]EU is the average of the available data for Member States weighted by GDP.

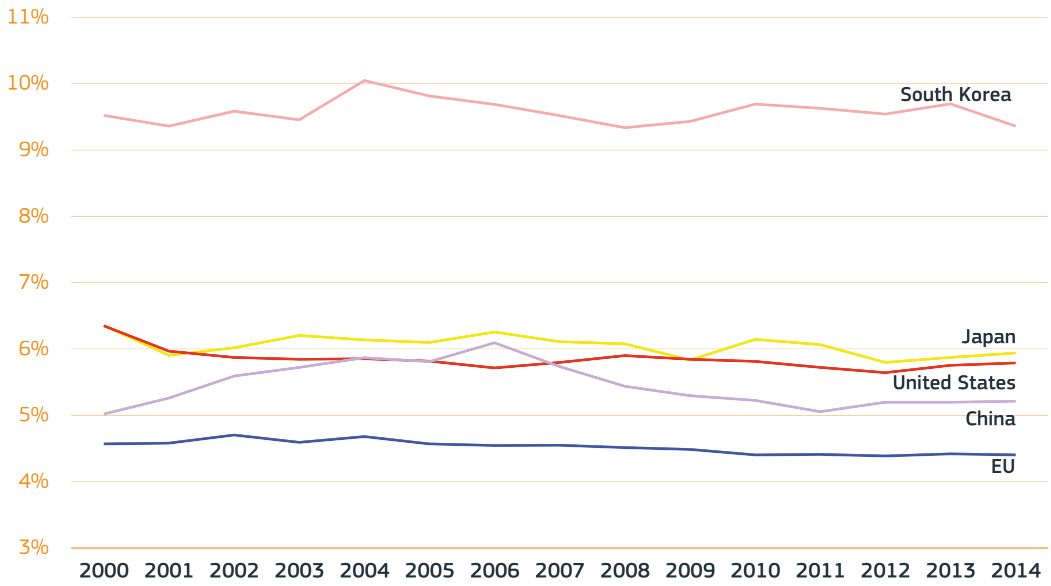
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/partI/i_3-b_figures/f_i_3-b_2.xlsx

6 See, for example, Oxford Economics (2012).

This is reflected in a lesser role for the ICT sector in the European economy than among other international players.

The value added of the ICT sector in the EU stagnated at around 4.5 % of GDP between 2000 and 2014. Hence, the contribution of the ICT sector to the European economy in 2014 was still below that of South Korea (8.9 %), Japan (5.4 %), the United States (5.29 %) and China (4.71 %). Differences in investment trends between the EU and some of these third countries may partly explain this gap in the role of ICT.

Figure I.3-B.3 Value added in ICT[1] as % of GDP, 2000-2014



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: PREDICT Project (DG JRC)

Note: [1]The operational definition of ICT, as defined in the PREDICT project, was used. The operational defintion of ICT allows for international comparison with non-EU countries.

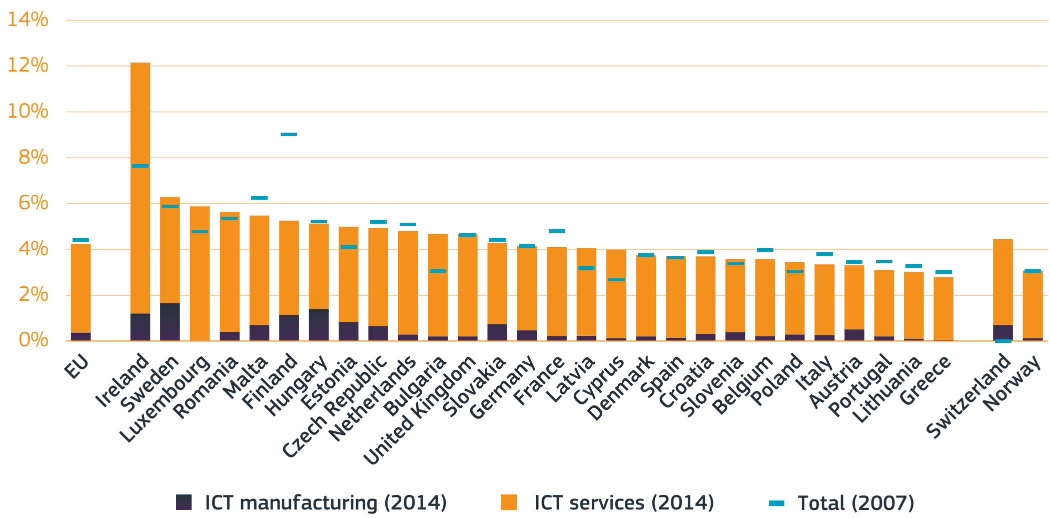
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_3.xlsx

There has been little progress in raising the share of ICT in the value added of most Member States, although there are some notable exceptions.

The value added of the ICT sector was highest in Ireland in 2014, with marked increases in the importance of the sector from 7.6% in 2007 to 12.2% of GDP in 2014. In Greece, the sector accounted for less than 3% of GDP in 2014, and in Finland there was a substantial decline in this share from 9% to 5.3% of GDP between 2007 and 2014.

On average, ICT services represented 91.2% of the ICT sector in 2014. In fact, in some countries, like Luxembourg, the contribution of ICT manufacturing industries to ICT value added is almost non-existent, while in others, such as Sweden and Hungary, this sector still contributes to a little more than one-quarter of the sector's value added.

Figure I.3-B.4 Value added in ICT[1] as % of GDP broken down by manufacturing and services, 2014 (and for 2007 without breakdown)



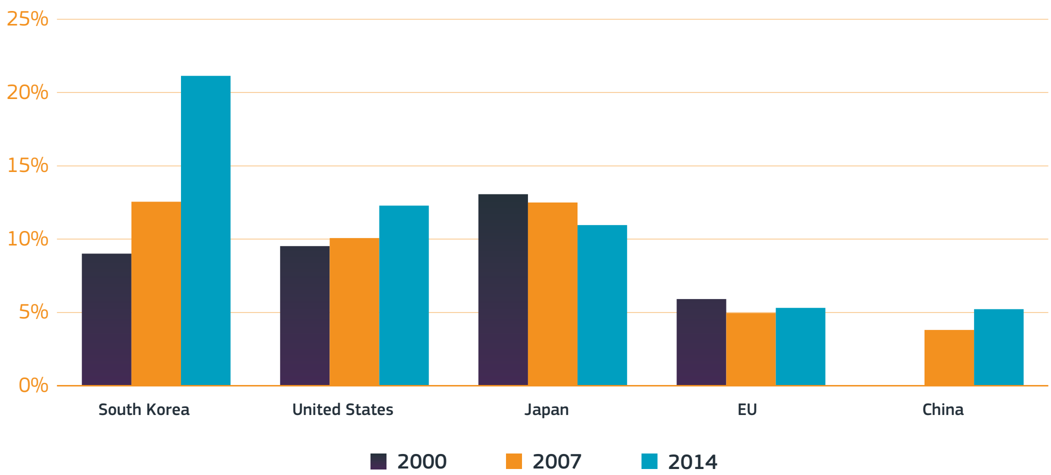
Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: PREDICT project (DG JRC)
Note: [1]The comprehensive definition of ICT, as defined in the PREDICT project, was used.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_4.xlsx

Europe's investment in R&D in the ICT sector also lags behind.

Private R&D intensity in the European ICT sector lags behind that of other major international players (see Figure I.3-B.5 below). Overall, in the period 2000-2014, the business R&D intensity in ICT of companies located in the EU was around half that of those based in the United States, Japan and South Korea. This illustrates that the EU ICT sector not only lags behind in terms of its size in the economy but is also not focused on R&D-intensive activities.

Figure I.3-B.5 R&D intensity of ICT[1], 2000, 2007 and 2014

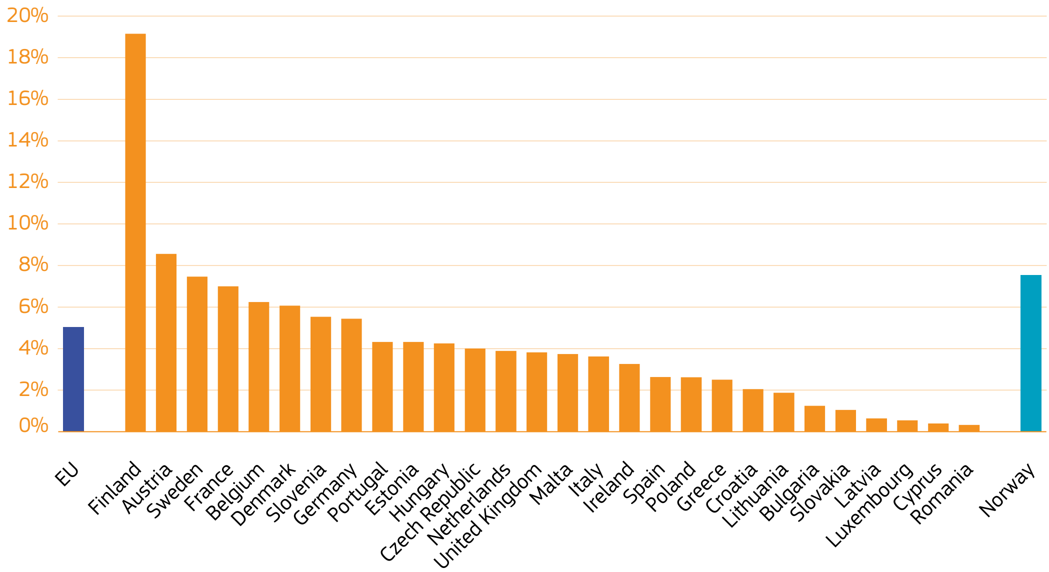


Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: PREDICT Project (DG JRC)
Note: [1]Business enterprise expenditure on R&D as % of value added. The operational definition of ICT, as defined in the PREDICT project, was used. The operational defintion of ICT allows for international comparison with non-EU countries.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_5.xlsx

However, some Member States stand out in ICT, due to their R&D investment in this sector.

Figure I.3-B.6 shows that, in 2014, Business Enterprise R&D expenditure (BERD) in the ICT sector was notably high in Finland (19.2 % of total value added), followed by Austria (8.6 %) and Sweden (7.5 %). On the contrary, BERD intensity in Luxembourg, Cyprus and Romania was significantly lower, with values of 0.5 %, 0.4 % and 0.3 %, respectively. This reveals the considerable variation across EU Member States in efforts by the private sector devoted to investing in R&D in the ICT sector, and explains why the EU lags behind other advanced economies, as mentioned above.

Figure I.3-B.6 R&D intensity of ICT[1], 2014



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

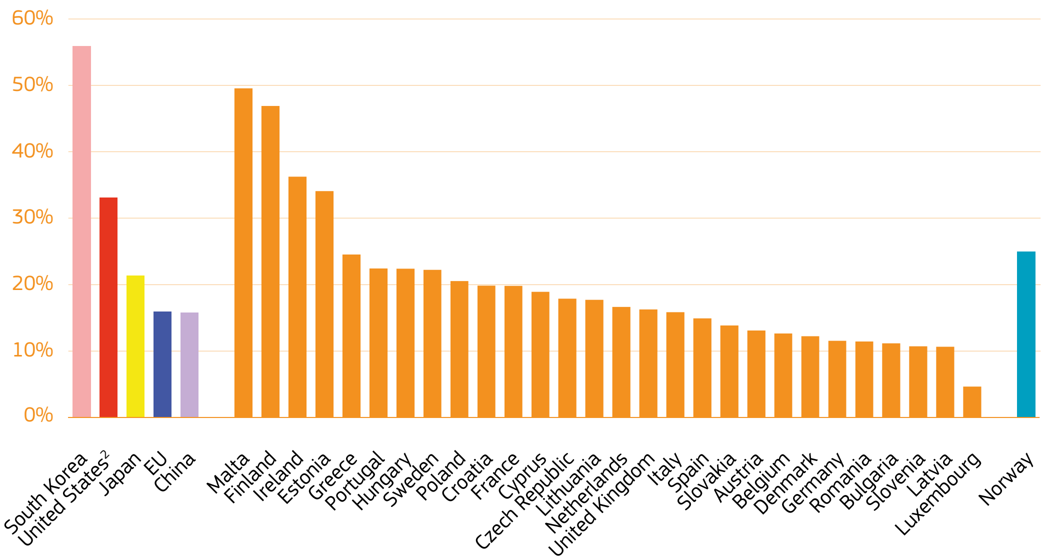
Data: PREDICT project (DG JRC)

Note: [1]Business enterprise expenditure on R&D as % of value added. The comprehensive definition of ICT, as defined in the PREDICT project, was used.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_6.xlsx

Different patterns also emerge when assessing the representativeness of business R&D expenditures on ICT in total BERD. South Korea is an outstanding example of a country where private investments in R&D are remarkably channelled to the ICT sector (more than half of the total BERD). This is correlated with the fact that the country has the highest ICT valued-added contribution to GDP. In the United States, 33.1 % of private R&D investments are allocated to the ICT sector versus 16.4 % in Europe. Malta and Finland (and also Ireland) have the highest shares of BERD in ICT relative to total private R&D investments since the ICT sector has a strong role in these economies. The most striking case is that of Luxembourg which despite relying heavily on the ICT sector, has the lowest share of BERD devoted to ICT which is probably due to higher private R&D investments in the financial sector.

Figure I.3-B.7 Business R&D expenditure on ICT[1] as % of total business R&D expenditure (BERD), 2014



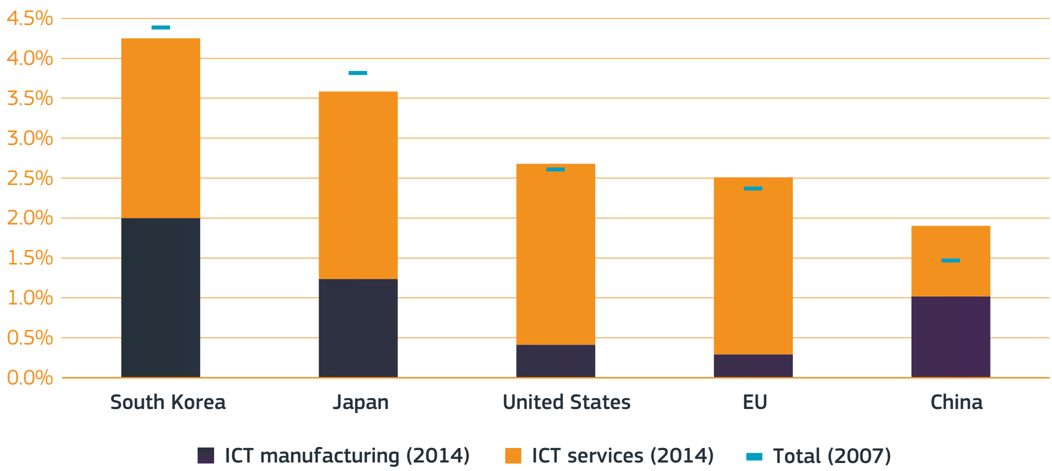
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: DG JRC, Eurostat, OECD
Notes: [1]The comprehensive definition of ICT, as defined in the PREDICT project, was used for all countries with the exception of EU, US, JP, CN and KR in respect of which the operational definition was used. [2]US: Business R&D expenditure (BERD) does not include most or all capital expenditure.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_7.xlsx

The share of jobs in the ICT sector in Europe is lower than in South Korea, Japan or the United States, even though more new jobs come from this sector.

Due to its dynamic and innovative nature, the ICT sector is a key source of new jobs in the economy. The importance of this sector for employment in the EU rose slightly between 2007 (2.4%) and 2014 (2.5%)[7] with ICT services representing almost 90% of total ICT employment. In fact, the ICT sector proved resilient to expanding its share of employment between 2007 and 2014, despite the economic crisis. Nevertheless, the EU still lags behind South Korea (4.2%), Japan (3.6%) and the United States (2.7%) with China catching up (from 1.5% in 2007 to 1.9% in 2014).

Most EU Member States also increased the weight of the ICT sector in total employment over 2007-2014. Luxembourg (4.28%), Malta (4.26%) and Ireland (4.16%) emerge as the Member States with the highest shares, even outperforming other third countries such as Switzerland (3.39%) and Norway (2.84%) in 2014, as illustrated by Figure I.3-B.9.

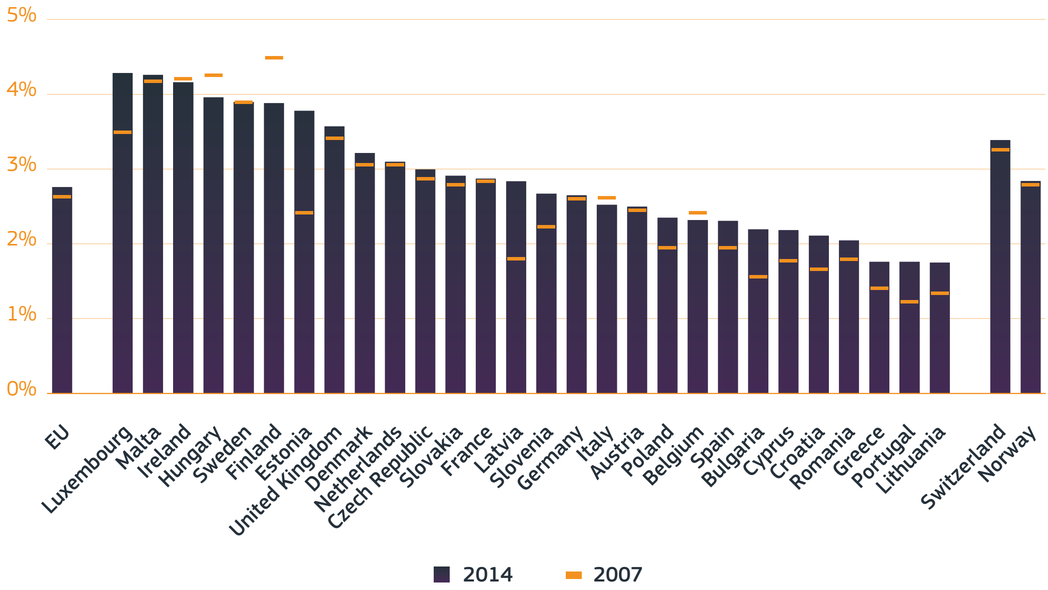
Figure I.3-B.8 Employment in ICT[1] as % of total employment broken down by manufacturing and services, 2014 (and for 2007 without breakdown)



Science, Research and Innovation performance of the EU 2018
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: PREDICT project (DG JRC)
Note: [1]The operational definition of ICT, as defined in the PREDICT project, was used. The operational defintion of ICT allows for international comparison with non-EU countries.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_8.xlsx

7 This follows the 'operational definition' of the JRC's PREDICT project which allows for comparisons between the EU and other international players. For this reason, the shares presented for the EU in this figure and in Fig.I.3-B.9 (which follows a more comprehensive definition of the sector) will be slightly different.

Figure I.3-B.9 Employment in ICT as % of total employment, 2007 and 2014



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: PREDICT project (DG JRC)

Note: [1]The comprehensive definition of ICT, as defined in the PREDICT project, was used.

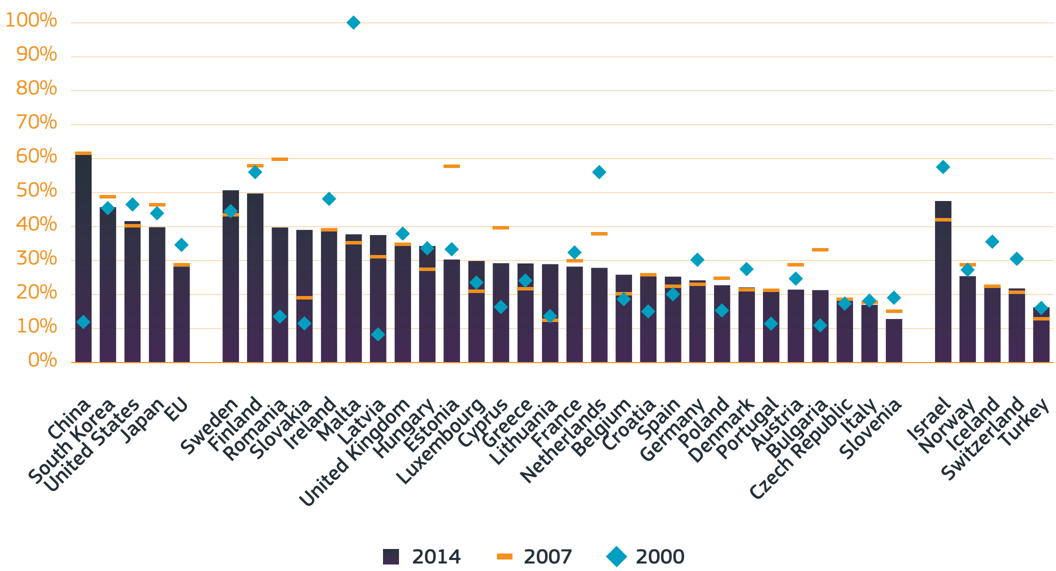
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_9.xlsx

Underinvestment in ICT research in Europe has translated into a lower degree of innovativeness in the sector.

ICT-related patents as a share of total patents in Europe have declined since 2000, from 34.6% to 28.3% in 2014. This compares with significantly higher shares of patenting in ICTs in Japan (39.8%), United States (41.7%), South Korea (45.7%) and China (61.2%) in 2014. In particular, in 2014, China registered a spectacular growth in ICT patenting since 2000 of almost 50 percentage points. Israel also appears as a top innovator in ICT with ICT-related patents accounting for nearly 48% of total patent applications in 2014.

Sweden, Finland and Romania are the EU Member States with the highest shares of ICT patenting relative to total patenting, with shares of 50.7%, 49.8% and 39.8% in 2014, respectively. On the contrary, Slovenia (12.8%), Italy (17%) and the Czech Republic (18.5%) are the countries with the lowest representation of ICT patenting in total patenting. Considerable differences are also found in the evolution pattern of ICT innovation across EU Member States.

Figure I.3-B.10 ICT-related[1] PCT patent applications as % of total PCT patent applications[2], 2000, 2007 and 2014



Science, Research and Innovation performance of the EU 2018

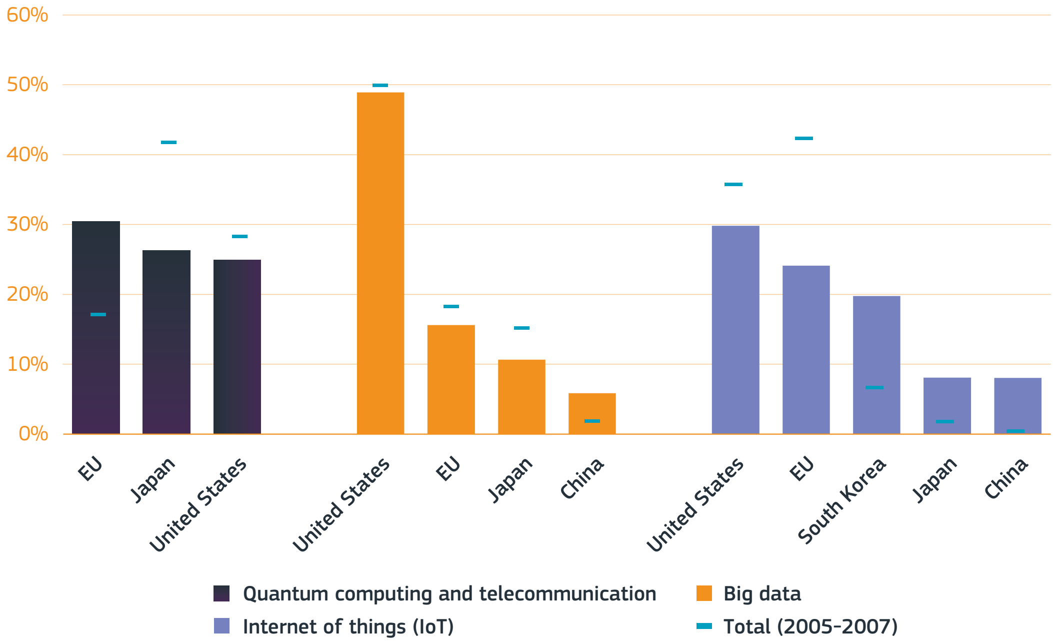
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: OECD
Notes: [1]Domains covered are: telecommunications, consumer electronics, computers, office machinery and other ICT.
[2]Patent applications filed under the PCT, at international phase, designating the European Patent Office (EPO). Patent counts are based on the priority date, the inventor's country of residence and fractional counts.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_10.xlsx

Europe lags behind the United States in particular with regard to some of the 'new-generation ICT technologies', including AI.

Some ICT technologies – 'New generation ICT technologies' – have an inherent disruptive capacity to shape new business processes, models and organisation and to set the path towards enhanced innovation in the ICT sector. While the EU was leading in 'quantum computing and telecommunication' with a share of around 30% of the patent families in this field, nevertheless, it has lost its positioning as the leader in inventive IoT patenting to the United States, and lags substantially behind the later in big data patenting. More recently, South Korea has increased its share in IoT patenting to the detriment of a lower share for the United States and the EU, as well as China, which has improved its position significantly as big data and IoT innovator from an initial relatively low share over the period 2005-2007.

Figure I.3-B.12 shows the evolution of the worldwide distribution of AI patenting between two different periods: 2000-2005 and 2010-2015. Japan emerges as the world's top inventor economy in AI in both periods under consideration, although its leadership weakened in 2010-2015 as South Korea and China increased their relevance significantly in the most recent period. The United States' share declined from 23.2% to 17.2% between both periods. The EU's share fell from19.1% in 2000-2005 to only 11.9% over 2010-2015, which may indicate that the EU may be 'missing the train' when it comes to the creation of new AI technologies. Within the EU, Germany stands out as the most active Member State in AI patenting in both periods, but its weight declined from 6.3% in 2000-2005 to 3.7% over 2010-2015. France and the UK also stand out in the EU context with a contribution of 2.1% and 1.9% to the world's AI patenting over 2010-2015.

Figure I.3-B.11 New-generation technologies -% share of IP5[1] patent families filed at EPO and USPTO by type of ICT technology, 2010-2012 (and for 2005-2007 without breakdown by type)

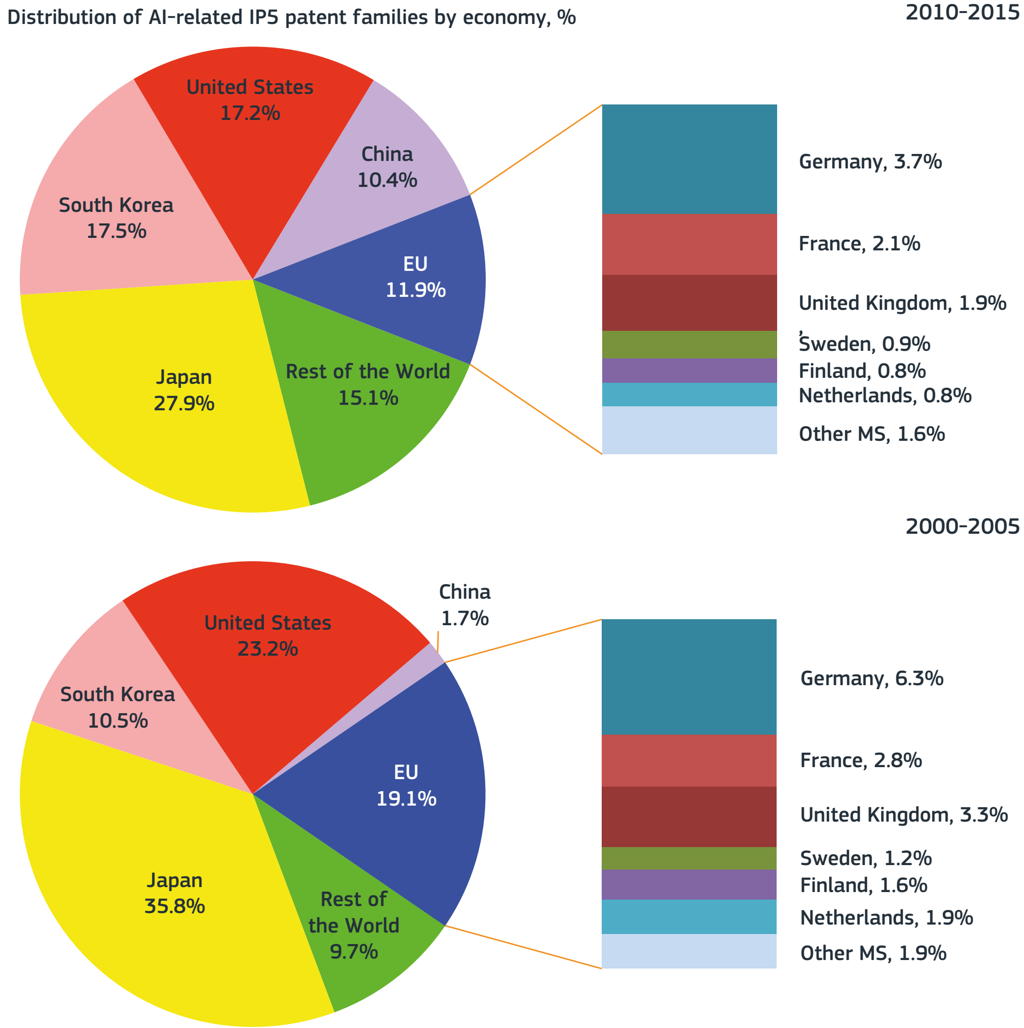


Source: OECD Science, Technology and Industry Scoreboard 2015

Note: [1]The five IP offices (IP5) is a forum of the five largest intellectual property offices in the world (EPO, USPTO, JPO, SIPO, KIPO). They account for 90% of all patent applications filed worldwide.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_11.xlsx

Figure I.3-B.12 Top inventors' economies in terms of AI patents

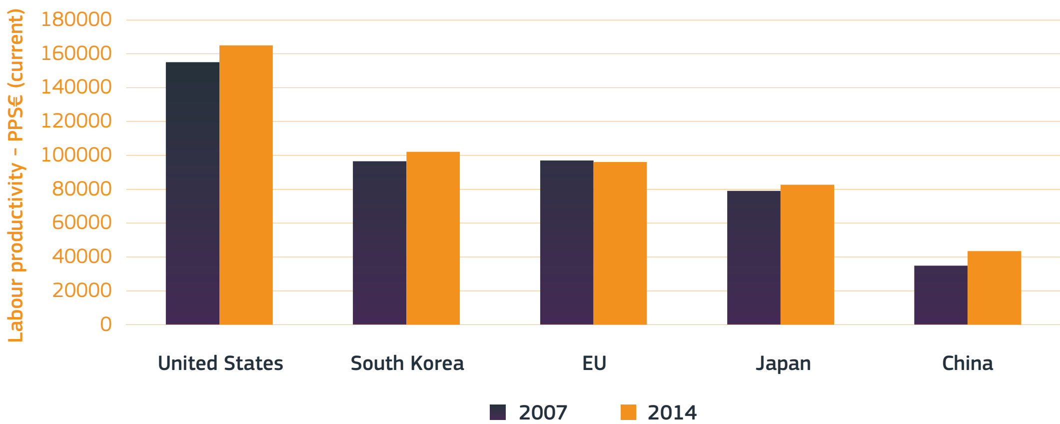


Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: OECD (STI Scoreboard 2017)
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_12.xlsx

In Europe, the ICT sector's productivity is lower than in the United States or South Korea.

According to Figure I.2-B.13, labour productivity in ICT stabilised in the EU at around 96 000 PPS€ per person employed in 2014. This compares with a lower productivity of 83 000 PPS€ in Japan and 44 000 PPS€ in China in the same year. Nevertheless, the EU labour productivity figure in the ICT sector is significantly lower than that of the United States (165 000 PPS€) and South Korea (102 000 PPS€).

Figure I.3-B.13 Labour productivity (GDP per person employed)[1] in ICT[2], 2007 and 2014

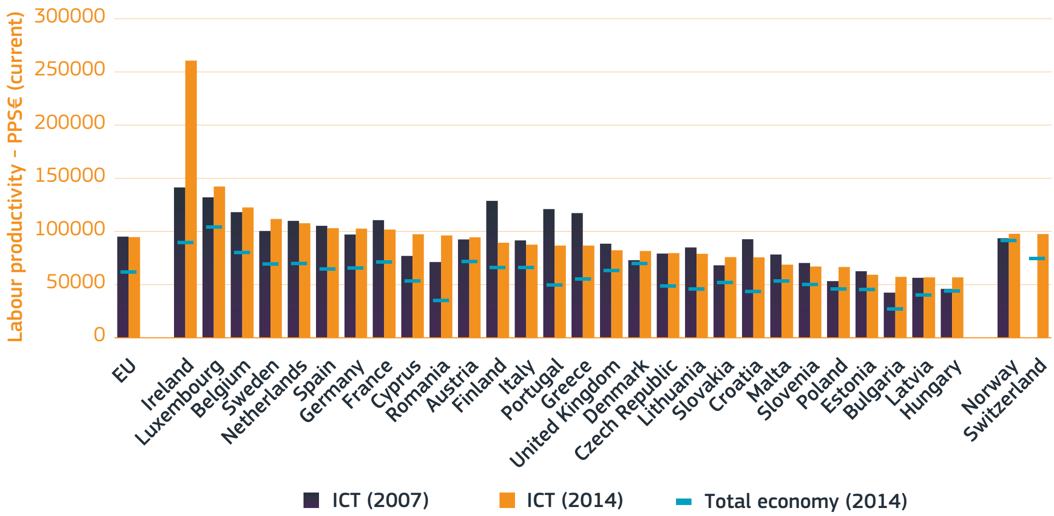


Science, Research and Innovation performance of the EU 2018
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: PREDICT project (DG JRC)
Notes: [1]GDP per person employed in current PPS€. [2]The operational definition of ICT, as defined in the PREDICT project, was used.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_13.xlsx

However, the ICT sector is one of the most productive in the European economy.

As shown by Figure I.3-B.14, the ICT sector is typically more productive than the overall economy due to its intrinsic innovative and productivity-enhancing nature. Overall, ICT labour productivity increased in the medium term (2007-2014) in around half of the EU Member States, while the other half saw a decline in ICT productivity. This decline was particularly apparent in Portugal, Greece and Finland. In 2014, Ireland, Luxembourg and Belgium registered the highest ICT productivity levels in Europe, with Ireland in the lead after a remarkable increase in ICT productivity between 2007 and 2014.

Figure I.3-B.14 Labour productivity (GDP per person employed)[1] in ICT[2], 2007 and 2014 (and total economy for 2014)

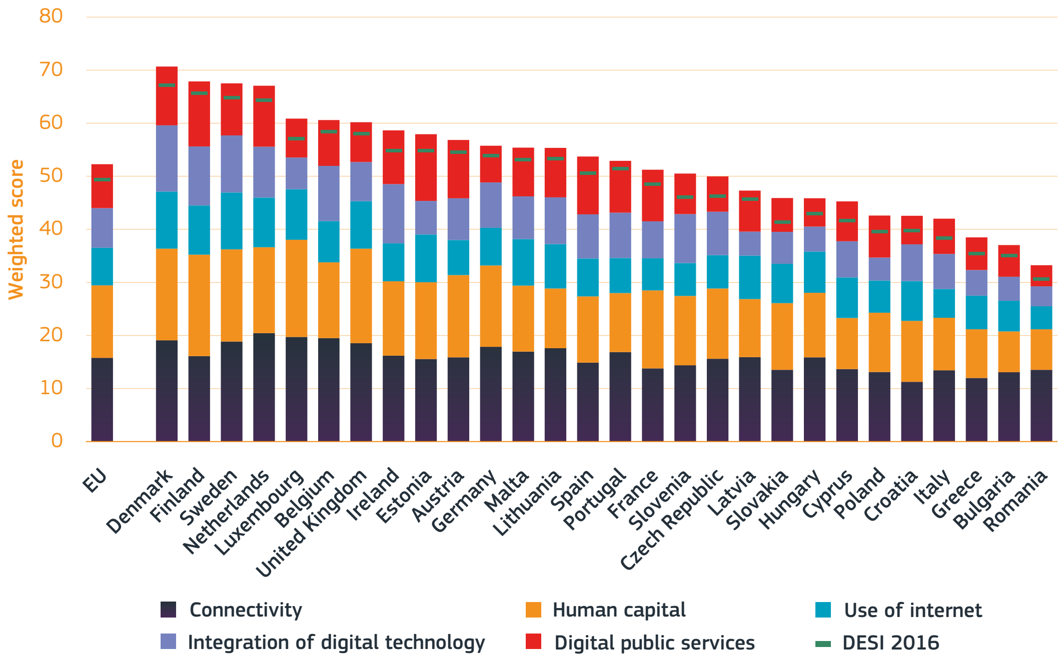


Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: PREDICT project (DG JRC. Directorate B)
Notes: [1]GDP per person employed in current PPS€. [2]The operational definition of ICT, as defined in the PREDICT project, was used.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_14.xlsx

Despite this European lag in the ICT sector's productivity, overall the EU Member States are making progress in improving their digital capacity.

The European Commission's Digital Economy and Society Index (DESI) is a composite index which weighs relevant indicators on Europe's digital performance and tracks the evolution of digital competitiveness in EU Member States. In 2017, all EU Member States improved their overall digital capacity as measured by the DESI. Scandinavian countries – Denmark, Sweden and Finland – were the top digital players, followed by Luxembourg, Belgium and the UK. The lowest overall digital performances were in Romania, Bulgaria, Greece and Italy. In the EU, Slovakia and Slovenia have progressed most in relation to 2016.

Figure I.3-B.15 Digital Economy and Society Index (DESI)[1] by main dimension, 2017 (and total for 2016)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission, Digital Scoreboard 2017

Note: [1]The Digital Economy and Society Index (DESI) is a composite index that tracks the evolution of digital competitiveness. The index is the weighted average of the five main dimensions: connectivity, human capital, uses of internet, integration of digital technology and digital public services.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_15.xlsx

The digital divide between the most-advanced and least-advanced digital players still persists.

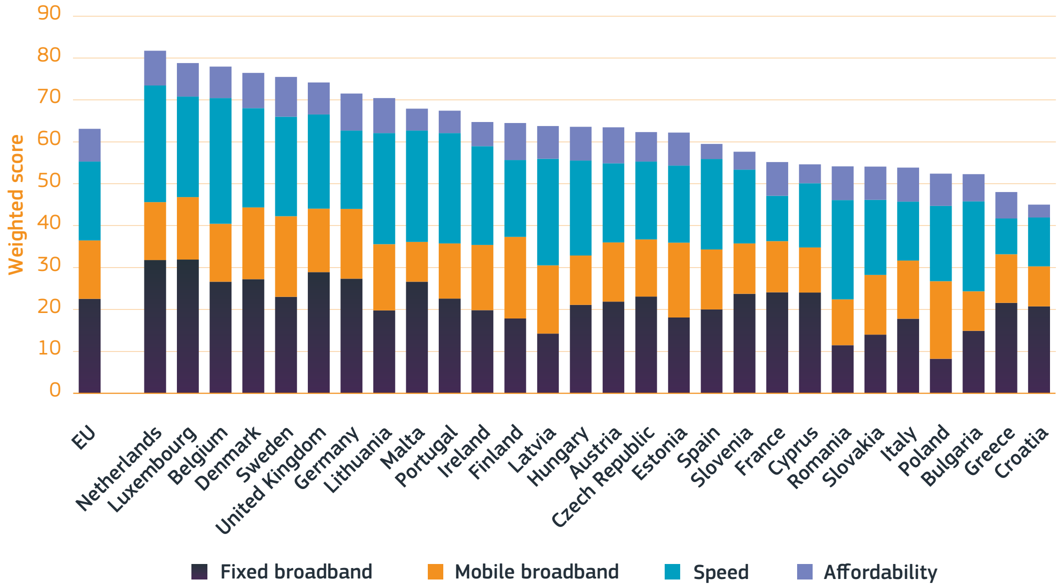
The *connectivity* dimension of the DESI indicator (Figure I.3-B.16) examines the coverage and uptake of fixed and mobile broadband infrastructure and networks, including the speed and affordability of such connections. In 2017, the Netherlands, Luxembourg and Belgium were in the lead in this dimension with scores above 75, while Croatia, Greece and Bulgaria were the lowest performers with weighted scores below (or slightly above) 50. This differential in the scores between the top and bottom ranking shows there is still room to improve the quality of connectivity throughout Europe to boost ICT diffusion.

The *human capital* dimension (Figure I.3-B.17) assesses the level of digital skills in European economies, including basic skills such as internet access and more advanced workforce skills such as STEM competences. Here, Finland, Luxembourg and the UK registered the highest scores (above 70) while Greece, Bulgaria and Romania had the lowest scores (below 40). Again, efforts must be made to foster the widespread use of these skills to ensure that all European citizens can exploit and fully grasp the opportunities offered by digitalisation.

The dimension *integration of digital technology by businesses* (Figure I.3-B.18) analyses practices linked to business digitisation, such as the use of electronic invoices and cloud technologies, and also includes an e-commerce subdimension. Businesses are the most advanced in this respect in Denmark, Ireland and Finland (scores above 55), and the least developed in Romania, Poland and Bulgaria (scores below 22.5) with e-commerce practices still far behind their full potential for use.

As for the *digital public services* dimension (Figure I.3-B.19) which focuses on e-government aspects such as pre-filled forms, the top scores (above 77) were in Estonia, Finland and the Netherlands while the lowest scores (below 36) were in Romania, Hungary and Croatia.

Figure I.3-B.16 'Connectivity' dimension of the Digital Economy and Society Index (DESI)[1], 2017



Science, Research and Innovation performance of the EU 2018

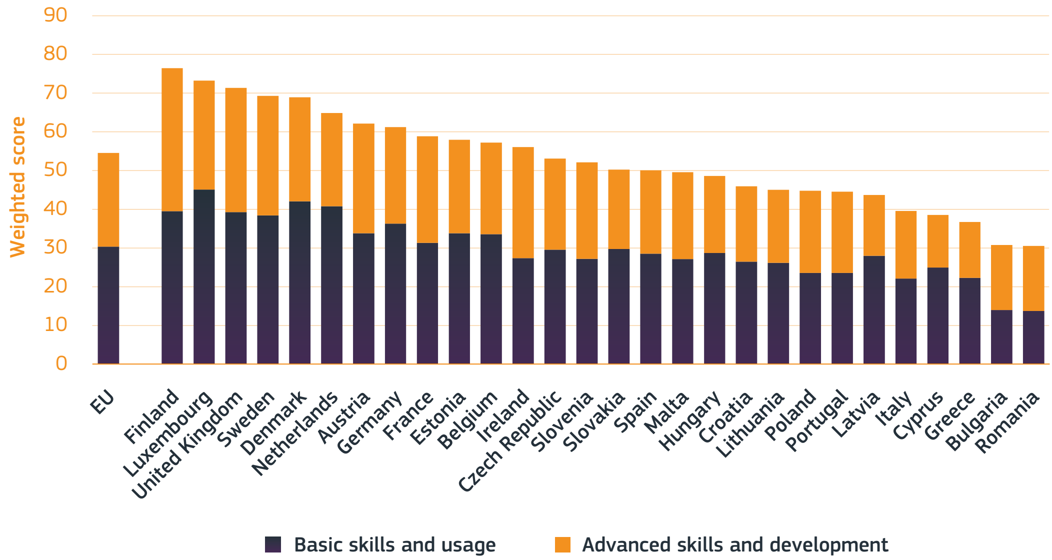
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: European Commission - DG CONNECT, Digital Scoreboard 2017

Note: [1]The Digital Economy and Society Index (DESI) is a composite index that tracks the evolution of digital competitiveness. The connectivity dimension index is the weighted average of the four sub-dimensions: fixed broadband, mobile broadband, speed, and affordability.

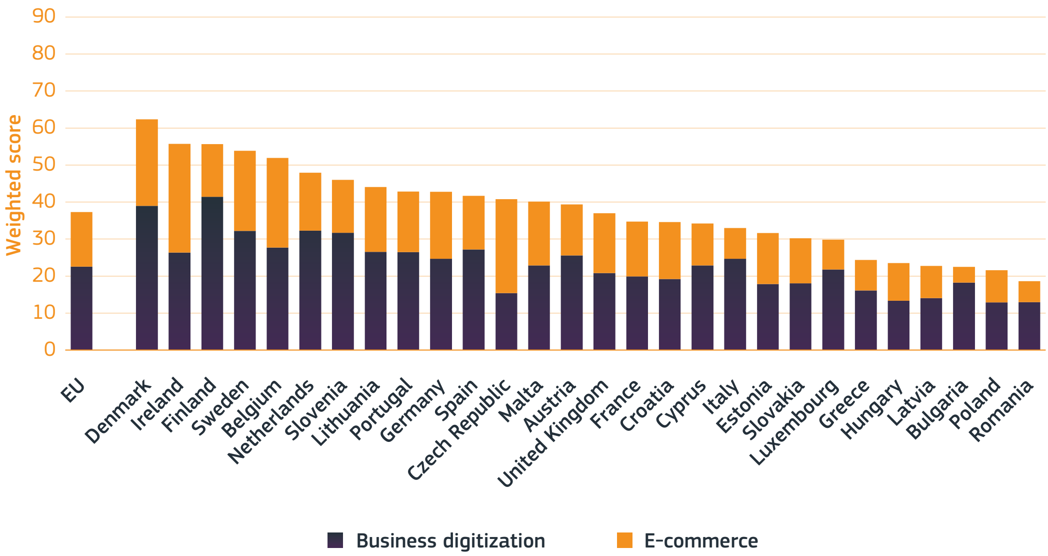
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_16.xlsx

Figure I.3-B.17 'Human capital' dimension of the Digital Economy and Society Index (DESI)[1], 2017



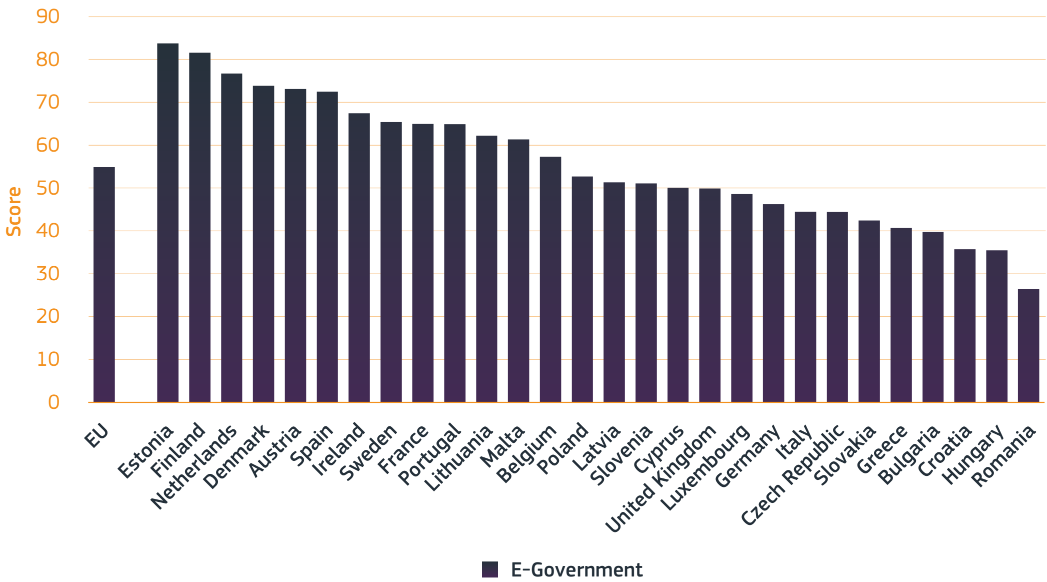
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: European Commission - DG CONNECT, Digital Scoreboard 2017
Note: [1]The Digital Economy and Society Index (DESI) is a composite index that tracks the evolution of digital competitiveness. The human capital dimenson index is the weighted average of the two sub-dimensions: basic skills and usage, and advanced skills and development.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_17.xlsx

Figure I.3-B.18 'Integration of digital technology' dimension of the Digital Economy and Society Index (DESI)[1], 2017



Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: European Commission - DG CONNECT, Digital Scoreboard 2017
Note: [1]The Digital Economy and Society Index (DESI) is a composite index that tracks the evolution of digital competitiveness. The integration of digital technology dimension index is the weighted average of the two sub-dimensions: business digitisation and e-commerce.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_18.xlsx

Figure I.3-B.19 **'Digital public services' dimension of the Digital Economy and Society Index (DESI)[1], 2017**



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: European Commission - DG CONNECT, Digital Scoreboard 2017
Note: [1]The Digital Economy and Society Index (DESI) is a composite index that tracks the evolution of digital competitiveness. The integration of the digital public services dimension index comprises one sub-dimension: e-government.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-b_figures/f_i_3-b_19.xlsx

Different barriers appear to be undermining ICT diffusion and hence full exploitation of the benefits of ICTs which requires adequate policy responses.

Bridging and closing the digital divide between more advanced and less digitally advanced countries requires a set of policy responses aimed at overcoming the main barriers to ICT diffusion within and across Member States. Indeed, many of those are associated with the completion of the Digital Single Market, as highlighted in the European Commission's 'Single Market integration and competitiveness report' (2016)[8]. One of the main issues concerns the need to improve system interoperability together with the definition and use of well-established standards. Without unified standards and full interoperability, the efficiency of ICT investments declines and can also generate hesitations over the so-called 'vendor lock-in' effect – i.e. not being able to change supplier (OECD, 2017).

In addition, there are legal and regulatory barriers to the creation and roll-out of new business models, especially when these rely substantially on digital technologies. The sharing economy and the spread of online platforms have challenged existing regulations and it is now clear that the regulatory environment will need to be flexible enough to accommodate these new innovation channels while at the same time ensuring that competition in the market, consumer protection and data security are all in place.

8 See also World Bank (2016).

CHAPTER I.3-C: SKILLS AND HUMAN RESOURCES

The growing knowledge orientation of the economy and society, together with current demographic trends in Europe, make investment in skills and their lifelong upgrading increasingly important.

Skilled human capital for research, innovation and economic development is crucial to sustain the needs of a knowledge economy. The EU is facing an increasing demand for skilled labour, including researchers, whilst at the same time it appears that labour related to routine activities is being replaced more and more by machines.

An additional challenge comes from ongoing demographic developments, such as the falling number of young people entering the labour market, which is expected in the future in many Member States, while the baby-boomer generation is set to retire within the next decade. The EU's working age population (20-64) peaked in 2010 at 307 million and has been declining ever since, with Southern, Central and Eastern European countries most affected by the shrinking labour force. At the same time, life expectancy continues to rise by about two years each decade. In the EU, the population of 65 years and older has grown by about 2 million per year, from 90 million in 2012 to 98 million in 2016, and the old-age dependency ratio is also growing, directly affecting employment in the health and care sectors and indirectly (longer working life) the labour market.

Another factor is migration. In 2015, while the natural population change in the EU (births minus deaths) was, for the first time, negative, at -0.1 million, this was compensated for by a record net migration to the EU of 1.8 million. In 2016, while the natural change was again slightly negative, net migration totalled 1.5 million.

The demographic shift towards lower shares of young people and larger shares of elderly people is confronting Europe with important challenges. Given a global massification in tertiary education, a more favourable demography outside Europe, and strong investment in excellence (United States, China) in other world regions, the EU is facing growing competitive challenges as regards the quality and quantity of its human capital. This could endanger its traditional comparative advantage as regards skilled labour. Further investment in skills and their lifelong upgrading will also be necessary to bridge the productivity growth gap between the EU and the United States and South Korea.

A strong growth in employment requiring a high level of qualifications is expected in the coming decade – at the same time, the number of jobs at medium- and low-qualification levels is likely to shrink.

According to the 2016 Cedefop skills forecast (see Figure I.3-C.1) the economically active population (employed and disposable unemployed, aged 15 and over) will stagnate between 2015 and 2025. However, trends will differ significantly between Member States, with the economically active population, for mainly demographic reasons, shrinking strongly in Lithuania (-19.7 %), Latvia (-11.3 %) and Estonia (-7.6 %). Germany, the EU's largest Member State, will face a decline of 3.8 %. At the same time, the economically active population will continue to increase in most Western and Northern European Member States (UK +3.7 %, France +5.7 %), with Luxembourg (+22.9 %) expected to show the highest growth rate.

In the same period, employment in the EU is expected to increase by 3 %. The gap between employment growth and growth in the active population implies a decline in unemployment, both in absolute and relative terms. While employment is expected to increase in most EU Member States, with Cyprus (+15.3 %), Ireland (+14.3 %) and Luxembourg (+9.3 %) expected to show the highest growth, it is forecast to decline in five Member States: Estonia (-4.1 %), Romania (-2.2 %), Germany (-1.9 %), Bulgaria (-1.6 %) and Latvia (-1.2 %), in most cases because of a shrinking labour force.

Furthermore, the EU is facing a shift to employment at higher qualification levels. While employment at high qualification levels is expected to increase by 22.6 % in the period 2015-25, employment at medium qualification levels is forecast to fall slightly (-2.1 %) and employment at low qualification levels to decline significantly (-17.6 %).

In the EU, employment growth plus the need to replace people leaving workplaces (retirement, migration and other reasons) will lead to 97 million job opportunities in the next decade, of which over 40 million will be in jobs requiring high qualifications.

The trends shown might contribute to sustaining the gap in unemployment rates between different qualification levels. In 2016, according to Eurostat data, while the overall unemployment rate in the EU stood at 8.6 %, it was nearly twice as high for those with a low level of qualifications (lower secondary education or less), reaching 16.1 %, while the unemployment rate for highly skilled people (with at least tertiary education) in the EU was only 5.1 %.

Figure I.3-C.1 Key results of the 2016 Cedefop skills forecast

	Qualification level	2015-2025
Labour Force (econ. active population, aged 15+), change	All	+0.2%
Employment, change	All	+3%
	High	+22.6%
	Medium	-2.1%
	Low	-17.6%
Job opportunities	All	97.1 million
	High	40.4 million
	Medium	13.7 million
	Low	42.9 million

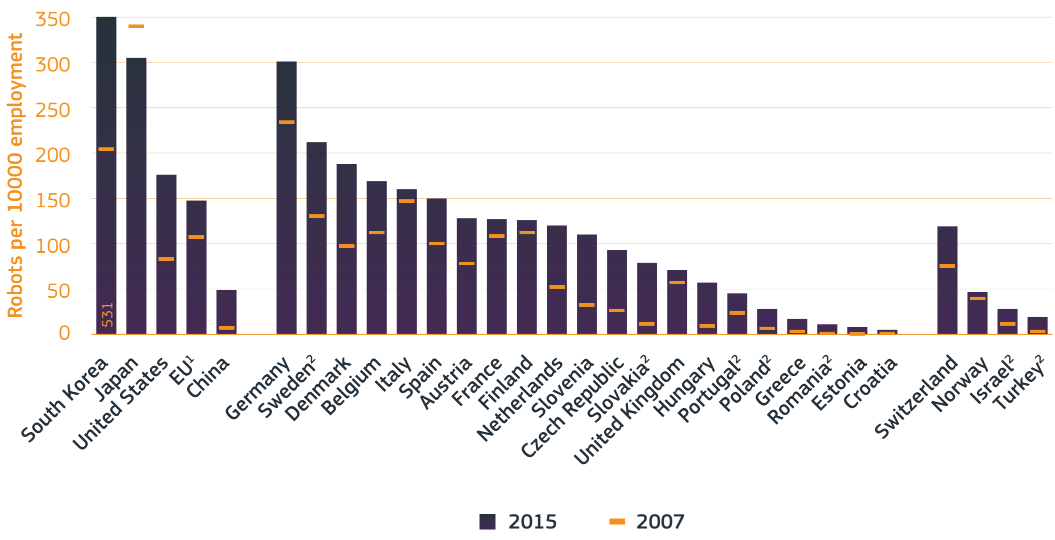
Source: Cedefop, 2016 skills forecast
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_1.xlsx

The manufacturing sector is characterised by a growing use of industrial robots. Countries with a large car industry tend to have high numbers of industrial robots per persons employed.

There is an ongoing debate on the impact of technical progress on employment. Currently, the manufacturing sector is still more affected by automation and rationalisation than services. Replacing workers by machines is ongoing with even more complex manual tasks being taken over increasingly by robots. In the future, AI might replace skilled people even in the service sector.

Currently, 0.3 million industrial robots (out of a worldwide stock of 1.6 million) are deployed in EU Member States. The number is increasing by about 40 000 per year. Germany, with its large car industry (about half of the robots are deployed in the automotive industry) has the highest number of industrial robots per 10 000 persons employed in the EU's manufacturing industry, followed by Sweden and Denmark. The EU has a similar density as the United States, but lags behind Japan and South Korea. China is catching up quickly, but still has a much lower density than the EU.

Figure I.3-C.2 Estimated number of multi-purpose industrial robots per ten thousand persons employed in manufacturing industry, 2007 and 2015



Science, Research and Innovation performance of the EU 2018

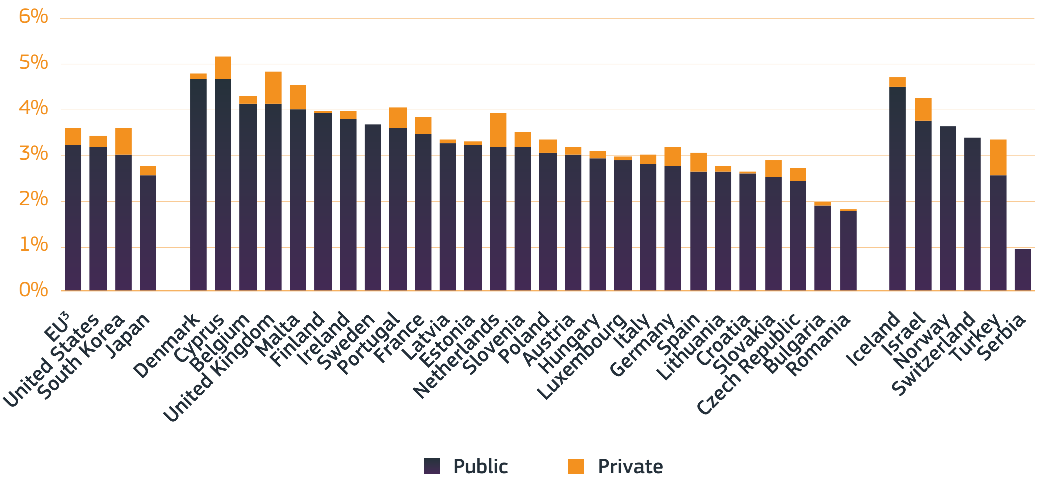
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, International Federation of Robotics (IFR), World Robotics Report 2016
Notes: [1]EU was estimated as the average of the available data for the Member States weighted by employment. [2]PT, RO, SK, SE, TR, IL: revised employment data according to ILO employment by economic activity 2015.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_2.xlsx

In the EU, investment in tertiary education lags behind that of the United States and South Korea, despite significant public efforts. Private investment in the EU is much lower than in these countries and public spending has fallen slightly in recent years. In the EU, there are large differences in spending on tertiary education, with the UK, the Netherlands, the Nordic countries and Cyprus in the lead.

Total investment in education in the EU is at a similar level as in the United States and South Korea and higher than in Japan. However, there are large differences in spending levels between EU Member States, reflected both in primary/secondary education and in tertiary education.

As regards non-tertiary education (mostly pre-primary, primary and secondary) very low levels of spending, as the figures available show for Bulgaria and Romania, are somewhat reflected in educational outputs, as evidenced by international skills tests in compulsory education, although non-financial factors play an important role, too. However, while high levels of spending per pupil do not necessarily translate into corresponding educational outcomes, there is a consensus that investment in higher participation rates (a higher number of learners) has both social and economic benefits.

Figure I.3-C.3 Total educational expenditure on non-tertiary education[1] from public and private sources as % of GDP, 2014[2]



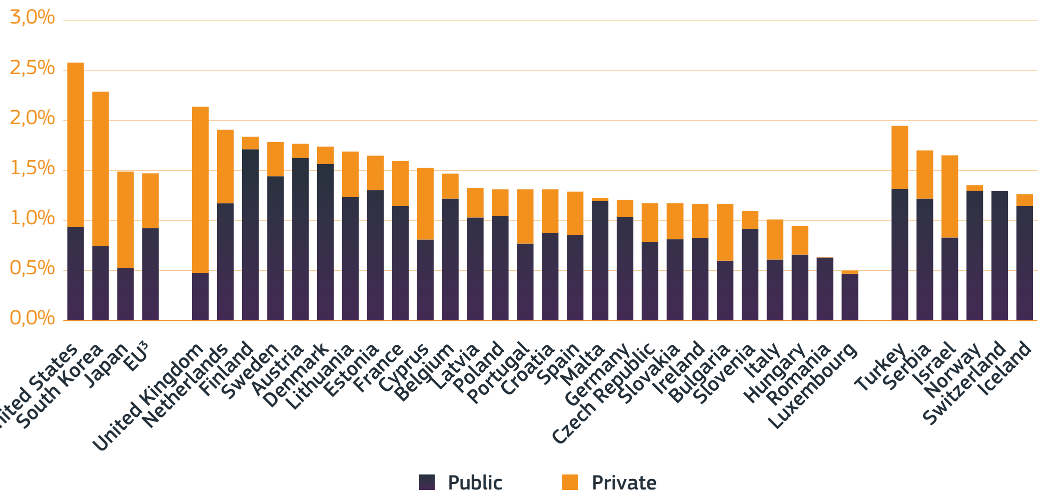
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, OECD
Notes: [1]ISCED 2011 levels 1-4. [2]IL, US, JP, KR: 2013. [3]EU was estimated and does not include EL.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_3.xlsx

There is a general consensus among education economists that early investment in education gives the highest returns, since the outcomes of earlier stages of education also determine results at later stages. For example, high levels of numeracy at lower secondary level are important for the outcomes of learning at the upper secondary level and have an impact on the take-up of science and technology studies at tertiary level, fields of study where there is a potential gap in the future supply of graduates.

While spending on primary and secondary education in the EU is comparable to the levels found in North America or East Asia, there is a marked gap in tertiary education (see Figure I.3-C.4), caused mainly by lower levels of private spending in Europe. Public and private spending on tertiary education as a % of GDP is about 1 percentage point lower in the EU, compared to the United States.

The spending gap per tertiary student currently amounts to nearly EUR 10 000 per year (or about EUR 200 billion for tertiary education as a whole). The Nordic countries, the Netherlands, the UK and Cyprus (where a high share of tertiary students study abroad) show relatively high levels of tertiary spending. On the other hand, tertiary spending levels are relatively low in Bulgaria and Romania (and also in Luxembourg, although this has to be seen in the context of a high GDP per capita and many students studying abroad). There is a high correlation between tertiary education spending levels and participation and attainment rates, as well as scientific excellence, important factors for R&I systems.

Figure I.3-C.4 Total educational expenditure on tertiary education[1] from public and private sources as % of GDP, 2014[2]



Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, OECD
Notes: [1]ISCED 2011 levels 5-8. [2]IL, US, JP, KR: 2013. [3]EU was estimated and does not include EL.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_4.xlsx

Since 2013, the absolute number of EU tertiary students has been in decline for demographic reasons (the age group 20-24 dropped from 31.4 million in 2010 to 29.8 million in 2015) and as a result of an approaching saturation rate. This anticipates a possible decline in the number of tertiary graduates in the medium term, especially for Central and Eastern European countries.

As tertiary participation rates approach saturation in many Member States, and because of the shrinking cohort size, the number of tertiary students in the EU started to decline in 2014 – for demographic reasons, this decline will continue in the near future. In 2000, the EU had 16 % of the world's tertiary student population. In 2015, the share was down to 9 %, while China's share increased in the same period from 7 % to 20 % and India's share rose from 9 % to 15 %.

The decline in tertiary students is strongest in Central and Eastern European countries, where the small cohorts of the post-1990 demographic crisis are now at the tertiary student age. In the period 2013-2015, the number shrank by more than 10 % in Estonia (-14.8 %), Hungary (-14.3 %), Poland (-12.5 %), Romania (-12.4 %), Slovenia (-12.4 %), Slovakia (-12.0 %) and Lithuania (-11.9 %). In the EU-15, the decline since 2013 was strongest in Portugal (-9.0 %). The number of tertiary students is still rising in some EU-15 Member States, in Cyprus (+16.3 %) and in Malta (+5.1 %). (In both these countries, the relatively new higher education systems are still in the expansion phase.) Despite an unfavourable demography, student numbers are still increasing in Germany (+7.1 %) as a result of a growing number of foreign students and an ongoing rise in participation rates (which, as a result of an orientation towards vocational education, have traditionally been relatively low). Denmark (+7.8 %) and Ireland (+7.6 %) show similar growth rates. The number is also still increasing, although at a slower pace, in France (+3.7 %), Belgium (+3.3 %) and Austria (+0.8 %).

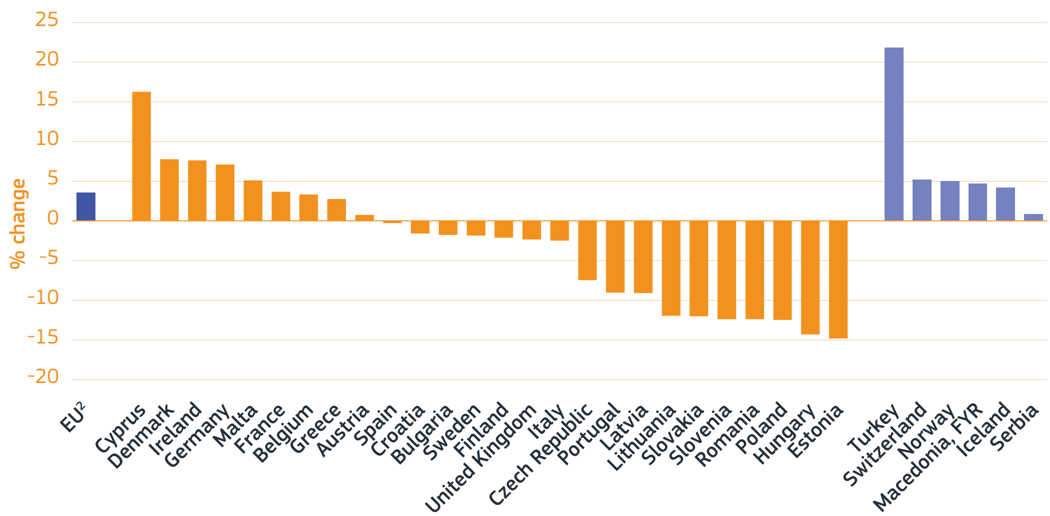
At the same time, the European student population is becoming more international. The number of mobile students from abroad rose in the EU from 1.43 million in 2013 to 1.54 million in 2015 (+8.2 %), of whom 0.88 million came from outside Europe. In 2013, women outnumbered men by about 1 million, representing 54 % of the EU tertiary student population, with the share of male students catching up a little in recent years.

Figure I.3-C.5 Number of tertiary students (million), 2000-2015

	2000	2010	2013	2014	2015
World	**99.7**	**181.4**	**199.0**	**210.7**	**212.7**
EU	16.0	20.0	19.8	19.7	19.5
China	7.4	31.0	34.1	41.9	43.4
India	9.4	20.7	28.2	30.3	32.1
United States	13.2	20.4	20.0	19.7	19.5
Brazil	2.8	6.6	7.5	8.1	8.3
Russian Federation	6.3	9.3	7.5	7.0	6.6
Japan	4.0	3.8	3.9	3.9	3.9

Science, Research and Innovation performance of the EU 2018
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, UNESCO
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_5.xlsx

Figure I.3-C.6 % change in the number of tertiary students between 2013 and 2015[1]



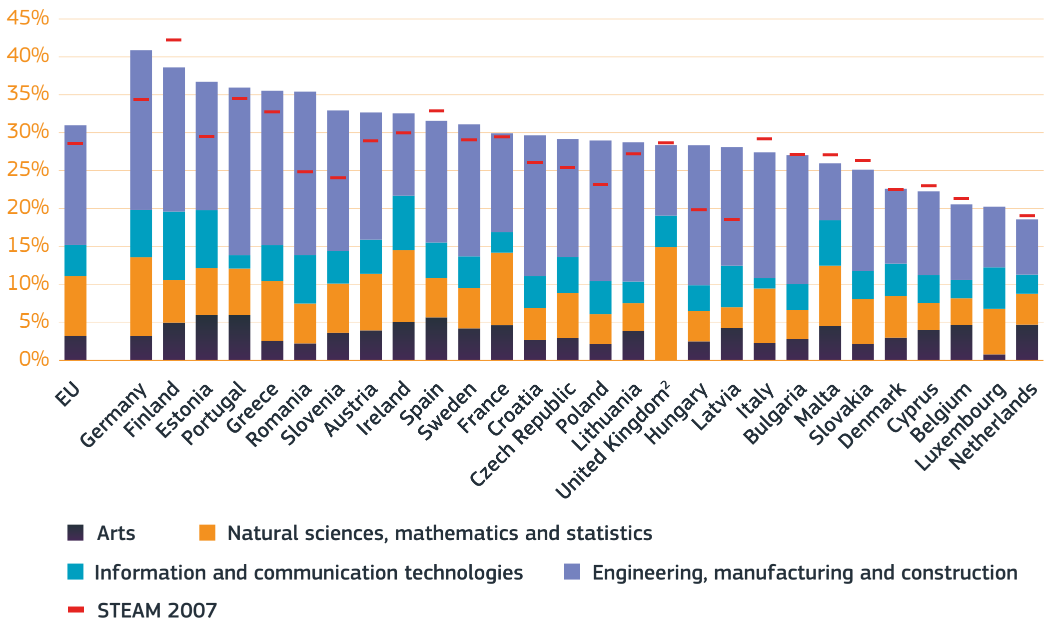
Science, Research and Innovation performance of the EU 2018
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat
Notes: [1]IS: 2013-2014; [2]EU: 2014-15. [2]EU was estimated and does not include LU and NL.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_6.xlsx

The share of STEM students (science, technology, engineering, mathematics) has increased since 2007, with strong improvements in many Central and Eastern European countries.

The share of STEM students increased since 2007 from 24.6% to 27.8%. Countries with a high share include Germany, Finland, Estonia and Portugal. Countries that progressed most include Estonia, Romania, Slovenia, Hungary and Latvia. Countries with limited university systems, like Malta, Cyprus and Luxembourg, tend to have low STEM shares, since many have to go abroad to study or graduate in these fields. Shares are also relatively low in Belgium and the Netherlands. The importance of design for product marketing and innovation is increasingly recognised. Therefore, art/design students are seen increasingly as an important asset – contributing to 'creative industries' – in modern economies. Correspondingly, STEM is sometimes extended to STEAM. The share of STEAM students increased from 28.6% in 2007 to 31.0% in 2015 (thus, the share of arts students declined from 4.0% in 2007 to 3.2% in 2015). However, the inclusion of the arts does not change the order of leading countries.

While there is still a scientific debate about the optimal number and share of university graduates in the population and their relevance for balanced R&I systems, available statistical data show that returns on tertiary education in terms of average earnings and the risk of unemployment are high, suggesting that there has yet to be an oversupply of tertiary graduates. However, manufacturing-oriented economies, like Germany and Austria, traditionally also rely on a strong supply of graduates from vocational education and training, most of them at an upper-secondary level.

Figure I.3-C.7 Tertiary students in science, technology, engineering, the arts and mathematics (STEAM) as % of total tertiary students, 2015[1] (and for 2007 without breakdown)



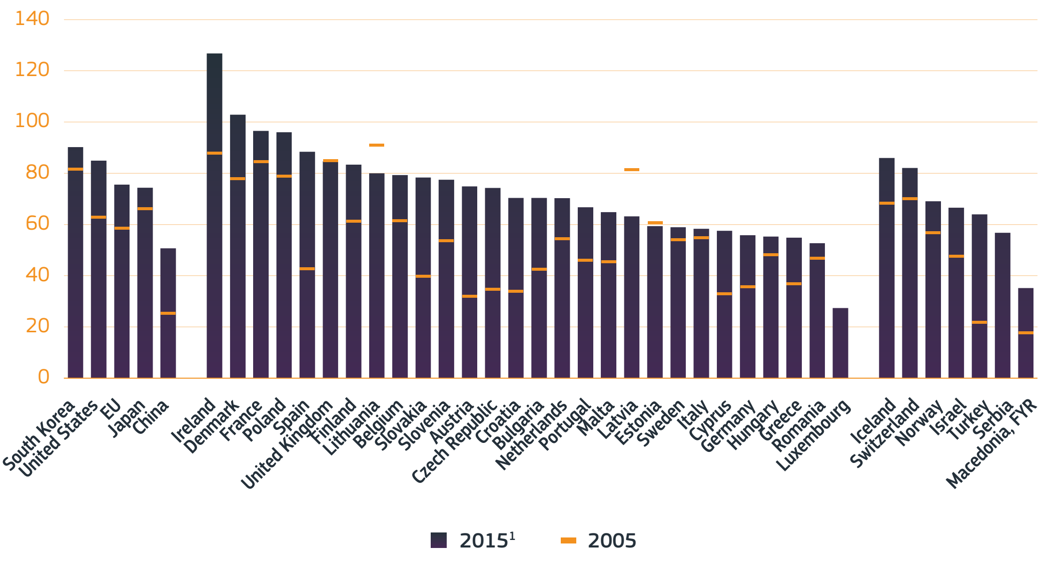
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat
Notes: [1]IE, EL, IT: 2014. [2]UK: Data are not available for the arts for 2015.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_7.xlsx

Although the EU still lags behind the United States and South Korea, the number of tertiary graduates per 1000 population in the EU has stopped growing and is even expected to fall in the future.

As regards new tertiary graduates per thousand population (see Figure I.3-C.8), the EU performs at a similar level as Japan, but below the United States and South Korea. While figures in China and the United States continue to grow, the number of new tertiary graduates per population has hardly grown in the last decade in the EU and has fallen in South Korea and Japan. Differences between Member States are large, with Ireland leading and several Eastern European countries (Poland, Lithuania and Slovakia) showing high numbers of new graduates and thus the latter catching up on tertiary attainment. While Central and Eastern European countries experienced high growth rates in the past, the number of graduates in these countries is expected to fall in the future as cohort size declines.

Gender imbalances are larger than for the number of students. In 2013, women represented 58.3% of tertiary graduates in the EU. In the EU, Germany has the best gender balance (male share of tertiary graduates 49.9%), while men represent less than 40% of tertiary graduates in many Central and Eastern European countries, notably in the Baltic States.

Figure I.3-C.8 New graduates from tertiary education per thousand population aged 20-29, 2005 and 2015

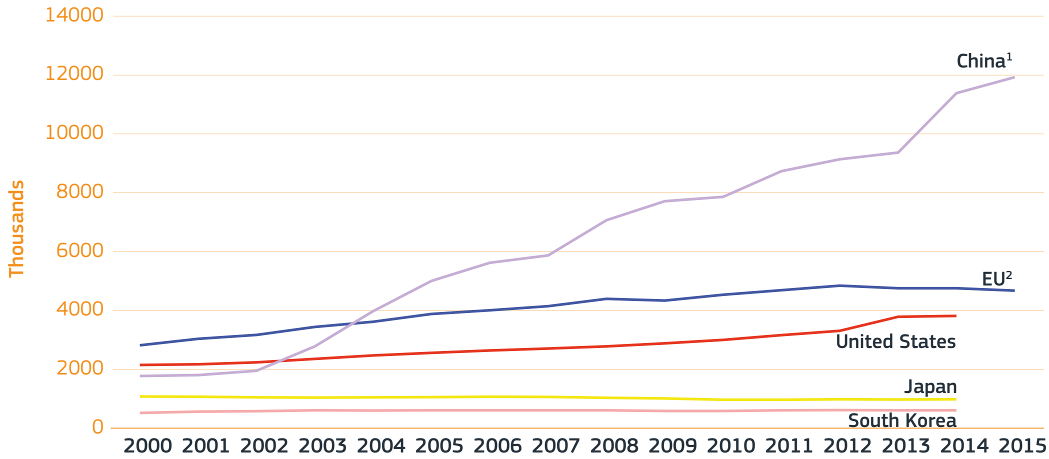


Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, OECD, UNESCO (UIS)
Note: [1]IS: 2013; EL, IT, RS, IL, US, JP, KR: 2014.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_8.xlsx

In terms of the absolute number of tertiary graduates, the EU still scores above the United States but has been overtaken by China, which is now by far the world's largest producer of tertiary graduates.

In 2004, China (whose population is 2.7 times the EU total) overtook the EU in terms of the absolute number of tertiary graduates (see Figure I.3-C.9). The number of tertiary graduates has grown six-fold in China since 2000 to reach about 12 million in 2015, more than double the EU figure. At the same time, the number of tertiary graduates in Japan and South Korea stagnated, as tertiary participation rates in these countries are reaching saturation and demographic factors come into play.

Figure I.3-C.9 Total number of tertiary graduates, 2000-2015



Science, Research and Innovation performance of the EU 2018

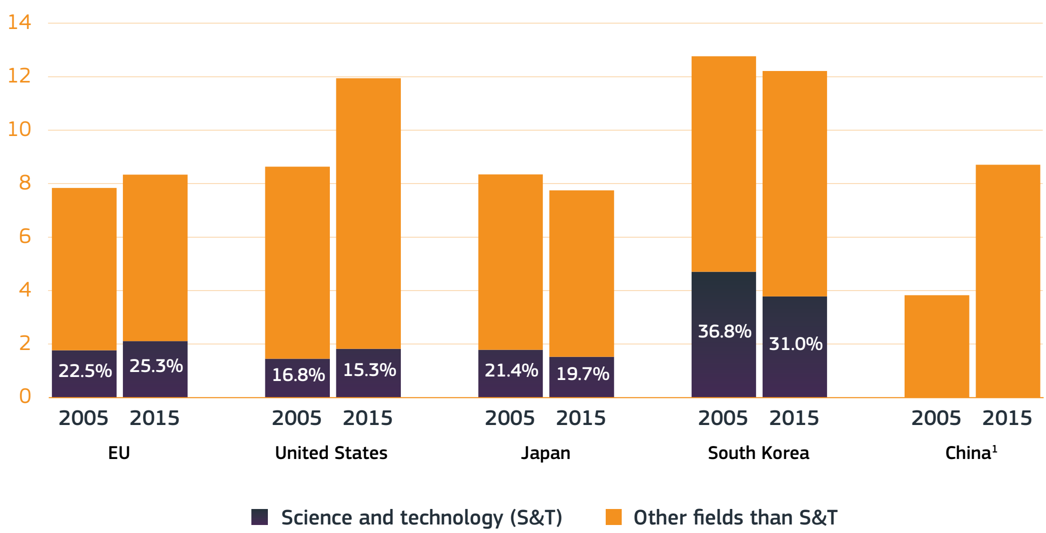
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, OECD, UNESCO (UIS)
Notes: [1]CN: the value for 2003 was estmated. [2]EU: the value for 2011 was estimated.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_9.xlsx

Since 2005, the EU has made progress in the share of science and technology graduates, while this share has declined in South Korea, Japan and the United States. Women represent only one-third of all science and technology graduates.

As regards science and technology graduates (see Figure I.3-C.10) the EU countries have progressed more since 2005 in terms of graduates per 1000 population than Japan and South Korea (partially a result of the Bologna effect of more degree levels and hence more double-counting). It is also doing better in the science and technology share among graduates (increasing from 22.5% to 25.3%) than Japan (declining from 21.4% to 19.7%) and the United States (decreasing from 16.8% to 15.3%). However, South Korea still has a much higher share (2005: 36.8%, 2015: 31.0%) of science and technology graduates in all tertiary graduates and more graduates relative to population.

Women represent only about 34% of all science and technology graduates in the EU. The share of female science and technology graduates is relatively high in Estonia (45%), Poland (45%), Romania (44%), Cyprus (42%) and Italy (41%). It is lowest in Austria (25%) and the Netherlands (26%).

Figure I.3-C.10 Tertiary graduates per thousand population broken down by science and technology and other fields, 2005 and 2015

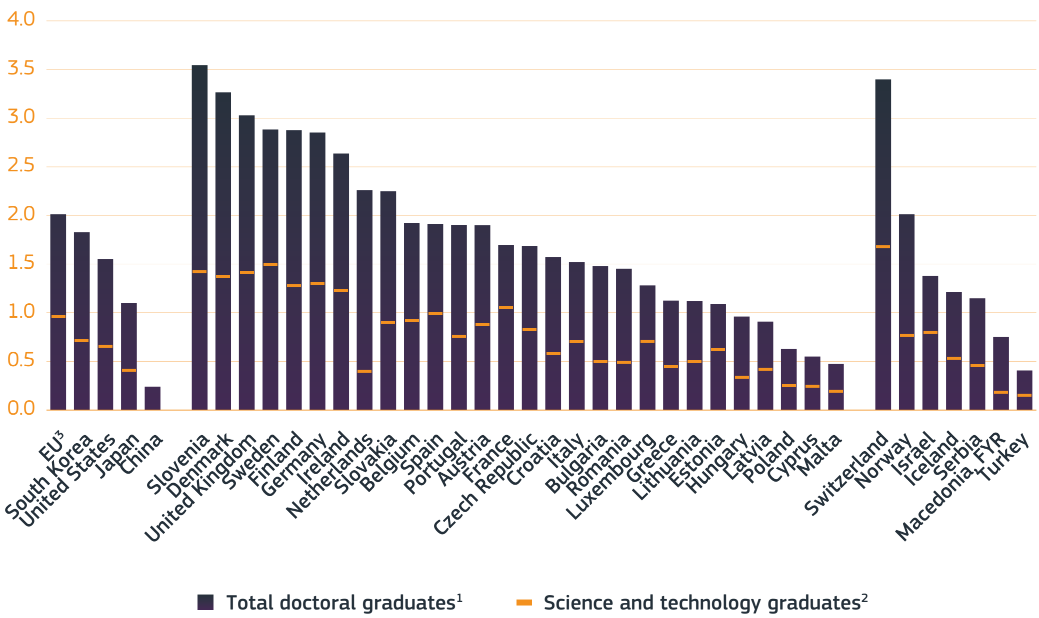


Science, Research and Innovation performance of the EU 2018
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, OECD, UNESCO (UIS)
Note: [1]CN: the data refer to total graduates (a breakdown between S&T and non-S&T is not available).
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_10.xlsx

The EU performs well in the production of new doctoral graduates, including in the field of science and technology. Some EU countries are among the best performers worldwide.

When it comes to new graduates at the doctoral level (see Figure I.3-C.11), the EU performs at the same level as South Korea, but outperforms the United States and Japan. Slovenia, the Nordic countries, the UK and Germany perform well, while in smaller countries, where a high share of doctoral students attain their degree abroad, the data available understate performance. Many Eastern and Southern European countries have a relatively low production of doctoral graduates, partially a result of a perceived lower attraction of academic careers.

Figure I.3-C.11 New doctoral graduates per thousand population aged 25-34, 2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD, UNESCO (UIS)

Notes: [1]IS: 2013; EL, IL, US, JP, KR: 2014. [2]NL, IS: 2013; EL, IL, US, JP, KR: 2014. [3]EU was estmated. The estimated EU value for science and technology graduates per thousand population does not inlcude EL and NL.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_11.xlsx

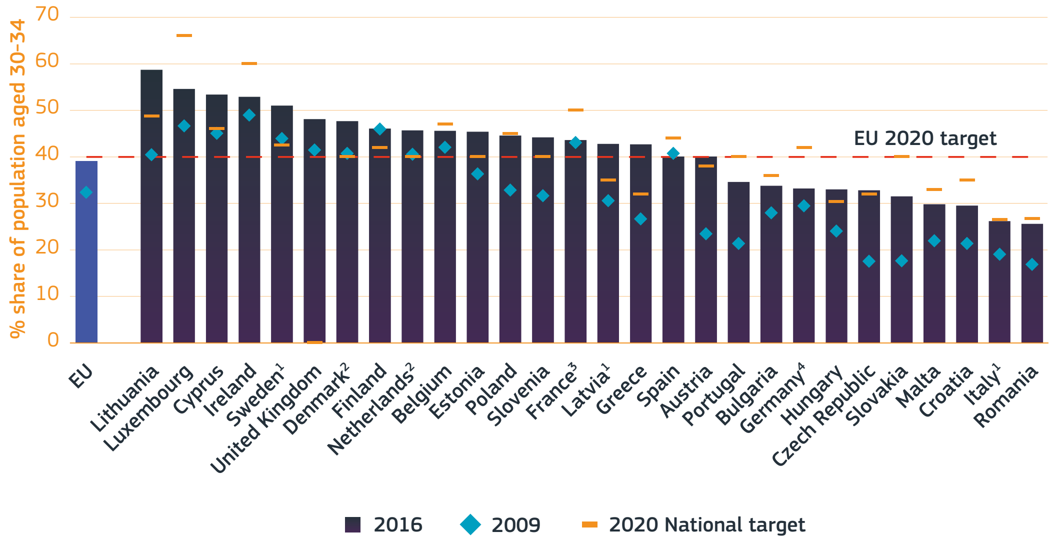
The EU has made good progress as regards the headline target on tertiary attainment – some countries have already reached it, but differences between EU Member States are still large.

Progress in the number of tertiary graduates is (with some time lags) also reflected in the evolution of the EU headline target on tertiary attainment (of 30-34-year-olds). With a tertiary attainment level of 39.1 % in 2016 (see Figure I.3-C.12), the EU is on track to reach the headline target of 40 % by 2020 and will probably even surpass it. There is a notable gender gap with females' tertiary attainment already reaching 43.9 %, 9.5 % above the level for men. Latvia (female attainment rate 26 percentage point higher than that of men), Slovenia (21.7 %) and Lithuania (20.7 %) show the biggest gender gap, while Germany (-0.4 %) shows the smallest.

Lithuania, Luxembourg, Cyprus, Ireland and Sweden already have attainment rates of over 50 %. Malta, Croatia, Italy and Romania still show relatively low tertiary attainment rates. After Mexico, Italy has the lowest tertiary attainment rate among OECD countries. Despite the progress achieved, the EU still lags behind tertiary attainment levels (data for 25-34-year-olds and relating to 2015) of the United States (47 %), Japan (60 %) and Korea (69 %).

However, tertiary attainment is only a proxy for the skills levels acquired. Studies, such as the OECD PIAAC survey, show big differences between the skills levels of tertiary graduates in EU countries and hence the need to focus more on the quality of education in some countries. As educational attainment rates in tertiary education reach saturation in many Member States, attention must shift to the quality of education and the acquisition of skills relevant for the labour market. The demographic dividend, the declining cohort size in many countries, could help to provide the resources for that.

Figure I.3-C.12 EU headline target on the tertiary attainment of population aged 30-34



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat

Notes: [1]LV, IT, SE: the 2020 national targets are set as averages between the values provided by the Member States (LV: 34-36%, IT: 26-27%, SE: 40-45%). [2]DK, NL: the 2020 national targets are set at over 40%. [3]FR: the 2020 national target includes persons aged between 17 and 33 years. [4]DE: the 2020 national target includes ISCED11 level 4 attainment.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_12.xlsx

BOX 5: Transferable skills to tackle education obsolescence and foster innovation

Prof. Diego Rubio, IE School of International Relations

The world of work is changing faster and more drastically than in any other time in recent history. By 2030, it is expected that nearly half of today's jobs will be automated or outsourced, 65% of today's schoolchildren will be employed in jobs that currently do not exist, and more than a third of what are now considered 'core skills' will be different (U.S. Department of Labor, 1999; Benedikt and Osborne, 2013; WEF, 2016).

Technological and socio-economic disruptions are transforming the employment landscape at an unprecedented rate. This is challenging our educational systems, which seem increasingly unable to supply the new set of competencies demanded by the labour market to meet society's changing needs. Since 2008, mismatches between skills and jobs have grown by 29% in Europe (Manpower, 2017), creating substantial problems for recruiting, productivity losses, and missed opportunities for improving the EU's R&I performance.

There are at least two ways to address these problems of a growing skills gap and increased education obsolescence. One is to use developing foresight methods and big data analysis to anticipate which skills will be required in the coming years, so that they can be included in national vocational education and training (VET) curricula and lifelong learning education programmes. The other way is to expand the traditional talent pipeline of formal disciplines and 'hard skills', to place transferable skills at the heart of our educational models.

Transferable skills (often referred to as soft, transversal, key, or behavioural skills) can be described as those non-job-specific competences that are central to occupational proficiency across a wide range of sectors and levels, since they enable employees to navigate their environment and work effectively either alone or with others. Taxonomies vary greatly, but typically they include communication and interpersonal skills, as well as attributes such as creativity, critical thinking, time-management, decision-making, adaptability and problem-solving, among many others.

The technification and automation of developed economies has increased the demand for such skills to the point of becoming some of the most demanded competences by employers in Europe (Deming, 2015; GMAC, 2014). In fact, there is growing evidence that shows these competences rival technical skills in their ability to predict employment and earnings, among other outcomes, and that their demand is likely to increase over the coming years (Balcar, 2014; Carnevale, 2013; Kautz, et al., 2014). This is due to a number of factors:

1. Transferable skills are more versatile and durable than technical ones, enhancing workers' adaptability and occupational mobility, and enabling greater levels of business renewal and societal resilience during economic downturns (EC, 2011; Keep and Payne, 2004).

2. They are not easily automatised, since they cannot be performed by most AI and robots.

3. They promote better R&I outputs by facilitating knowledge and technology transfer, fostering creativity, and enabling researchers to work more effectively in the increasingly mobile and multidisciplinary research environment (Herrmann and Peine, 2011; KIRD, 2010; OECD, 2012 and 2015). a study conducted by the Australian government concluded that the combination of technical capabilities with transferable skills had enabled researchers "to contribute to some of the most transformative innovations developed in recent times" (Commonwealth of Australia, 2011).

4. They are centrally important for human capital development, making a significant contribution to developed economies (Cedefop 2010; International Labour Organization, 2008) which, in the case of the UK, has been estimated to be worth around 6.5% of its annual GDP (Development Economics, 2015).

5. They have major positive effects beyond the labour market, enhancing individuals' social well-being and academic performance (Durlak et al., 2011; Padhi, 2014; Weedon, 2013).

Yet, despite their importance, transferable skills still occupy second place in European policy agendas. Some countries (Finland, Norway, France, Germany and the UK) are taking important steps by increasing resources and setting up pioneering programmes for learning and skills training in educational and working environments. However, the overall results are still insufficient. According to Cedefop's European skills and jobs survey, 26% of European workers acknowledge that they do not have the transferable skills needed to carry out their work properly, while 48% of the employers interviewed indicate that a lack of skills is one of the key reasons they could not hire the necessary employees (Cedefop, 2014). In the UK, for instance, recent surveys indicate that soft skills are associated with between 33% – 40% of all reported skills-shortage vacancies, and suggest that the problem will increase in the future (Development Economics, 2015; UKCES, 2014).

This shortage of transferable skills is causing major problems in European countries by fuelling unemployment, adversely affecting workers' well-being, diminishing economies' productivity, and lowering business capacity to innovate and adapt to changing circumstances (Clarke, 2016; McKinsey, 2014; Mourshed et al., 2016;). To address these issues, EU Member States should:

1. Develop concrete education and training policies aimed at fostering the acquisition, development, and certification of transferable skills at all levels, following the good practices and models developed by pilot projects such as NESSIE, HISS, GRASS and VALEW, among others. Some measures should include: adopting problem-based learning methodologies, increasing teacher training and support, introducing more inter-disciplinarity into curricula, promoting the 'environmental factor' and extra-curricular activities, and introducing new digital technologies and gamification systems designed to develop transferable skills, such as eLene4work, ModEs and S-Cube, to mention but a few.

2. Create a European standardised taxonomy for the description and measurement of transferable skills at a regional level, following the example of other internationally comparable datasets on cognitive skills which already exist (e. g. PISA, PIAAC).

3. Introduce transferable skills as part of European forecast tools (e. g. CEDEFOP and EUCLID) to develop a comprehensive, consistent and detailed view of future skills needs and vacancies across the EU.

4. Promote awareness of the importance of transferable skills among all stakeholders, including public institutions, civil society and private business, which should increase their support to the acquisition and valuation of transferable skills in all HR processes – from recruitment and employee training to performance assessments (Martinez Lucio, 2007; Thelen, 2004).

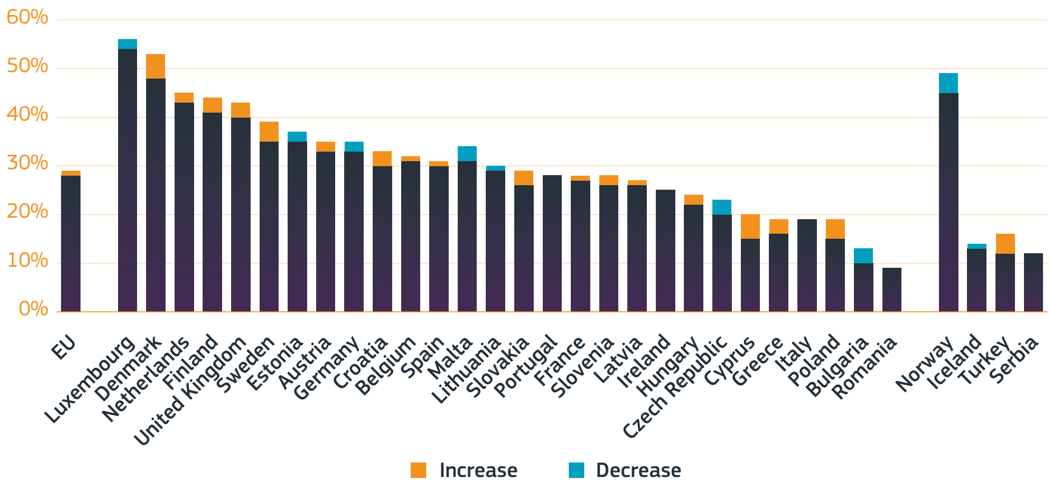
If implemented correctly and in a timely manner, these measures should help the EU to raise labour productivity and create a more innovative and versatile workforce, public institutions, and private sector, which will be better prepared to cope with the uncertainties and fast-changing nature of the economy and society in the 21st century.

As regards the increasingly important digital skills, the EU is making progress, but there is a considerable digital divide between Member States, linked to income levels.

With reference to the increasingly important digital skills, the Eurostat ICT household survey (See Figure I.3-C.13) for 2016 shows significant differences between Member States in the share of the population aged 15-74 with above-average digital skills. The Nordic countries, Luxembourg, Netherlands and the UK perform best in this area. They also tend to have relatively high shares of ICT start-ups. The lowest performers in EU populations as regards digital skills are Romania and Bulgaria, countries where low per-capita incomes lead to a relatively low household penetration of digital equipment.

The share of individuals with digital skills in the EU population seems to be increasing. As regards high computer skills, it rose from 23% in 2007 to 25% in 2012 to 29% in 2014. With reference to above-average digital skills, it increased from 29% in 2015 to about 30% in 2016. In 2016, the countries that made most progress include Denmark, Sweden, Cyprus and Poland.

Figure I.3-C.13 Individuals with above average digital skills as % of total population, 2016 (with the change compared to 2015)



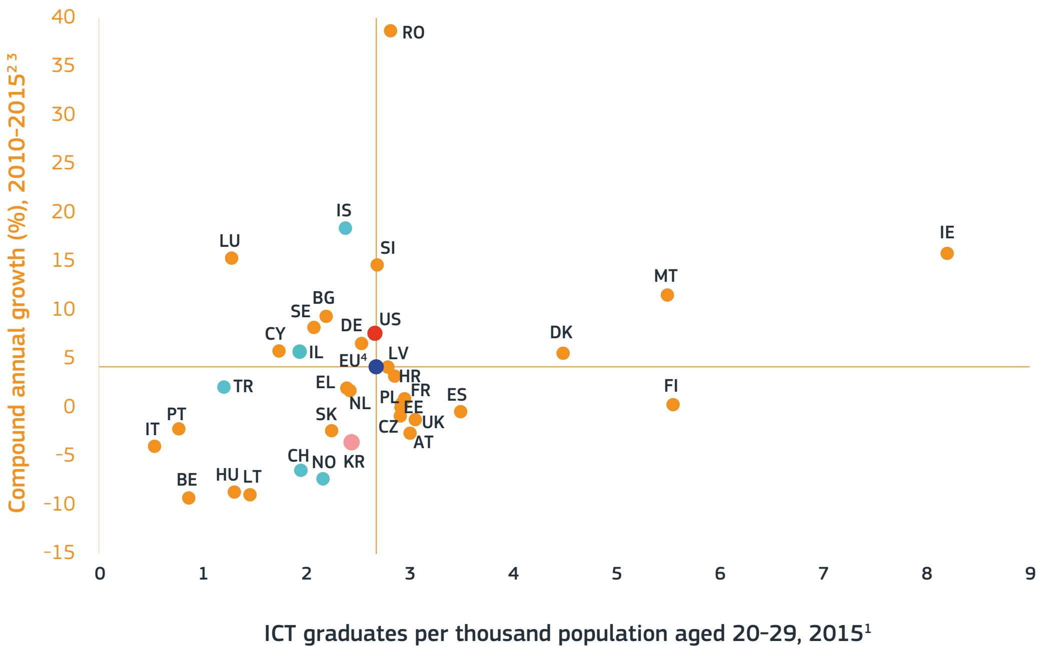
Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_13.xlsx

Although the number of computing graduates has increased recently by about 5% per year, there are still not enough graduates to fill the available vacancies.

While ICT skills are improving, there is still a growing need for IT professionals. Recently, the number of ICT practitioners has been growing by about 4% annually. Growth is fuelled by new developments such as big data, the IoT, the cloud and the growth of the app economy.

In the period 2010-2015, the number of computing graduates in the EU increased on average by over 5% per year. However, in several Member States it declined. As a result, there are not enough graduates to fill the vacancies available in this sector. According to a Commission estimate in the context of the digital skills initiative, there could be up to 500 000 vacancies for ICT professionals in the EU by 2020. Member States with a high number of computing graduates per 1000 population aged 25-34 include Ireland (where many American ICT companies have their European headquarter), Malta (where an online gaming cluster has developed), Finland (with its important video-game sector) and Denmark, while figures are relatively low in Italy, Portugal and Belgium. However, in some countries, including Romania, the figures available tend to understate performance since computing is often integrated into subject areas like mathematics. Nevertheless, of concern is the fact that, since 2007, the number of graduates from computing studies has fallen by over 10% in countries like Italy and Belgium (see Figure I.3-C.14).

Figure I.3-C.14 Graduates in the field of ICT per thousand population aged 20-29, 2015 and compound annual growth, 2010-2015



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: [1]NL: 2012; IS: 2013; EL, IT, IL, US, KR: 2014. [2]EU: 2009-2015; NL, IS: 2010-2012; IT, IL, US, KR: 2010-2014; LU: 2011-2015; FR, HR: 2013-2015. [3]Break in series between 2013 and the previous years due to change of classification (ISCED97/11 replaced by ISCED-F 2013). IL, US, KR: data based on ISCED97. [4]EU was estimated from the available data for the Member States and does not include EL, IT and NL.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_14.xlsx

Employment in science and technology has been resilient during the crisis. The number of researchers and R&D personnel has expanded considerably since 2008.

An adequate supply of skilled human resources is vital for the functioning of R&I systems and for the development of science and technology-intensive economic sectors. The EU is facing growing demographic challenges in the coming decades with small young cohorts entering the labour market combined with a retiring baby-boomer generation and a potential risk of sectoral and regional bottlenecks in the supply of skilled workers. However, rapid technological progress and change in workplace requirements, growing interdisciplinarity and the resulting low predictability of future skills needs combined with fluctuating migration levels make planning and foresight difficult. a certain surplus of skilled people can stimulate economic development and innovation, as these people move into non-traditional job areas or become entrepreneurs, while the growing internationalisation of labour markets is making regional or national skills gaps less severe. On the other hand, there is growing international and intersectoral competition for highly skilled people.

In 2016, the EU's active population (referring to the total labour force, which includes both employed and unemployed people) amounted to about 245 million, of whom 224 million were employed and 21 million were unemployed (see Figure I.3-C.15). Human resources in science and technology (HRST) accounted for 126 million people in the EU, or 56.3 % of total employment, a share that has been increasing constantly in the past. Those, who have successfully completed tertiary-level education (HRSTE) accounted for 43.8 % of total employment, with Ireland, Cyprus and Luxembourg showing the highest shares. Those who have both completed tertiary-level education and are currently employed in an S&T occupation (HRSTC) accounted for 22.6 % of total employment. This implies that 50 % of tertiary education graduates are employed in S&T occupations.

In the past, human resources in science and technology have grown faster than total employment and jobs in this area proved more resilient during the crisis. Whilst total employment increased on average by 0.2 % per year between 2007 and 2016, HRST grew by 2.4 % annually, or by nearly 20 million, over the whole period, research personnel by 2.3 % and the number of researchers by 2.8 %. This reflects the labour force's rising educational attainment, as well as the shift towards skill-intensive jobs and a knowledge-intensive economy. In absolute terms, the stock of human resources in science and technology is still growing, partly because of increasing attainment rates. Overall, there is no evidence yet of a skills gap, but the situation might change in the future and there are already bottlenecks in certain regions and sectors, such as ICT.

Figure I.3-C.15 Key data on human resources in science and technology in the EU

	Total (000s) 2016[1]	As % of total employment 2016	Compound annual growth (%) 2007-2016[2]
Active population	244594	109	0.36
Total employment (LFS)	223681	100	0.19
HRST - Human Resources in Science and Technology	103802	46.4	2.00
HRSTE - Human Resources in Science and Technology - Education	75771	33.9	3.14
HRSTO - Human Resources in Science and Technology - Occupation	78628	35.2	1.51
HRSTC - Human Resources in Science and Technology - Core	50596	22.6	2.90
SE - Scientists and Engineers	17189	7.7	2.26
Total R&D personnel (FTE)	2849	*1.3*	2.33
Researchers (FTE)	1818	*0.8*	2.79

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat

Notes: [1]Total R&D personnel FTE), Researchers (FTE): 2015. [2]Total R&D personnel (FTE), Researchers (FTE): 2007-2015; breaks in series occur between 2014 and the previous years and between 2011 and the previous years for HRST data.

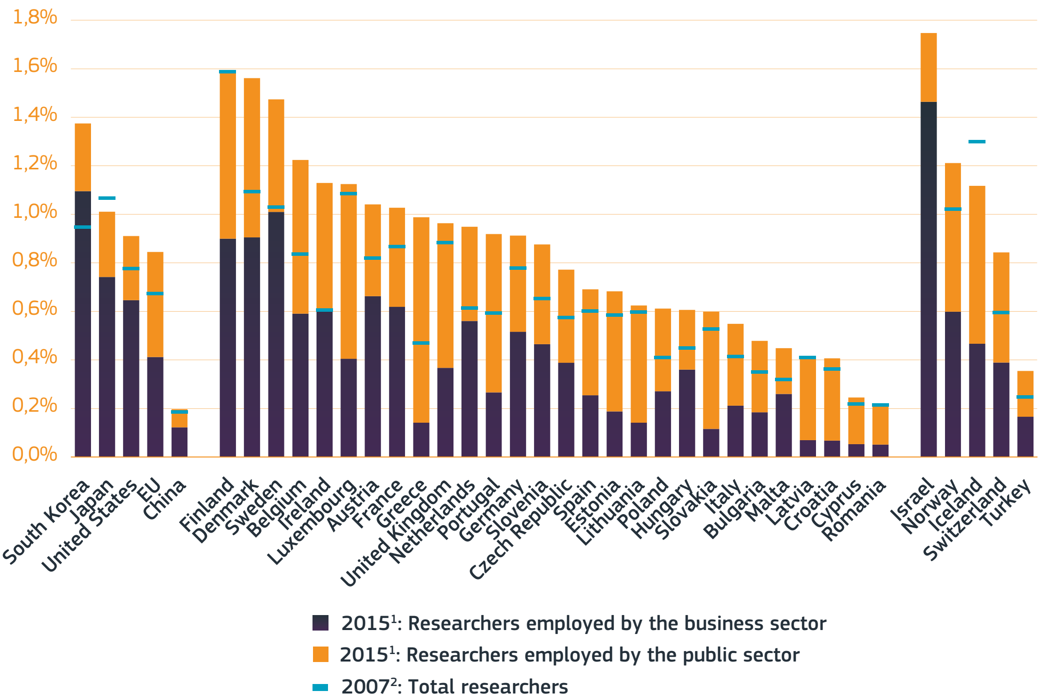
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_15.xlsx

The share of researchers in the workforce reflects economic structures and development levels and is strongly correlated with countries' innovation outputs. Countries with high shares of researchers in total employment tend to be innovation leaders.

In terms of researchers, as a percentage of total employment, the EU lags behind the United States, Japan and especially South Korea, notably when it comes to researchers employed in the business sector (see Figure I.3-C.16). However, compared to the United States and especially to Japan, where the number of researchers is stagnating, the EU is catching up, while South Korea is pulling further ahead.

China shows even stronger growth. It already has the largest number of business researchers in absolute terms and might soon overtake the EU, too, in terms of the total number of researchers. In the EU, the Nordic countries (Finland, Denmark and Sweden) show the highest share of researchers in total employment and also perform well as regards researchers employed by the business sector. The south-eastern European countries – Croatia, Bulgaria, Cyprus, Romania and Latvia – show relatively low levels, particularly for researchers in the business sector. On the other hand, many Central and Eastern European countries (notably Bulgaria, Hungary and Poland) plus Malta are catching up in terms of researchers and business enterprise researchers. There is a high correlation between the employment share of researchers in the business sector and innovation outputs.

Figure I.3-C.16 Total researchers (FTE) as % of total employment, 2007 and 2015



Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies
Data: Eurostat, OECD
Notes: [1]CH, IL: 2012; FR, TR, US: 2014. [2]CH: 2008.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_16.xlsx

Although females represent almost half of the graduates at doctoral level, women still represent less than one-quarter of all researchers and only one-sixth of researchers in the business sector.

The share of female researchers is still far from a gender balance. In 2015, women represented only 23.7 % of researchers in the EU, with marked differences between European countries. The Baltic States (Latvia 50.5 %, Lithuania 46.5 % and Estonia 43.1 %), and south-eastern European countries (Croatia 51.0 %, Bulgaria 49.8 % and Romania 45.0 %) have the highest shares, probably partly as a result of comparatively less-attractive salaries but greater job safety.

Figure I.3-C.17 Researchers (FTE) - total and business enterprise, 2015

	Total researchers (FTE)			
	2015[1] (thousands)	% of female researchers[2]	Compound annual growth (%) 2007-2015[3]	As % of total employment[4]
EU	1817.7	23.7	2.8	0.8
Belgium	55.1	:	5.3	1.2
Bulgaria	14.2	49.8	3.0	0.5
Czech Republic	38.1	24.1	4.0	0.8
Denmark	41.8	32.9	4.2	1.6
Germany	357.5	22.7	2.6	0.9
Estonia	4.2	43.1	1.6	0.7
Ireland	21.5	29.3	6.8	1.1
Greece	35.1	38.9	9.2	1.0
Spain	122.4	38.6	0.0	0.7
France	268.4	26.1	2.6	1.0
Croatia	6.4	51.0	0.5	0.4
Italy	120.7	36.1	3.3	0.5
Cyprus	0.9	38.6	0.9	0.2
Latvia	3.6	50.5	-1.7	0.4
Lithuania	8.1	46.5	-0.5	0.6
Luxembourg	2.9	27.3	6.9	1.1
Hungary	25.3	26.4	4.8	0.6
Malta	0.8	29.4	6.5	0.4
Netherlands	77.0	25.6	1.7	0.9
Austria	42.3	23.0	3.7	1.0
Poland	96.7	35.3	5.8	0.6
Portugal	39.6	43.7	1.6	0.9
Romania	17.5	45.0	1.9	0.2
Slovenia	7.9	34.7	-0.2	0.9
Slovakia	14.4	41.3	1.9	0.6
Finland	37.5	:	-0.1	1.6
Sweden	68.7	28.0	2.0	1.5
United Kingdom	289.3	:	1.7	1.0
Iceland	1.9	36.0	6.5	1.1
Norway	30.8	:	3.0	1.2
Switzerland	36.0	:	9.4	0.8
Turkey	89.7	32.6	8.8	0.4
Israel	63.5	:	15.1	1.7
United States	1351.9	:	2.5	0.9
Japan	662.1	15.3	-0.2	1.0
China	1619.0	:	6.7	0.2
South Korea	356.4	18.9	6.1	1.4

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: [1]CH, IL: 2012; FR, TR, US: 2014. [2]The values refer to 2014 or to the latest available year (JP, KR: 2015). EU refers to 2013 and does not include BE, FI and UK. [3]CH: 2008-2012; PT, SI, JP: 2008-2015; IL: 2011-2012; EL: 2011-2015. [4]CH: 2012; FR, TR, IL, US, CN: 2014. [5]CH: 2012; FR, TR, IL, US: 2014. [6]CH: 2008-2012; SI: 2008-2015; IL: 2010-2014; EL: 2011-2015. [7]CH: 2012; FR, TR, IL, US, CN: 2014.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_17.xlsx

Figure I.3-C.17 (contd.) Researchers (FTE) - total and business enterprise, 2015

	Business enterprise researchers (FTE)				
	2015[5] (thousands)	% of female researchers[2]	Compound annual growth (%) 2007-2015[5]	As % of total employment[7]	As % of total researchers (FTE)
EU	885.7	16.3	3.6	0.4	48.7
Belgium	26.6	:	5.0	0.6	48.3
Bulgaria	5.5	40.1	19.5	0.2	38.6
Czech Republic	19.2	14.6	5.8	0.4	50.3
Denmark	24.2	27.7	3.0	0.9	58.0
Germany	202.0	13.7	1.9	0.5	56.5
Estonia	1.2	29.5	2.3	0.2	27.5
Ireland	11.5	22.9	6.0	0.6	53.8
Greece	5.0	27.6	5.7	0.1	14.3
Spain	45.2	30.9	0.9	0.3	36.9
France	161.8	20.5	3.8	0.6	60.3
Croatia	1.1	44.4	2.4	0.1	16.7
Italy	46.6	22.2	4.5	0.2	38.6
Cyprus	0.2	35.2	0.2	0.1	21.5
Latvia	0.6	45.8	5.4	0.1	16.7
Lithuania	1.8	30.7	4.4	0.1	22.7
Luxembourg	1.0	11.1	1.5	0.4	36.0
Hungary	15.0	17.8	10.0	0.4	59.4
Malta	0.5	23.4	8.8	0.3	58.0
Netherlands	45.5	17.2	1.1	0.6	59.1
Austria	27.0	15.7	3.8	0.7	63.7
Poland	42.8	19.3	20.2	0.3	44.3
Portugal	11.5	28.6	7.0	0.3	29.0
Romania	4.2	39.3	-1.4	0.1	24.3
Slovenia	4.2	25.7	0.5	0.5	53.1
Slovakia	2.8	18.0	7.2	0.1	19.4
Finland	21.3	:	-0.4	0.9	56.8
Sweden	47.1	22.5	2.0	1.0	68.6
United Kingdom	110.4	:	2.6	0.4	38.2
Iceland	0.8	:	-8.2	0.5	41.8
Norway	15.2	:	3.0	0.6	49.4
Switzerland	16.6	:	12.6	0.4	46.2
Turkey	41.8	23.8	15.5	0.2	46.7
Israel	56.5	:	7.6	1.5	:
United States	960.0	:	2.4	0.6	71.0
Japan	486.2	8.6	0.1	0.7	73.4
China	1014.6	:	7.5	0.1	62.7
South Korea	284.1	14.8	6.9	1.1	79.7

Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, OECD

Notes: [1]CH, IL: 2012; FR, TR, US: 2014. [2]The values refer to 2014 or to the latest available year (JP, KR: 2015). EU refers to 2013 and does not include BE, FI and UK. [3]CH: 2008-2012; PT, SI, JP: 2008-2015; IL: 2011-2012; EL: 2011-2015. [4]CH: 2012; FR, TR, IL, US, CN: 2014. [5]CH: 2012; FR, TR, IL, US: 2014. [6]CH: 2008-2012; SI: 2008-2015; IL: 2010-2014; EL: 2011-2015. [7]CH: 2012; FR, TR, IL, US, CN: 2014.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-c_figures/f_i_3-c_17.xlsx

CHAPTER I.3-D: INVESTMENT IN ECONOMIC COMPETENCES

Synergies and complementarities between 'economic competences' and other intangible and tangible assets have significant potential to enhance productivity and economic growth in Europe.

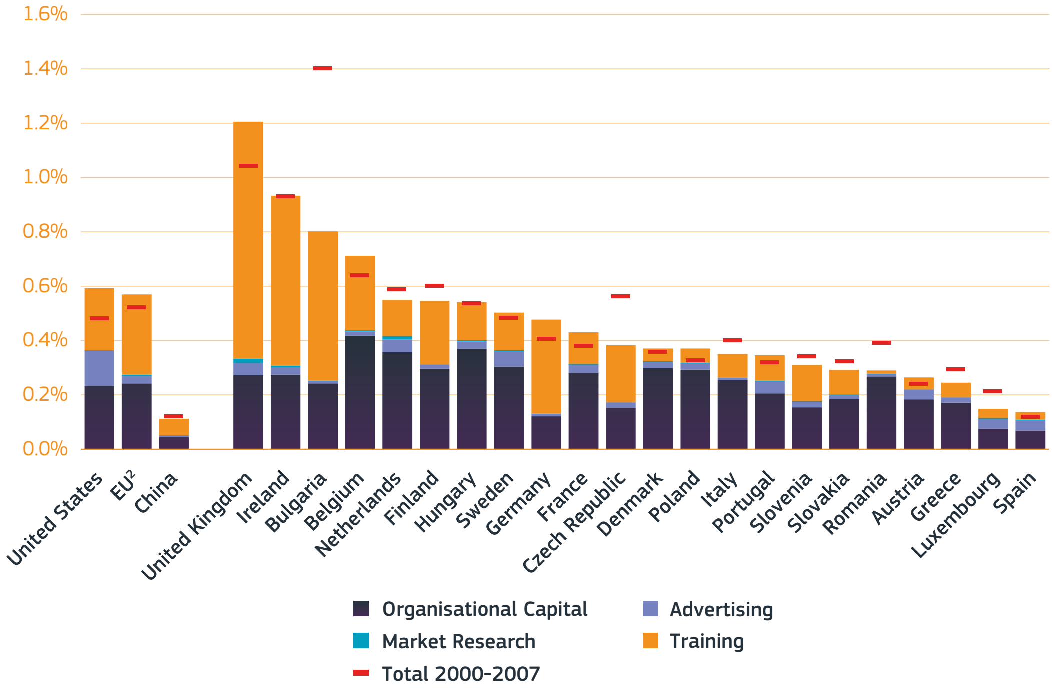
Economic competences are an increasingly relevant category of intangible assets which include investments in brand equity, firm-specific human capital, organisational capital and market research[9], and which lead to productivity growth. In fact, the impact of a given investment increases when some of these economic competences, such as training and effective organisational and managerial structures, are combined with other intangible (e.g. software) and tangible (e.g. hardware) assets. Due to the fast pace of technological change, mainly driven by the exponential growth of ICT, it has become clear that investing in economic competences can contribute to better reaping the opportunities created by the ICT boom and which require, for instance, the use of new business models and the deployment of specific skills that maximise exploitation of these technologies. Failing to acknowledge the need to invest in these complementary competences limits the desirable impact of ICT on productivity growth. This may be one of the explanations behind the 'productivity paradox'.

Public investment in economic competences in the EU has not substantially increased in contrast to developments in the United States.

The UK, Ireland and Bulgaria stand out as the Member States which, between 2008 and 2015, on average invested the most in economic competences, with a share above 0.8 % of GDP. This is driven mainly by significantly higher investments in *training* relative to other Member States that mostly focus their public investments in this area on *organisational capital* (Figure I.3-D.1). More recently, the EU has been outperformed by the United States due to significant investments in *advertising*.

9 'Brand equity' includes advertising expenditure and market research for the development of brands and trademarks; 'firm-specific human capital' concerns the costs of developing workforce skills, i.e. on-the-job training and tuition payments for job-related education; organisational structure is related to the costs of organisational change and development as well as company training expenses (see Corrado et al., 2005); finally, 'market research' includes aspects such as feasibility studies and firm-specific foresight exercises (see Thum-Thysen et al., 2017).

Figure I.3-D.1 Public investment in economic competences[1] by type, as % of GDP, 2008-2015 (and for 2000-2007 without breakdown by type)



Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, SPINTAN project: Smart Public intangibles

Notes: [1]Economic competences is one of the three broad categories of intangible assets. The other two categories are: computerised information and innovative property. [2]EU was estimated as the average of the values of the Member States for which data are available.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-d_figures/f_i_3-d_1.xlsx

Private investment in economic competences is also lower in the EU than in the United States. However, generally speaking, there is an increase in investment in the majority of the EU Member States[10].

Bloom et al. (2017) showed that 'good management' practices increase a firm's total factor productivity. Accordingly, the importance of competent management can be illustrated through the McDonald's example. Essentially, the company's success came from an effective and efficient organisational and managerial system applied at first to just one restaurant "which required upfront effort", but then could be replicated and scaled across stores[11] nation and worldwide. Moreover, brand equity, in particular in the 'tech sector', has grown significantly. While in 2010, eight of the 20 most valuable brands, according to Forbes, were technology companies, in 2016, their representation increased to half and four of them were in the 'top 5'. In addition, companies should invest in training and skills development in the context of fast-changing demand for new skills (OECD, 2017) especially if they want to remain competitive and thrive in the current digital era.

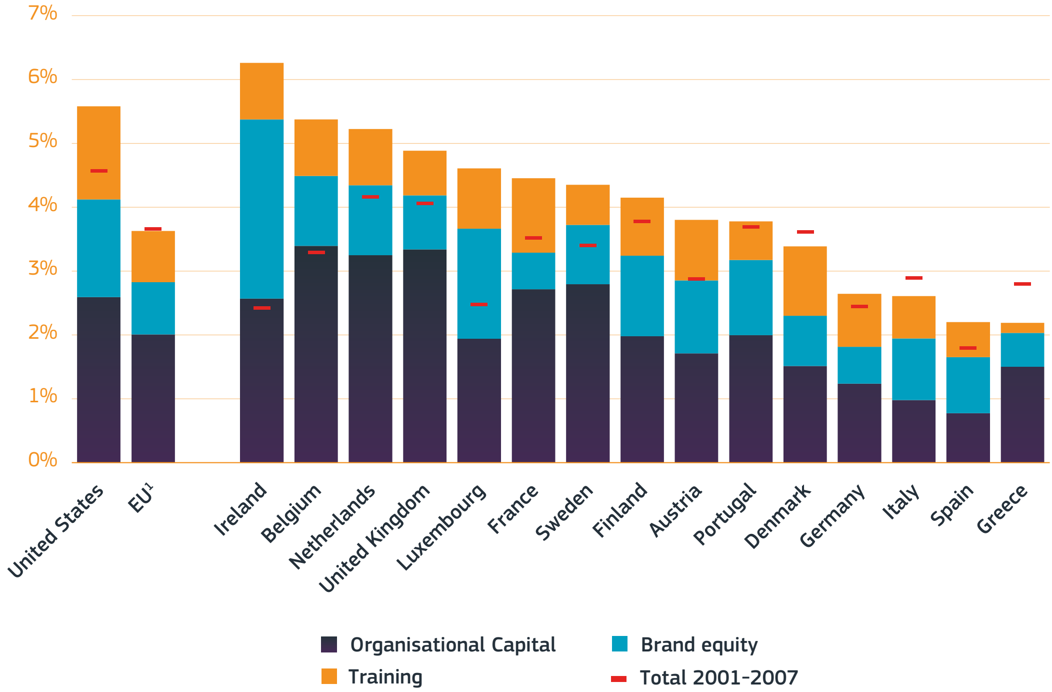
With the exception of Denmark, Italy and Greece, intangible investments in economic competences by businesses in the EU Member States (with available data) increased over 2008-2014 relative to the period 2000-2007. This rise was mostly noticeable in Ireland (where it more than doubled), Luxembourg and Belgium. However, on average, private investments in economic competences ranged from more than 6% of GDP in Ireland to slightly more than 2% of GDP in Greece between 2008 and 2015. Private intangible investments in *organisational capital* dominate in the majority of EU Member States, except Ireland, Luxembourg, Italy and Spain, where *brand equity* is the individual category within economonic competences that drives most of these business investments[12]. The EU lags behind the United States mainly due to higher relative private investments dedicated to *brand equity* and *training* in the latter.

10 However, this analysis of the EU should be made with the necessary caveats due to the lack of data available for more EU Member States.

11 https://hbr.org/2017/10/the-real-reason-superstar-firms-are-pulling-ahead.

12 In principle, public support should not target economic competences that build monopoly rents, e.g. brand equity (see Thum-Thysen et al., 2017).

Figure I.3-D.2 Private investment in economic competences[1] by type, as % of GDP, 2008-2014 (and for 2001-2007 without breakdown by type)



Science, Research and Innovation performance of the EU 2018

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies

Data: Eurostat, INTAN invest project

Notes: [1]Economic competences is one of the three broad categories of intangible assets. The other two categories are: computerised information and innovative property. [2]EU was estimated as the average of the values of the Member States for which data are available.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/parti/i_3-d_figures/f_i_3-d_2.xlsx

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