CHAPTER 5.1

INVESTMENT IN R&D

KEY FIGURES

17 %
of world R&D expenditure attributed to the EU

1 %
annual increase of EU R&D intensity since 2000

24
Member States have increased their R&D intensity since 2000

2/3
of EU R&D expenditure performed by the business sector

7 %
of EU public funding comes from the European Commission

What can we learn?

- With only 6% of the world population, the **EU accounts for almost 20% of global R&D expenditure**.
- **With 2.19% of its GDP invested in R&D, the EU is still far from its 3% target**. It underinvests compared to its main competitors, especially in terms of private investments.
- **EU R&D expenditure is largely dominated by a limited number of big countries** (61% in Germany, France and Italy together).
- **R&D intensity increased over the 2000-2018 period in 24 Member States**, with national R&D intensity ranging from 0.5% in Romania to 3.3% in Sweden.
- Member States are slowly steering their national budgets towards societal and environmental challenges.

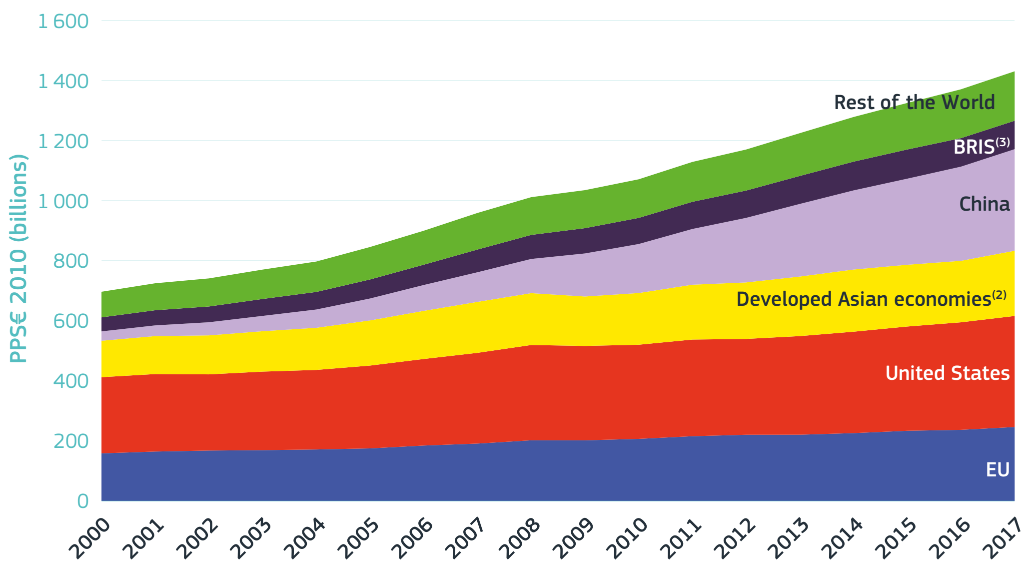
What does it mean for policy?

- R&I policy needs to **leverage further efforts in R&D investments**.
- Because of the scope, scale and urgency of the societal challenges facing Europe, policy is required to **pay more attention not just to the volume of R&D investments, but also to the overall direction of these investments**.
- Given the **significant increase in R&D tax incentives** over the last decade, there is a need to assess the use of this instrument in supporting transitions that require coordinated and strategic investment.

1. EU's share in world R&D expenditure is declining

World R&D expenditure is continuing to increase as all major regions have boosted their R&D spending. The EU's relative weight in this global R&D landscape is decreasing, although it still accounts for almost 20 % of global R&D expenditure. In 2017, the EU represented 17 % of total R&D expenditure in the world[1], down from 22 % in 2000 (Figure 5.1-1). The EU's continuously declining EU's share in world R&D expenditure is mainly due to the rapid rise of China whose share has increased almost fivefold from 5 % in 2000 to 24 % in 2017. The decline of the US share since 2000 has been even more pronounced than that of the EU, from 37 % in 2000 to 26 % in 2017. The share of the developed Asian economies shrank from 18 % in 2000 to 15 % in 2010, while the rest of the world's share has remained stable at around 12 %.

Figure 5.1-1 Evolution of world expenditure on R&D in real terms(1), 2000-2017



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat, OECD, UNESCO

Notes: (1)GERD in PPS€ at 2010 prices and exchange rates. (2)Japan+South Korea+Singapore+Chinese Taipei. (3)Brazil+Russian Federation+India+South Africa.

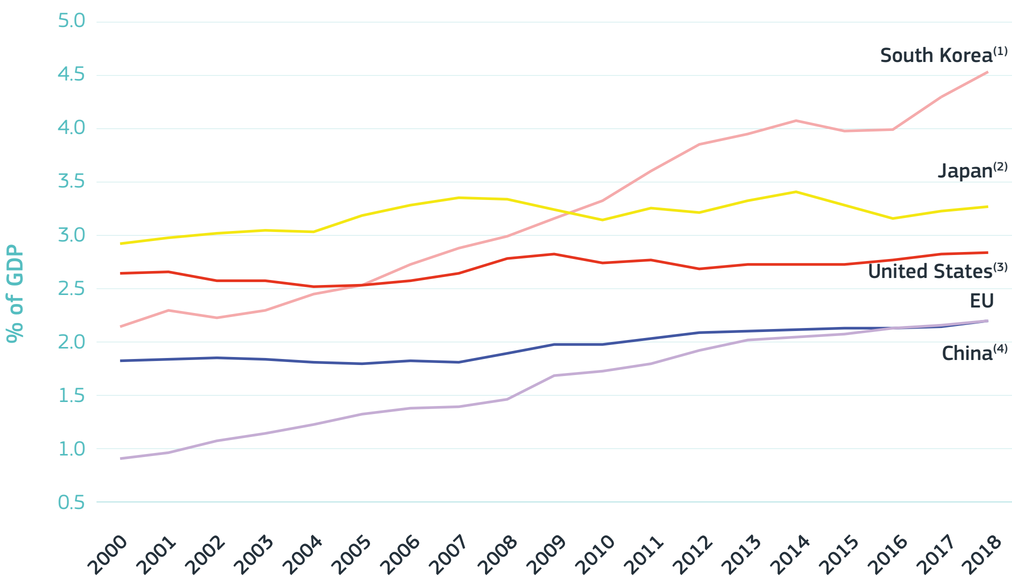
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter51/figure-51-1.xlsx

1 R&D expenditure is measured in PPS€ at 2010 prices and exchange rates.

The EU's relatively strong position in the world R&D landscape is partly due to R&D investment[2] being one of the five Europe 2020 headline targets[3]. The EU's target of devoting 3 % of its GDP to R&D activities and further national targets have mobilised increasing resources for R&D in the last two decades. In addition, R&D intensity targets have led to the portfolio of R&I support instruments becoming more complex, experimentation with new policies, and greater attention to impact assessment and evaluation (Box 5.1-1).

Although R&D expenditure in the EU has been increasing annually by 1% since 2000, it remains lower than the 3% Europe 2020 target, and visibly below the performance of most of its main competitors. At the EU level, R&D intensity increased from 1.81% in 2000 to 2.19% in 2018. However, to meet the 3% target by 2020, its R&D intensity would have to increase by more than 10% per year. R&D as a share of GDP in the EU is smaller than in South Korea (4.53%), Japan (3.26%) and the United States (2.83%). China has more than doubled its R&D intensity since 2000 and in 2018 its R&D-to-GDP ratio was equal to the EU's (Figure 5.1-2).

Figure 5.1-2 Evolution of R&D intensity, 2000-2018



Source: Eurostat (online data code: rd_e_gerdtot), OECD (Research and Development Statistics)

Notes: (1)South Korea: There is a break in series between 2007 and the previous years. (2)Japan: There is a break in series between 2008 and the previous years and between 2013 and the previous years. (3)United States: (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)China: There is a break in series between 2009 and the previous years.

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2 The R&D objective set at the EU level is expressed in terms of R&D intensity which measures the share of GDP invested in R&D.

3 At the 2002 Barcelona Summit, the European Council agreed that the EU should set the objective of devoting 3% of its GDP to R&D activities by 2010. In 2010, this target became one of five headline targets in the Europe 2020 Strategy to be achieved by 2020 (European Commission, 2010).

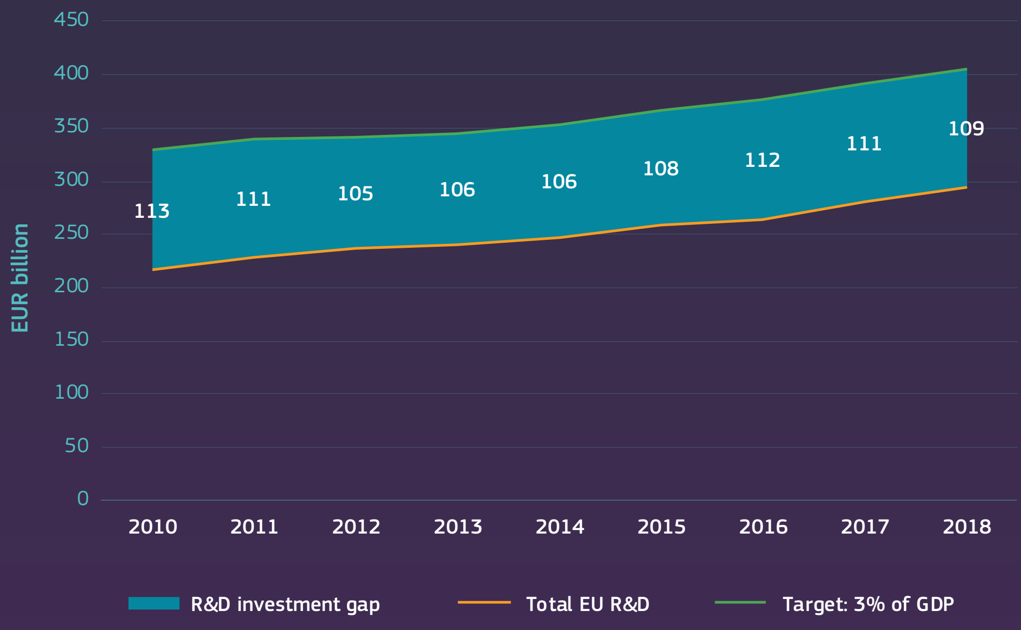
BOX 5.1-1 The 3 % target

As the Europe 2020 Strategy has come to an end, the 3 % investment target ceases to have a legal basis. The objective of investing 3 % of GDP in R&D was first set in the Lisbon Strategy with the aim of turning the EU into the most competitive and dynamic knowledge-based economy in the world by 2010. The ambition was reset in the Europe 2020 Strategy with a focus to 'increase combined public and private investment in R&D to 3 % of GDP' by 2020.

The Commission has monitored Member States' progress through the yearly European Semester cycle. At the beginning of 2020, the EU is still a long way from meeting its target. Although it has made progress over the past decade, the United States and key competitors in Asia invest in R&D at a higher rate than the EU. In order to reach an investment in R&D corresponding to 3 % of its GDP, the EU would need to invest an additional EUR 110 billion per year (Figure 5.1-3).

Although the EU has not fulfilled its R&D investment ambition, the 3 % target has proven to have had a clear mobilising effect as all Member States have set their own national targets. It has also stimulated reflections across Member States on their economic model and policy mix. It is a strong indicator within the European Semester that has provided a stimulus to the EU's R&I, growth and competitiveness policy. It is also an essential compass that can help accelerate the transition towards an environmentally, socially and economically sustainable Europe.

Figure 5.1-3 R&D investment gap in EU



Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: rd_e_gerdtot)

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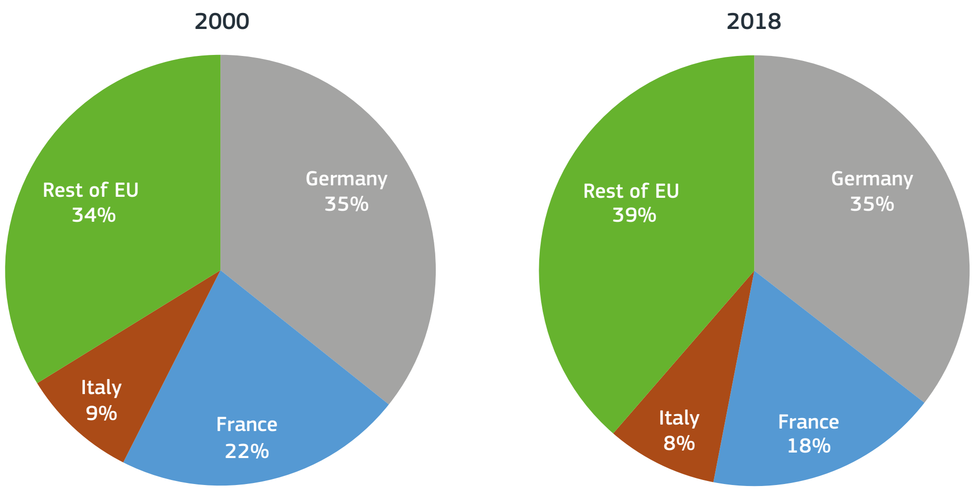
EU R&D intensity is largely influenced by a limited number of big countries[4]: namely, 61 % of the EU's R&D expenditure in 2018 was performed in Germany, France and Italy. R&D expenditure in the other EU countries together has increased by 5 % since 2000 (Figure 5.1-4). However, Germany alone still accounts for almost the same amount of R&D spending as other 24 Member States combined. Hence, to a large extent, the overall EU R&D intensity is determined by its value in these three countries. If they do not set more ambitious targets and move forward, EU R&D intensity will not change drastically.

R&D intensity increased over the 2000-2018 period in 24 Member States. Despite this obvious progress, most Member States remained far from their national 2020 targets. The intensity of R&D spending across EU Member States varies considerably, with national R&D intensity ranging from 0.5 % in Romania to 3.3 % in Sweden. To a large extent, these big differences can be explained by their industrial specialisations, quality of academic research environment, and access to a large integrated technology market[5]. Three countries have already reached their 2020 target: Germany (3.13 %, with a target of 3 %), Denmark (3.03 %, with a target of 3 %) and Cyprus (0.55 %, with a target 0.5 %). Many of the countries with the lowest initial level of R&D intensity made the greatest progress. R&D intensity in Czechia, Cyprus, Greece, Estonia, Hungary and Poland[6] increased by more than 2.5 % annually from 2000 to 2018, while Sweden and Finland, with the highest initial R&D intensity[7], faced declining intensity growth.

Figure 5.1-4 Distribution of Gross Domestic Expenditure in R&D (GERD) within the EU, 2000 and 2018



Source: Eurostat (online data code: rd_e_gerdtot)
Note: (1)France: break in series between 2010 and the previous years.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter51/figure-51-4.xlsx

4 The levels of R&D expenditure in Germany, France and Italy play an important part in aggregate EU R&D intensity.
5 van Pottelsberghe, 2008.
6 In 2000, the R&D intensity in Cyprus was 0.23 %, Greece 0.56 %, Estonia 0.6 %, Hungary 0.79 % and Poland 0.64 %.
7 In 2000, the R&D intensity in Sweden was 3.91 % and Finland 3.25 %.

Figure 5.1-5 Situation of each Member State with regard to its R&D intensity target[6][8]

	R&D intensity 2018	R&D intensity target 2020	R&D intensity compound annual growth (%) 2000-2018[1]	R&D intensity compound annual growth (%) 2010-2018	R&D intensity compound annual growth (%) required to meet the 2020 target 2018-2020
Belgium	*2.76*	*3.00*	2.0	3.7	4.2
Bulgaria	*0.75*	*1.50*	2.4	3.6	41.0
Czechia[7]	*1.93*	*:[2]*	3.1	4.7	:
Denmark	*3.03*	*3.00*	1.7	*0.5*	*Target reached*
Germany[7]	*3.13*	*3.00*	1.5	*1.7*	*Target reached*
Estonia	*1.40*	*3.00*	4.8	-1.4	46.2
Ireland	*1.15*	*2.00[3]*	0.3	-4.0	32.1
Greece	*1.18*	*1.30*	4.6	8.8	5.1
Spain	*1.24*	*2.00*	1.9	-1.1	26.8
France	*2.20*	*3.00*	0.5	0.1	16.8
Croatia	*0.97*	*1.40*	0.1	3.4	20.0
Italy	*1.39*	*1.53*	1.8	1.6	4.8
Cyprus	*0.55*	*0.50*	5.0	*2.7*	*Target reached*
Latvia	*0.64*	*1.50*	2.1	0.6	53.2
Lithuania	*0.88*	*1.90*	2.3	1.4	47.2
Luxembourg	*1.21*	*2.30 - 2.60[4]*	-1.1	-1.1	42.2
Hungary	*1.53*	*1.80*	4.4	3.8	8.3
Malta	*0.55*	*2.00*	0.8	-1.2	90.6
Netherlands	*2.16*	*2.50*	0.5	2.0	7.5
Austria	*3.17*	*3.76*	2.9	1.9	8.8
Poland	*1.21*	*1.70*	3.6	6.7	18.4
Portugal	*1.35*	*2.70 - 3.30[5]*	2.2	-1.6	49.1
Romania	*0.51*	*2.00*	1.4	0.2	99.0
Slovenia	*1.95*	*3.00*	0.4	-3.0	24.0
Slovakia	*0.84*	*1.20*	1.5	4.0	19.7
Finland	*2.75*	*4.00*	-0.9	-3.7	20.7
Sweden	*3.31*	*4.00*	-0.6	0.5	9.9
EU	*2.19*	*3.00*	1.1	1.3	17.1

Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: rd_e_gerdtot and t2020_20)

Notes: [1]HR: 2002-2017; EL, LU, SE: 2003-2017; MT: 2004-2017. [2]CZ: A target (of 1.0%) is available only for the public sector. [3]IE: The national target of 2.5% of GNP has been estimated to equal 2.0% of GDP. [4]LU: A 2020 target of 2.45% was assumed. [5]PT: A 2020 target of 3.0% was assumed. [6]DK, EL, FR, IT, LU, HU, NL, PT, RO, SI, SE: Breaks in series occur between 2000 and 2018; 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. [7]DE: new 2025 target of 3.5%. CZ: new 2030 target of 3.0%. [8]Values in italics are estimated or provisional.

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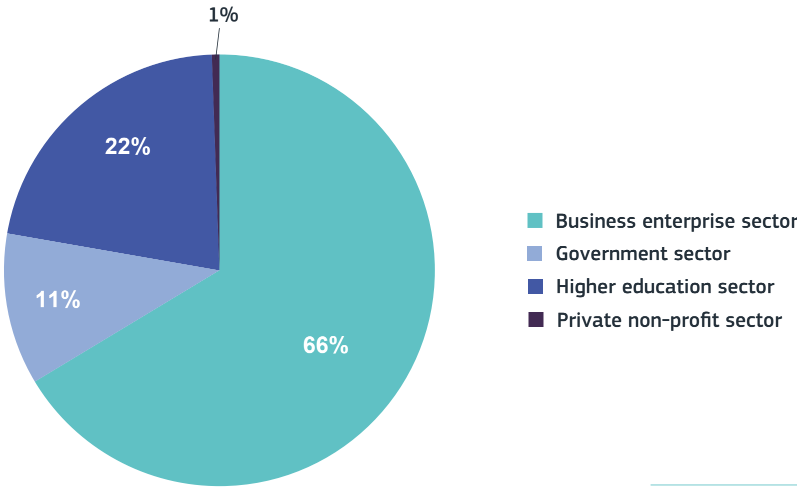
Public R&D expenditure accounts for one third of the total R&D performed in the EU, while the business enterprise sector continues to be the EU's strongest R&D performer, accounting for 66% of total R&D expenditure in 2018. Research, development and innovation are performed by four main institutional sectors: business enterprise, government, higher education and the private non-profit sector[8] (Eurostat, 2018). Figure 5.1-6 shows the shares of R&D expenditure in Europe, performed by these sectors in 2018. Public R&D expenditure is an aggregate of R&D expenditure performed by government and higher education sectors, while private R&D expenditure represents the sum of the business enterprise and private non-profit sector[9].

Figure 5.1-6 R&D expenditure by sectors of performance (%), EU, 2018



Source: Eurostat (online data code: rd_e_gerdtot)
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter51/figure-51-6.xlsx

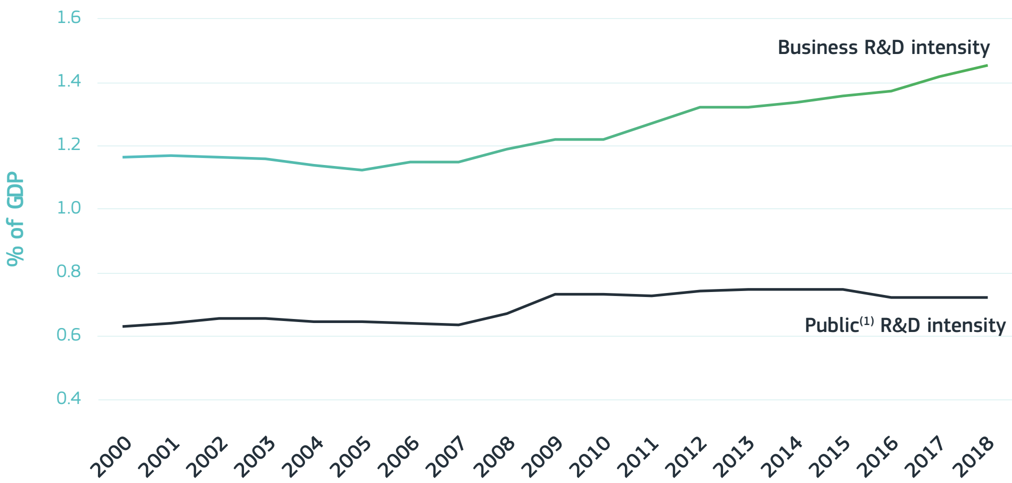
Over the last two decades, EU business R&D intensity has been steadily growing, while public R&D intensity has remained close to 0.7% of GDP (Figure 5.1-7). Despite this obvious progress, EU business R&D intensity is still significantly lower when compared to other main economies: China, United States, Japan and South Korea. On the other hand, among those four countries, only South Korea has a higher public R&D intensity than the EU.

Despite a fall of 4 percentage points from 2000 to 2017, the EU is maintaining its strong position in publicly performed R&D, accounting for slightly more than one fifth of the world's public R&D expenditure. China's increasingly strong presence in the R&D landscape is also evident in the public sector, as its share of world public R&D expenditure increased from 6% in 2000 to 19% in 2017. Over the same period, the United States' share declined, from 26% to 20% (Figure 5.1-8).

8 Expenditures by these four sectors are measured by BERD, GOVERD, HERD and PNPRD respectively.

9 In Europe, the private non-profit sector as an R&D performer is quite small (0.9% of GERD); consequently, when analysing private R&D expenditure, we usually only take business enterprise R&D expenditure into consideration.

Figure 5.1-7 Evolution of Business R&D and Public R&D as % of GDP in the EU, 2000-2018



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: rd_e_gerdtot)

Note: [1]Public equals to GOVERD plus HERD.

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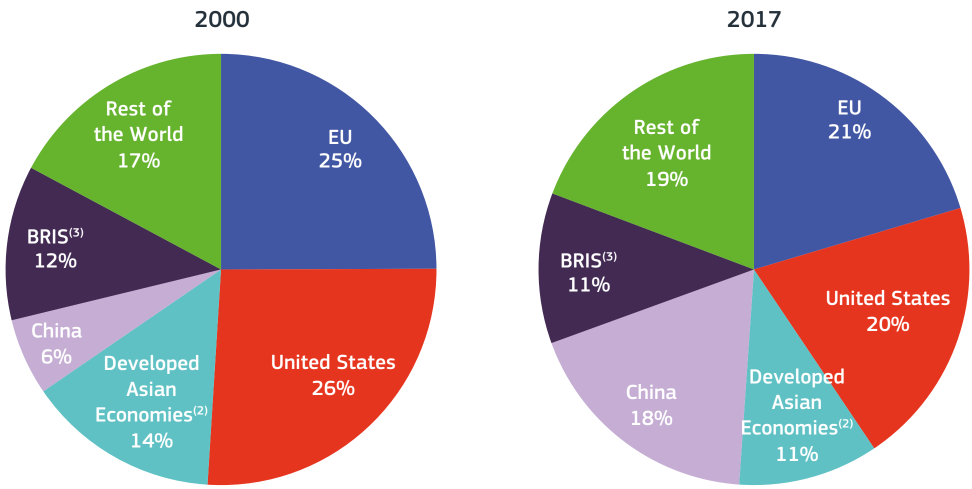
Figure 5.1-8 World public expenditure on R&D - % distribution[1], 2000 and 2017



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat, OECD, UNESCO

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

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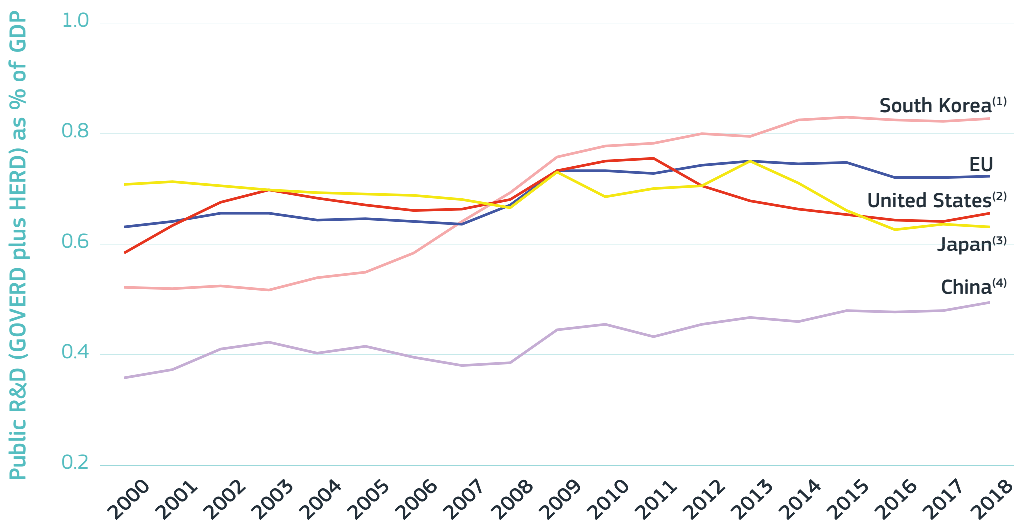
With a value of 0.72% of GDP in 2018, the EU has one of the highest public R&D intensities worldwide. Public R&D intensity is higher in the EU than in the United States, Japan and China. In 2018, the public R&D intensity in the US was 0.66%, in Japan 0.63% and China 0.49%. The only main economy with a higher public R&D intensity than the EU is South Korea with 0.83% of its GDP (Figure 5.1-9).

Figure 5.1-9 Evolution of public R&D intensity, 2000-2018



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: rd_e_gerdtot) and OECD (Research and Development Statistics)

Notes: (1)South Korea: There is a break in series between 2007 and the previous years. (2)United States: (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. (3)Japan: There is a break on series between 2008 and the previous years and between 2013 and the previous years. (4)China: There is a break in series between 2009 and the previous years.

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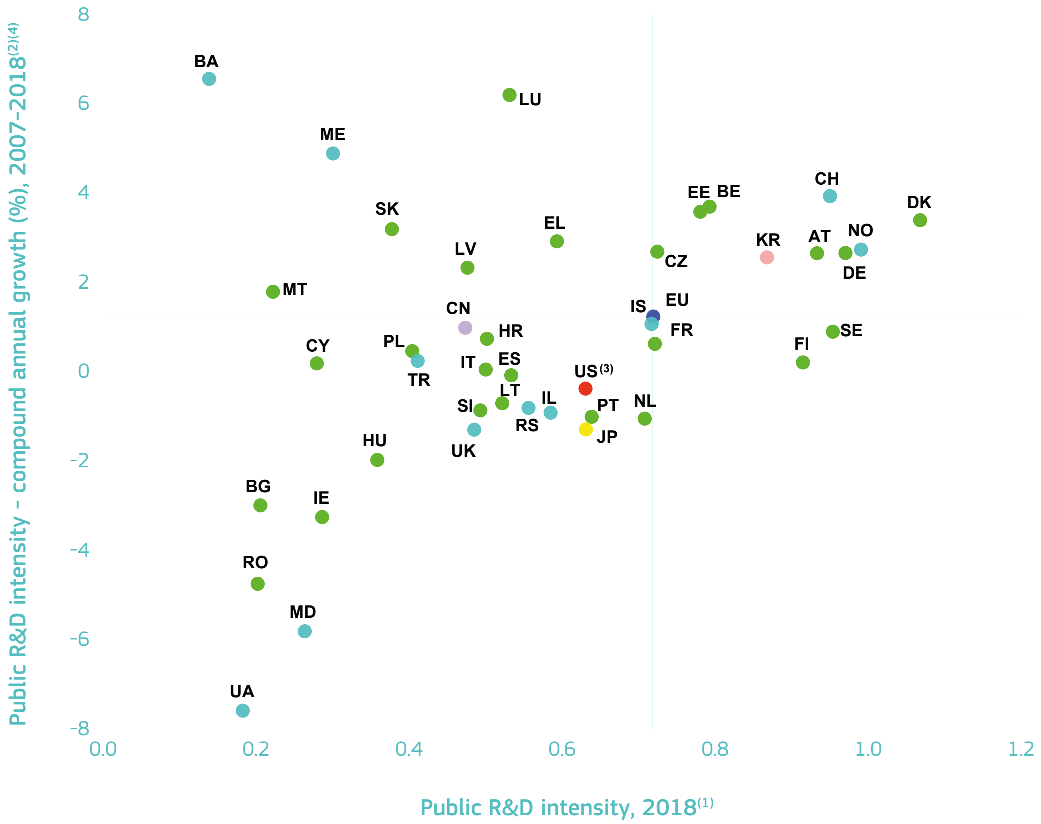
Trends in public R&D intensity are very diverse between Member States. Many Member States which already had a relatively strong public R&D system have kept increasing their investments, notably Denmark, Belgium, Germany and Austria (Figure 5.1-10). Estonia and Czechia boosted their public R&D intensities and are now above the EU average. Since 2007, Luxembourg, Slovakia, Greece, Latvia and Malta have also displayed strong growth rates in public R&D intensity, although they remained below the EU average in 2018. Some Member States which already had public R&D intensity well below the EU average, such as Bulgaria, Romania, Ireland and Hungary, have experienced budget cuts in their public R&D in recent years rather than building R&I capacities through more investments.

Focusing on business R&D, a strong business sector reflects the effectiveness of policies aimed at attracting and fostering business R&D investments and the development and growth of knowledge-intensive firms. Business R&D expenditure is determined to a large extent by a country's industrial structure and how its R&I systems function.

Figure 5.1-10 Public R&D intensity, 2018 and compound annual growth (%), 2007-2018



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat, OECD and UNESCO

Notes: (1)US, JP, CH, KR, CN, TR, IL: 2017; BA, MD, UA: 2016. (2)MD, UA: 2007-2016; CH, JP: 2008-2017; MK: 2015-2018; EL, PT: 2008-2018; RS: 2009-2018; ME: 2011-2018; BA: 2012-2016; (3)US: R&D expenditure does not include most or all capital expenditure. (4)JP, CN, BE, DE, FR, LU, NL, PT, RO, SI, IS, RS: Breaks in series occur between 2007 and 2018; 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.

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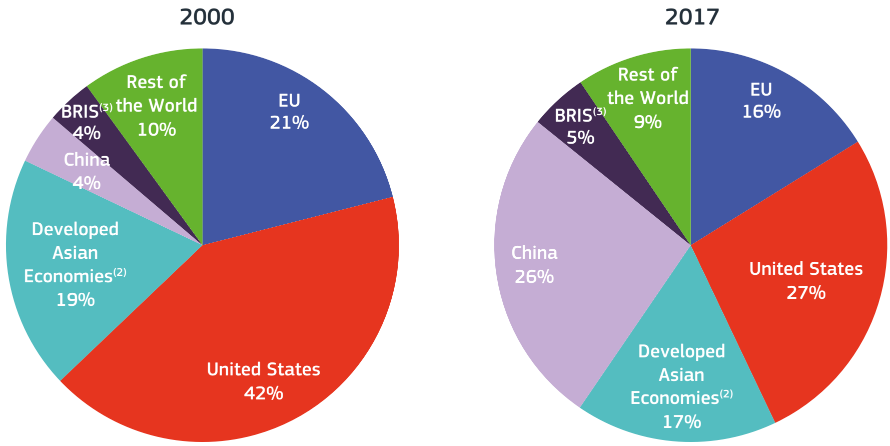
In the world's business R&D landscape, China now accounts for more than one quarter of global business R&D expenditure while the EU's share continues to decline. In 2000, together with the United States, the EU accounted for two thirds of global business R&D expenditure, while in 2017, their joint share was less than half. Since 2000, the EU's share of global business R&D expenditure has shrunk by 5 percentage points while, in parallel, the US share in world business R&D expenditure fell by a record 15 %. At the same time, China's stake rose from 4 % to 26 % (Figure 5.1-11).

Contrary to public R&D intensity, the EU's business R&D intensity is significantly lower compared to other main economies: China, United States, Japan and South Korea. China and South Korea have had continuous and very rapid growth in business R&D intensity since 2007, with annual increases of 4 % and 4.7 %, respectively. In 2018, business R&D intensity in South Korea was 3.64 %, in

Japan 2.59 %, in the United States 2.05 %, and in China 1.69 % (Figure 5.1-12).

Figure 5.1-11 World business enterprise expenditure on R&D – % distribution[1], 2000 and 2017



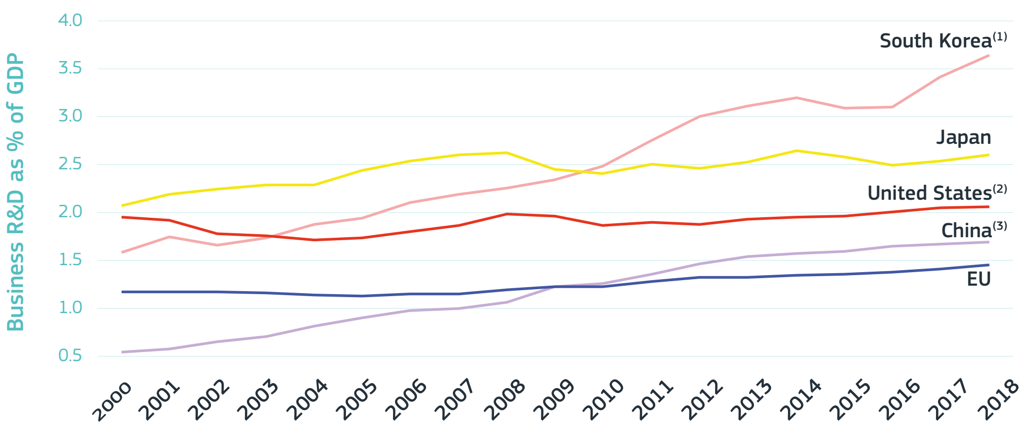
Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat, OECD and 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/2020/parti/chapter51/figure-51-11.xlsx

Figure 5.1-12 Evolution of business R&D intensity, 2000-2018



Science, research and innovation performance of the EU 2020

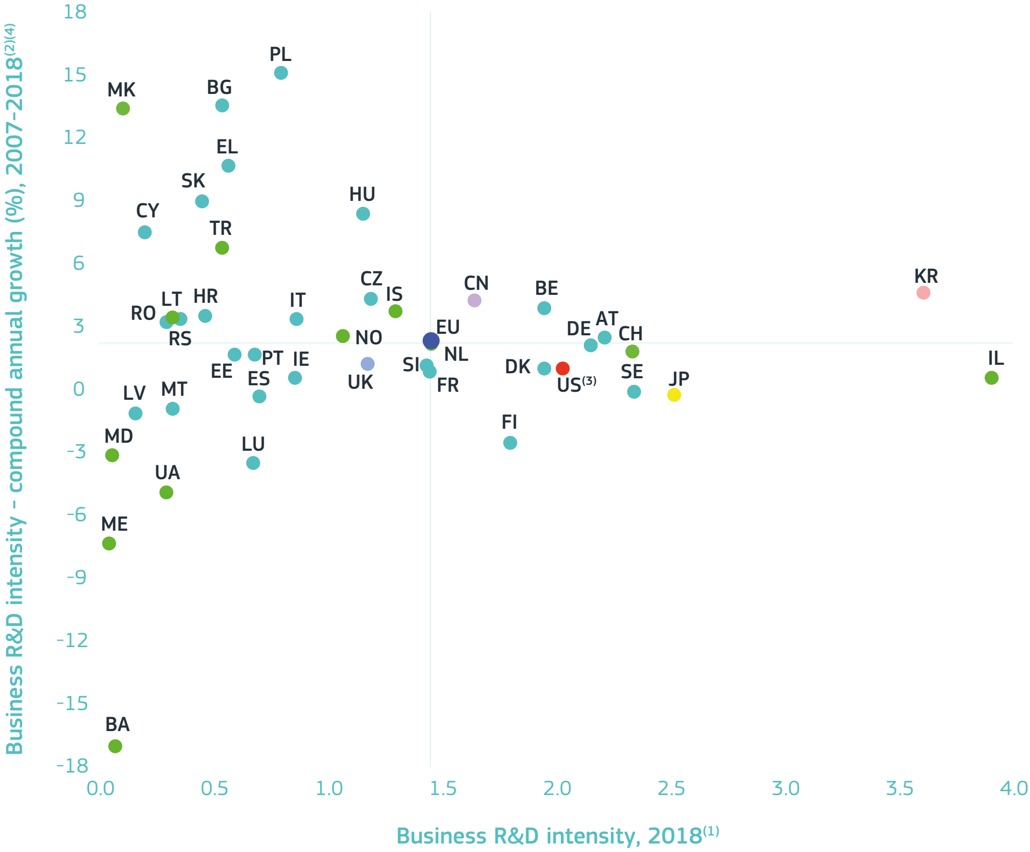
Source: Eurostat (online data code: rd_e_gerdtot), OECD (Research and Development Statistics)

Notes: [1]South Korea: There is a break in series between 2007 and the previous years. [2]United States: Business enterprise expenditure on R&D (BERD) does not include most or all capital expenditure. [3]China: There is a break in series between 2009 and the previous years.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter51/figure-51-12.xlsx

Only a few EU Member States with the best R&D systems (in particular, Austria, Germany, Denmark, Sweden and Belgium) resemble the private R&D intensity achievements of the main world economies, such as the United States, Japan, Switzerland and China (Figure 5.1-13). On the other hand, business R&D intensity increased most in Poland, Bulgaria, Greece and Slovakia between 2007 and 2018. However, their business R&D intensities remained below 1 % of the national GDP in 2018 and well below the EU average.

Figure 5.1-13 Business R&D intensity, 2018 and compound annual growth (%), 2007-2018



Science, research and innovation performance of the EU 2020

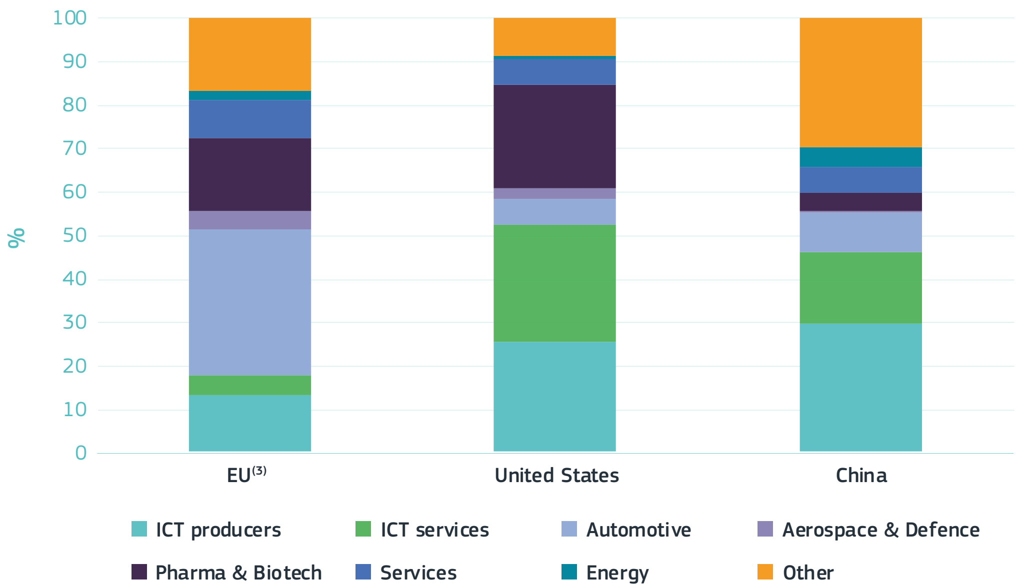
Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat, OECD and UNESCO

Notes: (1)US, JP, KR, CN, CH, TR, IL: 2017; BA, MD, UA: 2016. (2)MD, UA: 2007-2016; CH: 2008-2017; EL, ES, SI: 2008-2018; RS: 2009-2018; ME: 2011-2018; BA: 2012-2016; MK: 2015-2018. (3)US: R&D expenditure does not include most or all capital expenditure. (4)CN, IT, LU, NL, RO, SI, UK, IS, RS: Breaks in series occur between 2007 and 2018; when there is a break in series the growth calculation takes into account annual growth before the break in in series and annual growth after the break in series.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter51/figure-51-13.xlsx

To some extent, lower business R&D intensity in the EU compared to its main competitors can be explained by the sectoral composition of the economy. Less than 50% of the EU's industry[10] is in the high R&D-intensity sectors (e.g. ICT producers, ICT services, health industries) and around 40% in the medium-high R&D-intensity sectors (such as automobiles and other transport). Conversely, 80% of R&D investment by US companies, as well as over half of Chinese business R&D investment, is in the high R&D-intensity sectors (Figure 5.1-14).

Figure 5.1-14 Economic sectorial distribution[(1)(2)] of R&D spending by country/region, 2018



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on the 2019 EU Industrial R&D Investment Scoreboard

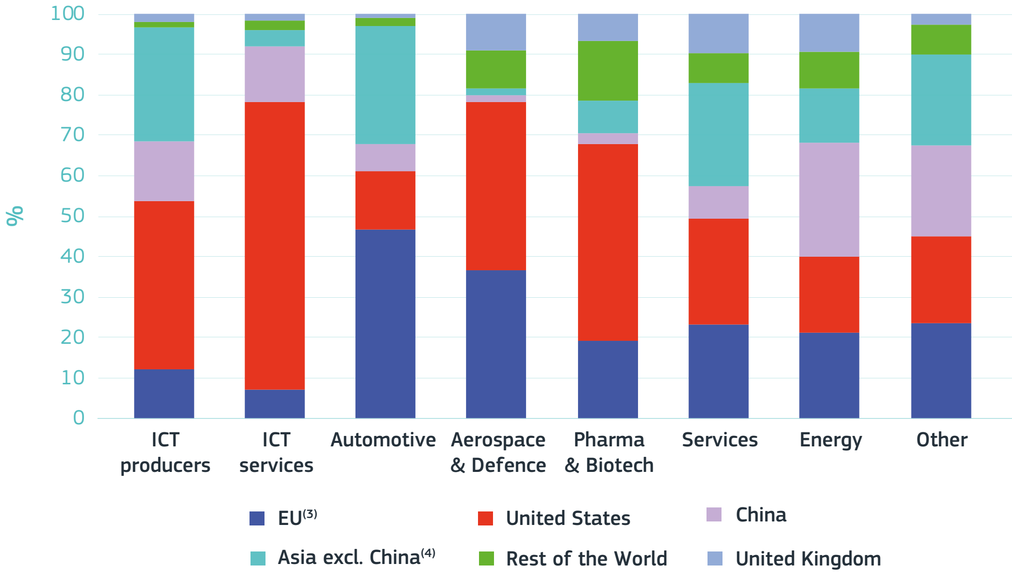
Notes: [(1)]R&D spending corresponding to the top global 2500 companies. [(2)]ICT producers: electronic and electrical equipment, technology hardware and equipment. ICT services: software and computer services. Automotive: automobiles and parts. Services: leisure goods, personal goods, banks, life insurance, non-life insurance, financial services, real estate investment and services, media, general retailers, food and drugs retailers, healthcare equipment and services, support services, travel and leisure. Energy: alternative energy, oil and gas producers, oil equipment, services and distribution, electricity. Other: chemicals, general industrials, industrial engineering, household goods and home construction, construction and materials, industrial transportation, mining, industrial metals and mining, food producers, tobacco, forestry and paper, beverages, fixed line telecommunications, gas, water and multi utilities, mobile telecommunications. [(3)]EU corresponds to the EU Member States shown in the dataset.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter51/figure-51-14.xlsx

10 Based on the 2019 EU Industrial R&D Investment Scoreboard (Hernández et al., 2019) which covers more than 90% of business spending on R&D (BERD) worldwide.

In terms of global positioning, the EU largely dominates R&D investments in the automotive sector and shows strong performance in aerospace and defence and in industrial engineering. US companies account for 71 % of the global R&D share of ICT services, 41 % in ICT producers and 48 % in pharmaceuticals and biotechnology – all three are high R&D-intensity sectors. While EU sectors with the largest global weight are automobiles (47 %) and aerospace and defence (37 %), China leads in terms of R&D investments in energy with 28 % of global R&D (Figure 5.1-15).

Figure 5.1-15 Geographical distribution of R&D[(1)] spending by economic sector[(2)], 2018



Science, research and innovation performance of the EU 2020

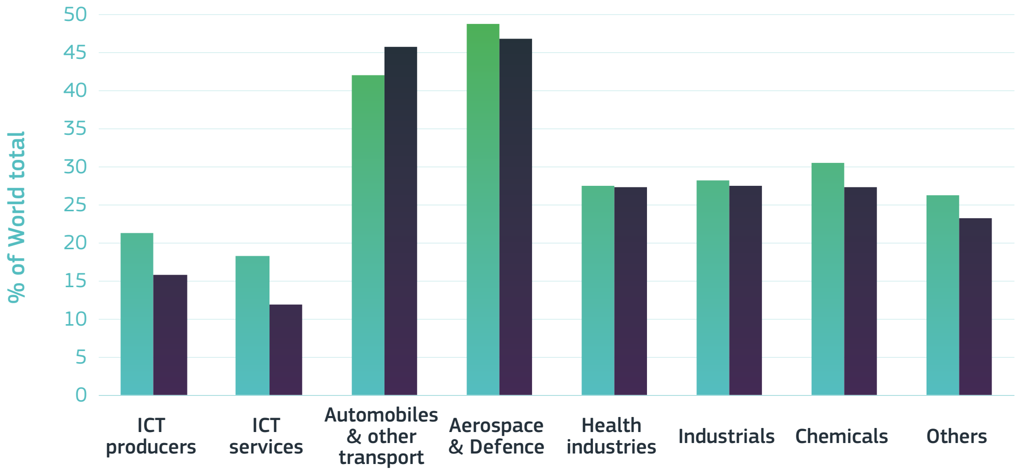
Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on the 2019 EU Industrial R&D Investment Scoreboard and EIB Investment report 2019-2020

Notes: [(1)]R&D spending corresponding to the top global 2 500 companies. [(2)]ICT producers: electronic and electrical equipment, technology hardware and equipment. ICT services: software and computer services. Automotive: automobiles and parts. Services: leisure goods, personal goods, banks, life insurance, non-life insurance, financial services, real estate investment and services, media, general retailers, food and drugs retailers, healthcare equipment and services, support services, travel and leisure. Energy: alternative energy, oil and gas producers, oil equipment, services and distribution, electricity. Other: chemicals, general industrials, industrial engineering, household goods and home construction, construction and materials, industrial transportation, mining, industrial metals and mining, food producers, tobacco, forestry and paper, beverages, fixed line telecommunications, gas, water and multi utilities, mobile telecommunications. [(3)]EU corresponds to the EU Member States shown in the dataset. [(4)]Asia excl. China includes Japan, South Korea, Singapore, Twain and Malasya.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter51/figure-51-15.xlsx

According to the latest EU R&D Industrial Scoreboard, **EU companies have reinforced their R&D specialisation in automobiles over the last decade**. On the other hand, they have reduced their global R&D share in ICT industries, aerospace and defence and chemicals (Figure 5.1-16). The decline in EU companies' share of global R&D in ICT sectors is taking place in a context where an important sector shift towards these industries has occurred worldwide. Between 2009 and 2018, the share of the global R&D investment in ICT services increased from 10.7% to 15%, and to a lesser extent in ICT producers, from 22.9% to 23.6%. Hence, this shift has not been driven by EU companies but rather by US and Chinese companies.

Figure 5.1-16 **Global R&D share of EU28 companies by economic sectors, 2009 and 2018**



Science, research and innovation performance of the EU 2020

Source: European Commission, Joint Research Centre and DG Research and Innovation, The 2019 EU Industrial R&D Investment Scoreboard

Note: Shares computed for 386 EU28 and 1 264 non EU28 companies for witch R&D, Net Sales and Operating profits data are available for the all period 2009-2018.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter51/figure-51-16.xlsx

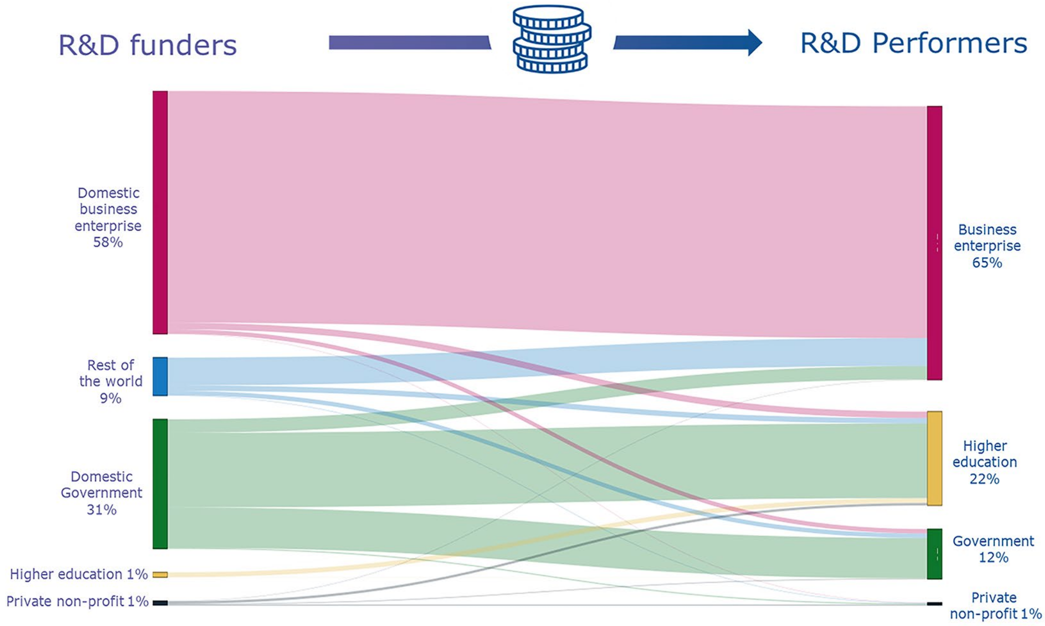
2 EU lags behind its main competitors in business R&D funding

There are five main sources of R&D funding: business enterprise, domestic government, higher education, the private non-profit sector, and the rest of the world. Figure 5.1-17 shows the shares of R&D funding in the EU and where those investments were performed in 2018. Altogether, the public sector finances slightly more than one third of R&D expenditure in the EU and the private sector slightly less than two thirds.

When assessing total public R&D support in Europe, besides domestic government investments, government support to business R&D through tax incentives[11] and funding from the EU budget should also be included. In many Member States, a substantial part of government support to business R&D is now made indirectly through R&D tax incentives. On the other hand, for most Member States, the main source of financing from the rest of the

11 Government-financed R&D includes only direct funding of R&D through grants, loans and procurements that governments give to private firms. Indirect government funding through R&D tax incentives is not recorded in government-financed R&D.

Figure 5.1-17 R&D funding in the EU



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: rd_e_gerdfund)

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter51/figure-51-17.xlsx

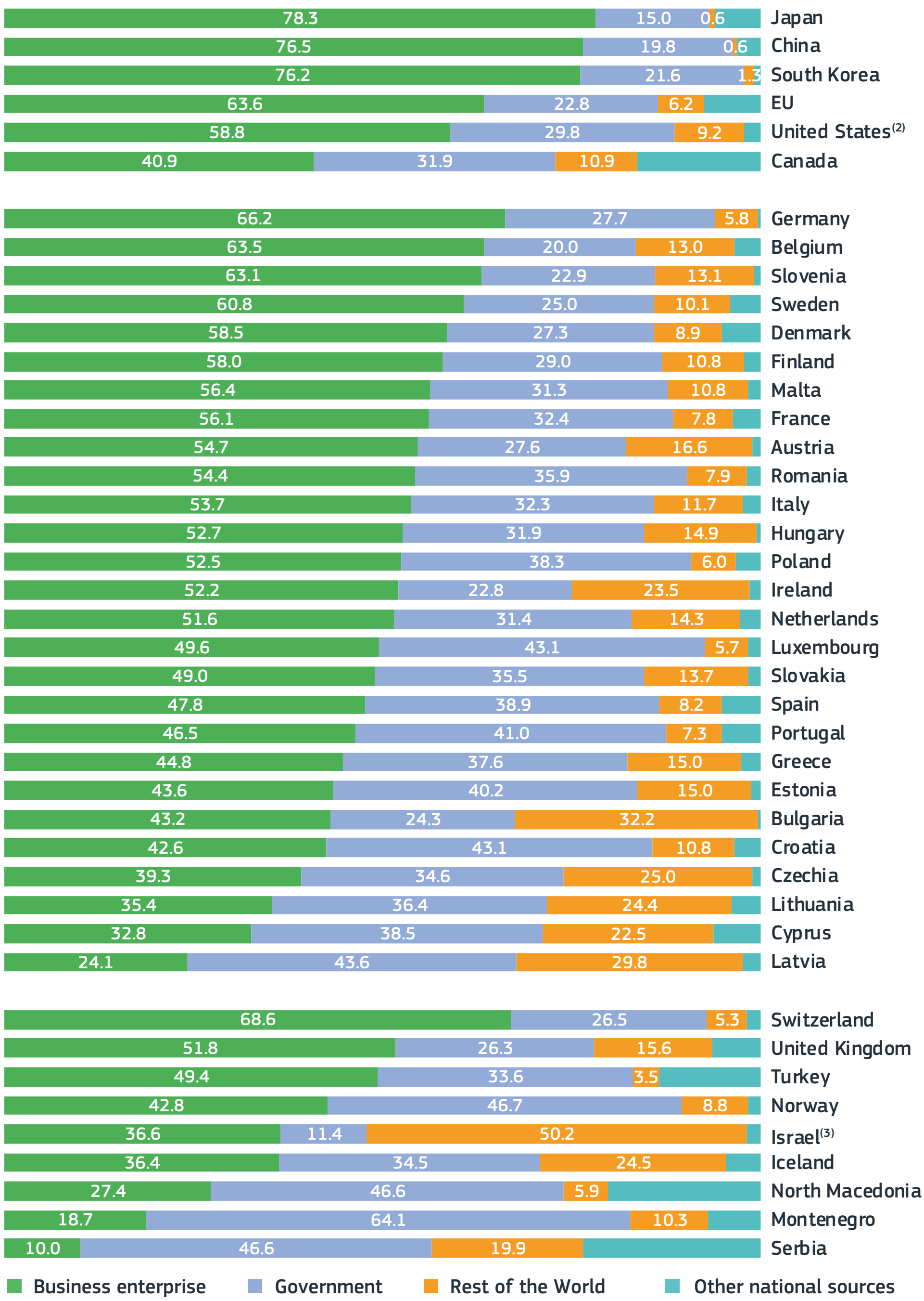
world is the European Commission, through its Horizon 2020 programme and the European Structural and Investment Funds.

The public sector is a main source of funding in less-research-intensive countries, where conditions for business R&D investment are still insufficiently attractive. Conversely, in the most-research-intensive countries, the business sector is the predominant source of funds. Businesses will invest where public policies are best, and where there are sufficient human resources and good research capacities. Hence, how much the private sector invests in a particular country relies largely on the return it can expect and therefore to the framework conditions in place.

Figure 5.1-18 shows the sources of R&D funding broken down into business enterprise, domestic government, rest of the world, and other national sources, while Figure 5.1-19 presents the European Commission's share of R&D funding from the rest of the world. Adding up investments from domestic governments and the EC, we find exceptionally high shares of publicly funded R&D in Latvia, Cyprus and Lithuania. The public sector is also the predominant investor in Greece, Luxembourg, Romania, Portugal, Slovakia and Spain.

In the most-research-intensive Member States (Germany, Sweden, Belgium, Denmark, Finland and Slovenia), the business sector is the predominant source of funds. In those countries, the R&I funding from the business sector is comparable to that in the United States (62 %), although significantly lower than in South Korea, China and Japan, where businesses finance more than 75 % of R&D.

Figure 5.1-18 Gross domestic expenditure on R&D (GERD) financed by sector (%), 2017[1]



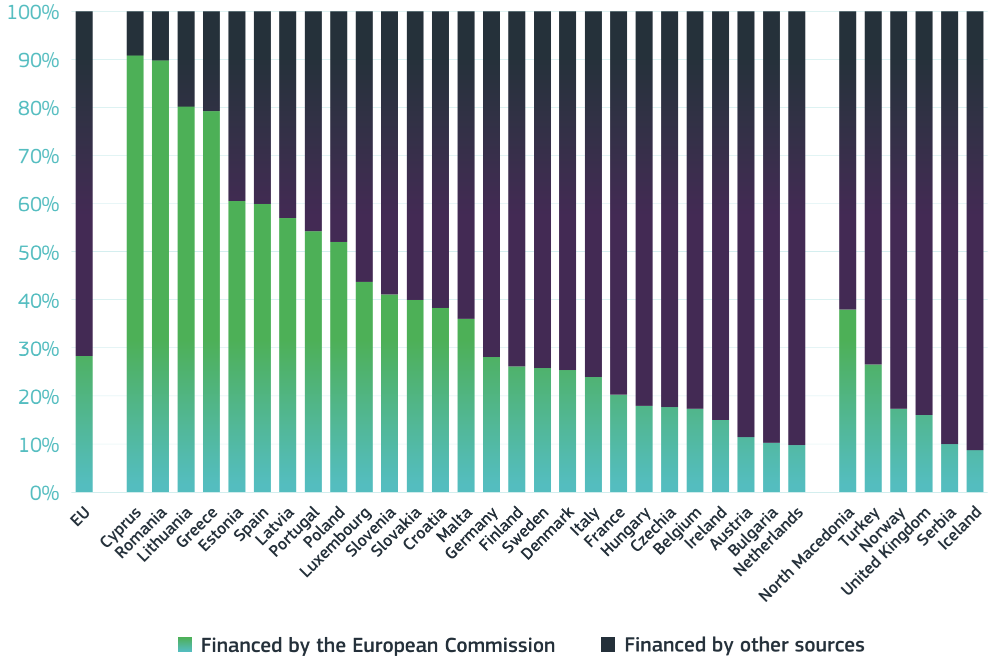
Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: rd_e_gerdfund) and OECD

Notes: [1]UK, IL : 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/2020/parti/chapter51/figure-51-18.xlsx

Figure 5.1-19 R&D expenditure financed by the Rest of the World, 2017(1)



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: rd_e_gerdfund)

Note: (1)TR: 2015; UK: 2016.

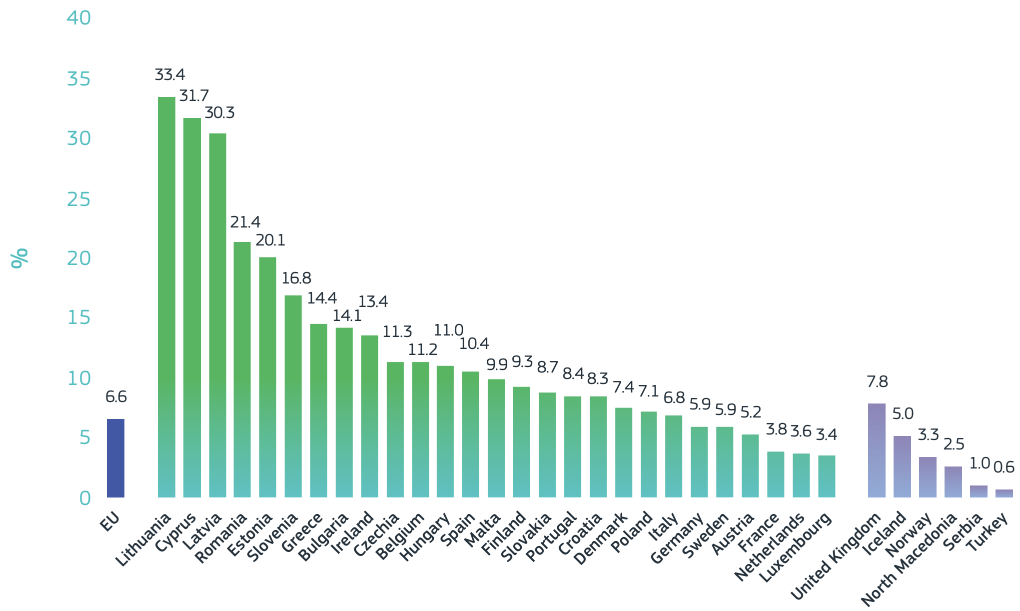
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter51/figure-51-19.xlsx

The European Commission's R&I funding programmes are now responsible for 6.6% of public funding for R&I in Europe and a significantly higher percentage when looking only at competitive funding. Budgets have increased massively over the last programming periods. The budget of almost EUR 100 billion proposed for the next Framework Programme, Horizon Europe, also represents a very strong increase compared to the current programme. Together with the European Structural and Investment Funds, the EC is an important source of R&I funding in many Member States (Figure 5.1-20).

Member States are slowly steering their national budget allocations for R&D towards societal and environmental challenges. Figure 5.1-21 shows an increase in energy-related government budget allocations for R&D (GBARD)[12] at the European level. Growth in the budget allocation for total civil, health and environmental-related R&D is more modest. In contrast, the R&D budget for defence has decreased significantly in recent years.

12 As GBARD measures only direct budget provisions, it does not account for the R&D performed.

Figure 5.1-20 R&D expenditure financed by the European Commission as % of total R&D expenditure financed by the public sector, 2017[(1)]



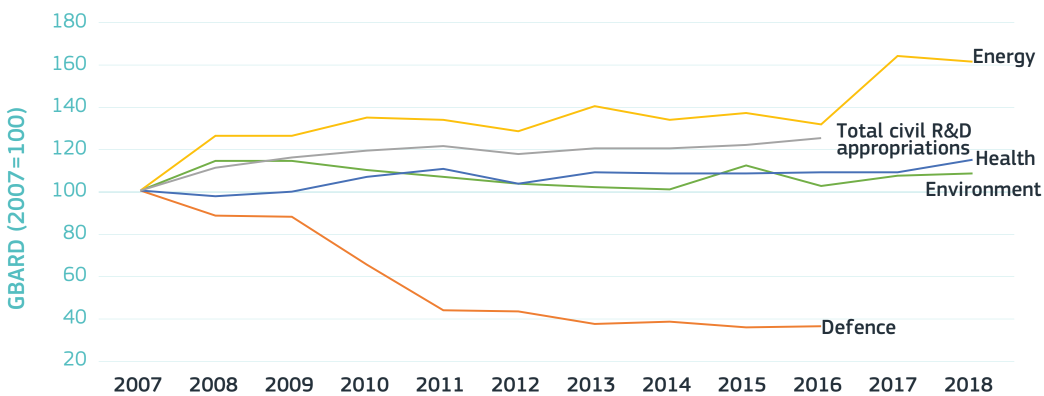
Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: rd_e_gerdfund)

Note: [(1)]TR: 2015; UK: 2016.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter51/figure-51-20.xlsx

Figure 5.1-21 Evolution of government budget allocations to R&D in the EU, 2007-2018



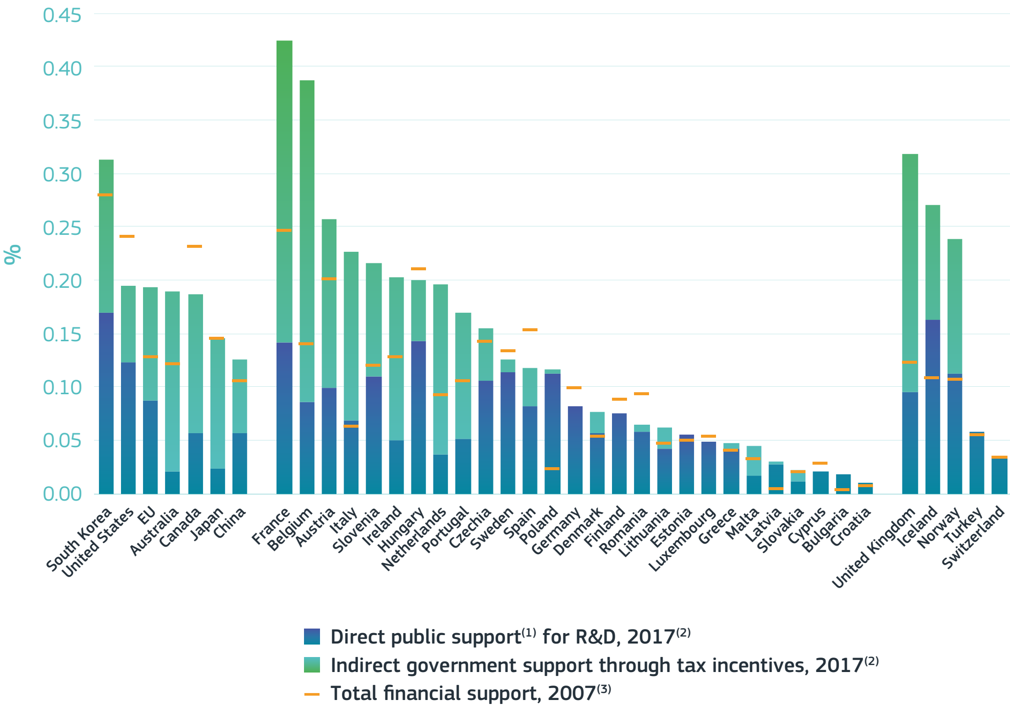
Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: gba_nabsfin07)

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter51/figure-51-21.xlsx

Business R&D intensity is significantly lower when compared to other main economies: China, United States, Japan and South Korea. **One important driver of business R&D expenditure is the expected return on investment. To improve the expected return, apart from direct support, governments are increasingly using R&D tax incentives**. Total public support for business R&D, comprising direct funding (e.g. grants, loans, procurement) and indirect support (R&D tax incentives[13]) increased substantially in the EU, from 0.13 % of GDP in 2007 to 0.2 % of GDP in 2017. Figure 5.1-22 shows that the level of public support for business R&D grew in most Member States between 2007 and 2017, particularly through the greater use of R&D tax incentives. Particularly strong increases in total public support for business R&D are evident in Belgium, Italy, France, the Netherlands, Slovenia, Poland, Latvia and Bulgaria.

Figure 5.1-22 Public support for business R&D as % of GDP, 2007 and 2017



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: rd_e_gerdfund) and OECD (R&D tax expenditure and direct government funding of BERD)

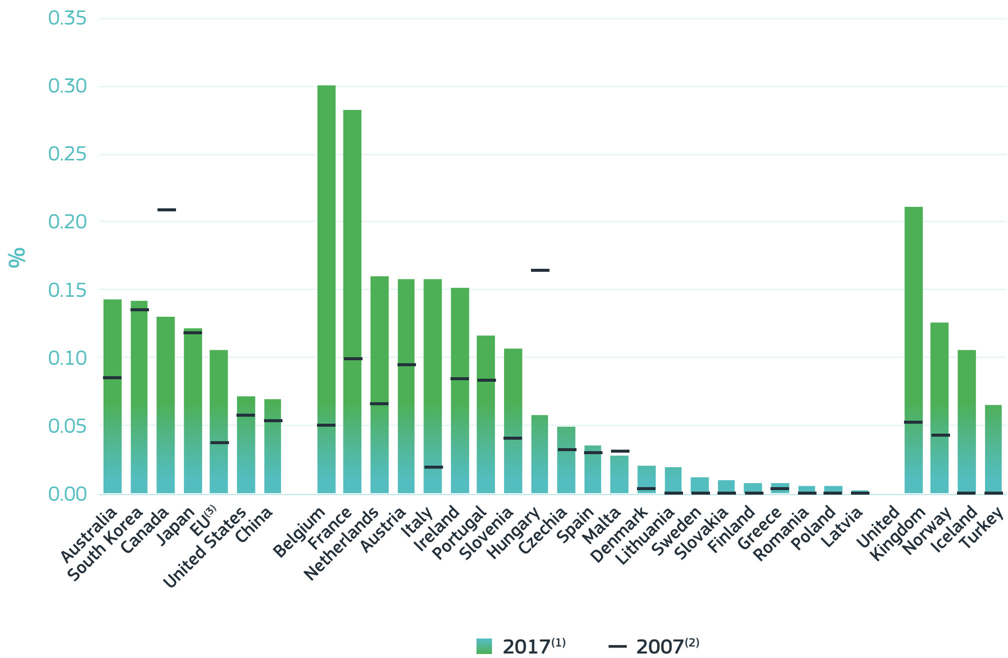
Notes: (1)Estimated direct public support for business R&D includes direct government funding, funding by higher education and public sector funding from abroad. (2)US: 2014 for tax incentives only; AU: 2015; FR: 2016 for tax incentives only; RO, UK: 2016; EL: 2015. (3)CH, TR: 2008; CN, MT: 2009; DE, EL: 2011. (4)The following countries have no tax incenitves for R&D: BG, DE, EE, HR, CY, LU, CH. (5)Elements of estimation were involved in the compilation of the data.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter51/figure-51-22.xlsx

13 Following the Frascati manual (OECD, 2015), we only focus on expenditure based tax relief, such as: R&D tax credits, R&D allowances, reduction in R&D workers' salary taxes and social security and accelerated depreciation of R&D capital.

In 2017, tax incentives for R&D in the EU accounted for 55 % of all public support for business R&D. The level of the forgone tax revenues in EU almost tripled since 2007, from 0.04 % of GDP in 2007 to 0.11 % in 2017 (Figure 5.1-23). In comparison to the EU, the use of tax incentives is traditionally high and rather stable in South Korea and Japan. China has slightly increased indirect support to business R&D but it is still below the EU level. In the EU, the number of countries offering R&D tax relief increased from 12 in 2000 to 21 in 2018 (Appelt et al., 2019). Trends in forgone tax revenues are very diverse among the Member States. There is an exceptionally high share of tax incentives in total public support for business R&D in the Netherlands, Belgium, Ireland and Italy.

Figure 5.1-23 Tax incentives for R&D as % of GDP, 2007 and 2017



Science, research and innovation performance of the EU 2020

Source: OECD (R&D tax expenditure and direct government funding of BERD)

Notes: (1)US: 2014; FI: 2014; EL, FR: 2016. (2)CN: 2009; EL: 2011. (3)EU was estimated by DG Research and Innovation. (4)BG, DE, EE, HR, CY, LU, CH have no tax incentives for R&D.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter51/figure-51-23.xlsx

Given that coordinated transformation needs coordinated and strategic investment, the question arises as to whether the above-mentioned increased use of R&D tax incentives among the Member States provides the right tools to achieve this goal. Direct measures, such as grants and loans, are effective in provoking certain desired R&D outcomes (Appelt et al., 2019; Ognyanova, 2017) such as innovation that supports a sustainable transition. The downside, however, is the higher administrative burden put on companies. Some countries are considering the possibility to use tax incentives to incentivise private actors' behaviour towards SDGs. This is the case for instance in Belgium[14], where a tax credit granted for environmentally friendly R&D investments was introduced. However, more generally speaking, the tax incentives regime – exactly because of its lack of directionality – may make it difficult for governments to have enough impact on steering private investment towards sustainability and systemic change[15]. Therefore, in order to establish consistency among national reforms and EU policies, a discussion is needed on the best policy mix to provide public support to business R&D expenditure.

Because of the scope, scale and urgency of the societal challenges facing Europe, policy is required to pay more attention not just to the rate (quantity and quality) of R&I investments but also to the overall direction of such investments. This can support the coordinated transformation of a broad range of interconnected systems that are crucial to our economy and society. Systems such as energy, agro-food, health, mobility, production and consumption all include a number of actors that must act together.

14 https://www.oecd.org/sti/rd-tax-stats-belgium.pdf

15 Moreover, while its effect of increasing R&D efforts is undeniable, recent analysis of existing evidence on the impact of tax incentives points to its limited impact on innovation (Mitchell et al. 2020).

3. Conclusions

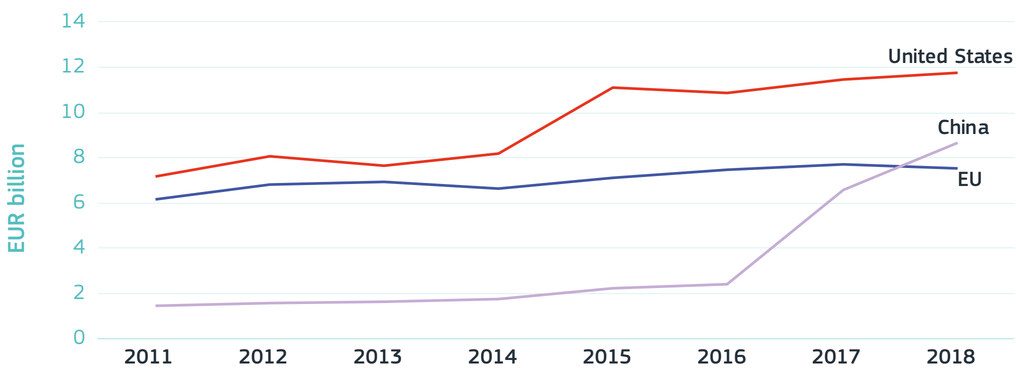
With just over 2% of its GDP in R&D, the EU is still a long way from its 3% target. It is underinvesting in R&D compared to its main competitors, especially in terms of private investments, while Asian countries, in particular China and South Korea, are investing at a rate that is eclipsing both the EU and the United States. If this continues, Europe risks being outpaced irreversibly.

The Commission is committed to focusing R&I investments on delivering the 'European Green Deal', its new strategy for growth (European Commission, 2019). R&I are called upon to play a strong role to support this initiative. Given the size of the challenge and its costly nature, with EUR 1 trillion mobilised for the Green Deal over the next decade, this demands investing record amounts in R&D if Europe is to become the world's first climate-neutral continent and can achieve the Sustainable Development Goals.

For R&I to deliver on Europe's ambitions, including becoming the world's first climate-neutral continent, R&I must also be given a clear sense of directionality[16]. Public investments in R&D can play an essential role in this. Bloomberg data show that, while the United States leads in climate-related R&D spending, China has recently quadrupled its spending, slightly overtaking the EU (Figure 5.1-24). Member States should reinforce their performance in climate-related R&D in order to boost their competitiveness in the novel technologies which are required for transition.

One of the main public investment instruments in Europe is the EU's R&I Framework Programme. The next one, Horizon Europe, will cover 2021-2027 and will continue to create new knowledge and solutions to attain the SDGs. It will provide even greater directionality through its mission-oriented approach (on, for example, climate change, healthy oceans, climate-neutral and smart cities, and soil health and food) and European partnerships. In addition, it has set a 35% spending target for the climate.

Figure 5.1-24 Investment in climate-related R&D, 2011-2018



Source: European Investment Bank based on data from Bloomberg New Energy Finance (BNEF)
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter51/figure-51-24.xlsx

16 In the same vein, the 2018 update of the Bioeconomy Strategy aims to accelerate the deployment of a sustainable European bioeconomy in order to maximise its contribution towards the 2030 Agenda and its SDGs, as well as the Paris Agreement (see European Commission, 2018).

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CHAPTER 5.2

INVESTMENT IN EDUCATION, HUMAN CAPITAL AND SKILLS

KEY FIGURES

1/11
ratio of tertiary students in Europe and the world

1 %
of spending on education in the EU is at the European level

7 %
of Europeans used the internet for doing an online course

8 out of 10
firms consider lack of staff with the right skills a barrier to their investment activities

174
robots per 10 000 workers in European manufacturing

What can we learn?

- Europe's **education and training investment** priorities are centred on formal education, while **demographic change** will influence all stages of education. With education and training systems broadening its focus primarily from the first-life decades to the needs of 30 and 70-years old learners, we could put each individual talent to use.

- The **digital skills gap** is particularly visible as **the number of ICT graduates in Europe is not keeping pace** with the continuously increasing demand on the market.

- **EU** countries continue to increase the number of researchers, as do their global competitors. **China is now reaching the EU level** in its total number of researchers.

- Although many European countries have increased their shares **of researchers in the total workforce, the EU lags behind the United States, Japan and South Korea in particular**.

- Although females represent roughly half of EU graduates at the doctoral level, **women represent only about a third of all EU researchers and only one fifth of researchers in the business sector**.

What does it mean for policy?

- EU policies need to develop a stronger sectoral cooperation on skills to adapt skills development in line with emerging technological needs.

- The EU needs to attract talents to research and sustain its excellence in research as **international competitors (in particular China)** are expanding their pools of talents.

- **Gender equality and gender 'main-streaming'** (integration of a gender perspective in the preparation and evaluation of policies) in research and promotion of these policies in R&I, should be maintained and, where possible, reinforced in order to make further progress. Further efforts are needed to increase shares of female graduates across STEM (science, technology, engineering and mathematics) fields.

1. Acquisition of skills relevant to future labour markets

The growing knowledge orientation of the economy and society, together with changes in the labour market and 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 a growing demand for skilled labour, including researchers, whilst at the same time, labour related to routine activities appears to be increasingly automated.

An additional challenge comes from ongoing demographic developments, such as the declining number of young people entering the labour market expected in many Member States in the coming years, while the baby boomer generation is set to retire within the next decade. The EU's working age population (15-64) peaked in 2009 at 336 million but has shrunk by 5 million since then. The shrinking labour force trend has been predominantly visible in southern, central and eastern European (CESEE) countries. At the same time, life expectancy continues to rise by about 2 years per decade: the population of 65 years and older in the EU is growing annually by about 2 million, rising from 90 million in 2012 to 101 million in 2018. Consequently, the old-age dependency ratio is growing, directly affecting employment in the healthcare sector and indirectly (longer working life) impacting the labour market.

Other factors are migration and developments outside Europe. While the EU's natural population change in 2017 (births minus deaths) was negative, at -0.3 million, this was more than compensated for by a net migration to the EU of 0.9 million. The demographic shift towards lower shares of young people and larger shares of elderly people is posing important challenges for Europe. Given a global massification in tertiary education, a more favourable demography outside Europe and strong investment in excellence in other world regions such as China and the United States, the EU is facing growing challenges in competitiveness. Any gaps in terms of the quality and quantity of Europe's human capital 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.

Strong growth in employment with high levels of qualification and an increase in low qualifications is expected within the coming decade while, at the same time, the number of jobs at medium levels is likely to shrink. According to the 2018 Cedefop skills forecast (Figure 5.2-1), the labour force (15-64+) will stagnate between 2021 and 2030. At the same time, total EU employment is projected to grow at a rate of 0.4 % per year. However, trends will differ significantly across the Member States, with employment – mainly for demographic reasons – shrinking annually during that period in Lithuania (-0.4 %), Latvia (-0.2 %) and Estonia (-0.2 %). Germany, the EU's largest Member State, will face a decline of 0.2 % per year. The majority of Member States will generate positive employment figures with Ireland and Cyprus (1.4 %), Luxembourg (0.9 %) and Spain (0.8 %) expected to show the highest growth rate.

The European employment outlook follows the job polarisation trend with a strong increase in highly qualified occupations (0.9 % annually within the EU) followed by rises in low qualification levels (0.4 %). It has been forecast that jobs revolving around medium-qualification levels will witness a decline in employment of 0.2 %[1,2].

In the EU, employment growth plus the need to replace people leaving workplaces (retirement, migration and other reasons) will lead to over 100 million job opportunities over the next decade, over 45 million of which will require high qualifications. The highest absolute number of job openings will be in Germany (17.6 million), France (12.4 million) and Italy (11.5 million). The trends shown may contribute to sustaining the gap in unemployment rates between different qualification levels. In 2017, according to Eurostat data, while the EU's overall unemployment rate stood at 7.6 %, it was nearly twice as high for those with low-qualification levels (lower secondary education or less), reaching 14.7 %, while highly skilled people (with at least tertiary education) in the EU reported an unemployment rate of only 4.5 %.

The employment of researchers and engineers will see strong growth, followed by ICT professionals. The forecast growth of both science and engineering as well as ICT professionals is expected to outpace the overall growth rate (Figure 5.2-1). These two groups are also the occupations most demanded by the current labour market with a share of 14 % among the majority of EU Member States[3]. Science and engineering professionals together with technicians, which a somewhat broader term referring to employment in the sector, shows a 12 % share of vacancies across the EU (Figure 5.2-2)[4].

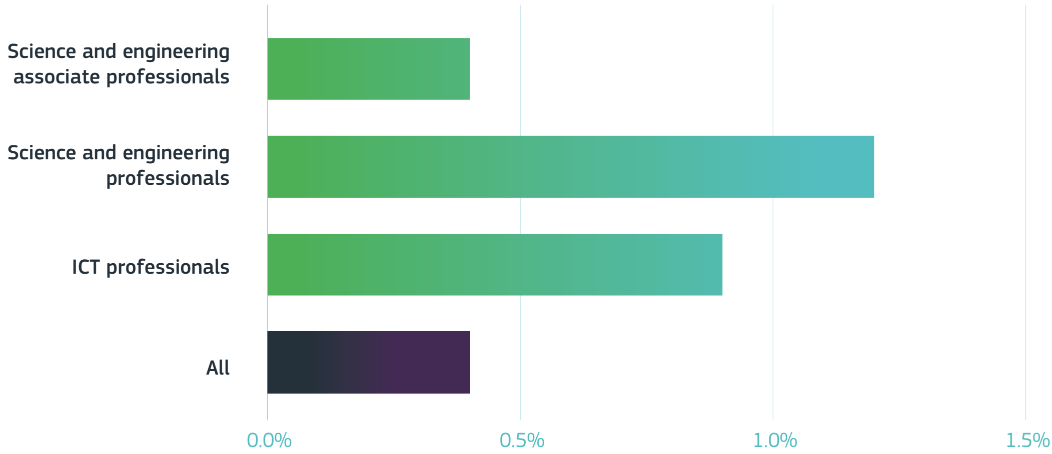
1 Jobs classified under the ISCO-88 major groups, based on Cedefop Skills Forecast 2021-2030, EU28, annual percentage rate.

2 According to Cedefop, medium-skill occupations are projected to see slow growth or even a decline in the number of jobs as automation and offshoring take their toll. But new workers will still be needed in these occupations to replace those who leave or retire.

3 Cedefop project Skills-OVATE gathers data for online vacancies in Europe. It navigates through data for 18 countries: Austria, Belgium, Czechia, Denmark, Germany, Hungary, Spain, Finland, France, Italy, Ireland, Luxembourg, the Netherlands, Poland, Portugal, Sweden, Slovakia and the United Kingdom. Data were gathered between 1 July 2018 and 31 March 2019.

4 The share includes 2-digit ISCO categories research & engineers professionals and technicians.

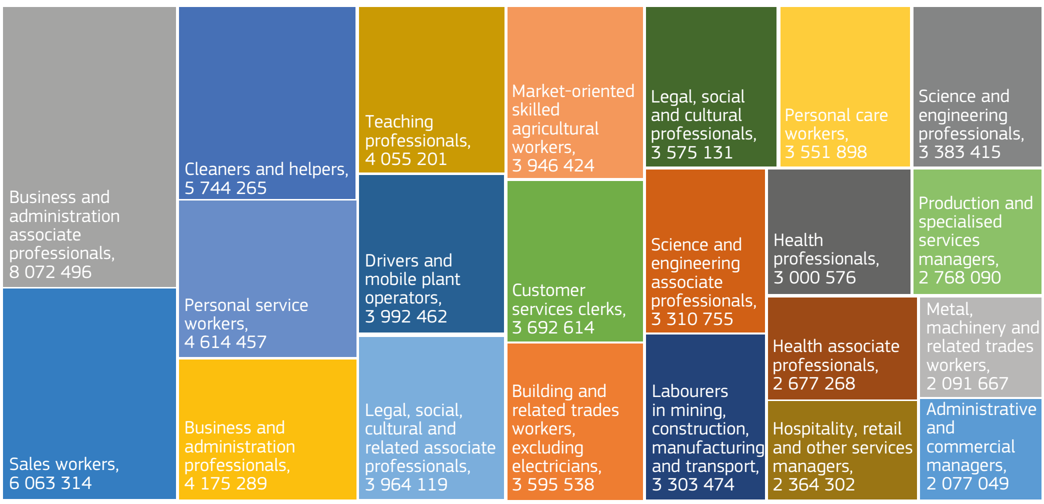
Figure 5.2-1 Employment change for selected qualifications (%), 2021 - 2030



Science, research and innovation performance of the EU 2020

Source: Cedefop Skills - Forecast
Note: Skills forecast accounting for economic developments until May 2017.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-1.xlsx

Figure 5.2-2 Top job openings by occupations group, EU28 2021-2030



Science, research and innovation performance of the EU 2020

Source: Cedefop Skills - Forecast
Notes: Skills forecast accounting for economic developments until May 2017.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-2.xlsx

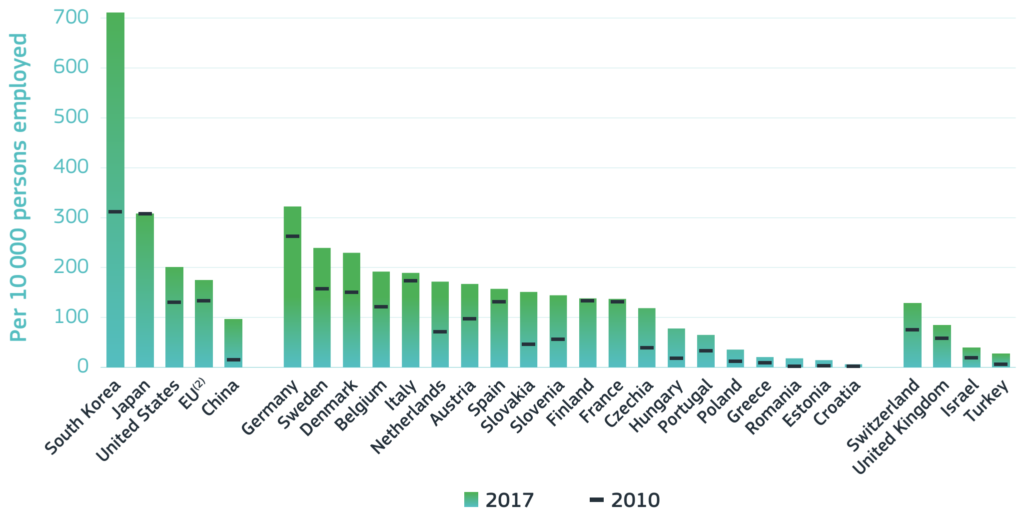
The manufacturing sector is characterised by a growing use of industrial robots. European countries with a large car industry tend to have high numbers of industrial robots per person employed. The ongoing debate on the impact of technical progress on employment concentrates on the levels of robots in the manufacturing sector, which supposedly is affected more by automation and rationalisation than the service sector. Yet it remains to be seen whether the effect of robots on employment in manufacturing will be disruptive (Klenert et. al, 2020). The replacement of workers by machines is ongoing with even more complex manual tasks being increasingly taken over by robots now. However, it is not only routine manual tasks that are being replaced. Future advances in artificial intelligence could have repercussions in the service sector, where jobs are not facilitating worker autonomy but are demanding a higher degree of planning, teamwork and customer-service skills (Pouliakas, 2019).

Currently, over 0.3 million industrial robots (of a worldwide stock of 2.1 million) are deployed in EU Member States, a number which is increasing by about 40 000 per year. The degree of robotisation varies significantly across Member States – for example, Germany's automotive industry is about twice as robot intensive as that in Czechia and Portugal[5]. Germany also has the highest number of industrial robots per 10 000 people employed in the manufacturing industry, followed by Sweden and Denmark. The EU has a similar density as the United States, but lags behind Japan and South Korea (Figure 5.2-3). Although China is catching up quickly, it still has a much lower density than the EU. The 138 000 industrial robots installed in China in 2017 represent an increase of 59 % compared to the previous year. This was considerably more than the total volume of robots installed in Europe and the United States together (91 000 units). Such a leap has helped China to compensate for its initially low levels. With the current number of 539 multipurpose industrial robots per 10 000 people employed in the automotive industry, China ranks among countries such as Portugal (613), Czechia (483) and Malaysia (427). Find out more on robotics in Chapter 7 - R&I enabling artificial intelligence.

As regards the increasingly important digital skills, although the EU is progressing, there is a divide between Member States in internet user skills and more advanced digital skills. Eurostat's ICT household survey (Figure 5.2-4) shows big differences among Member States in shares of the population aged 16-74 with above-average digital skills. The Nordic countries, Luxembourg, the Netherlands and the UK perform best in this area. Nearly all their households have internet access (Figure 5.2-5) and these countries tend to have relatively high shares of ICT start-ups. The lowest performers in the EU as regards their populations' digital skills are Romania and Bulgaria. European Commissions' Digital Economy and Society Index monitors human capital, which consists of internet user skills and advanced skills with development. According to the latest data, the top performing countries differ in both indicators (EC, 2019).

5 Estimated number of multipurpose industrial robots per 10 000 people employed in the automotive industry (ISIC rev.4: 29).

Figure 5.2-3 Robot density in manufacturing[1], 2010 and 2017



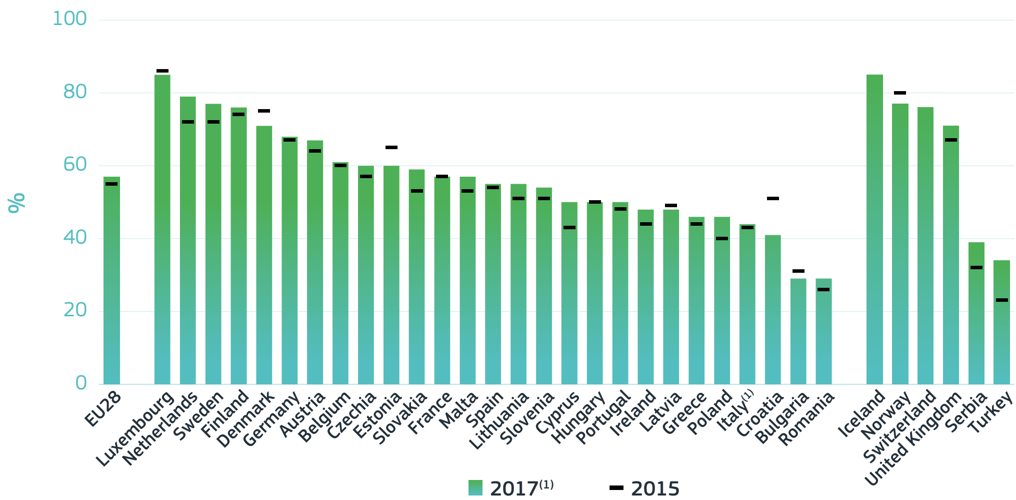
Science, research and innovation performance of the EU 2020

Source: International Federation of Robotics (IFR)

Notes: [1]Robot densities are defined as the number of robots in operation per 10,000 persons employed in the manufacturing (ISIC rev.4: C). [2]EU: employment weighted average of the available data for Member States and includes UK. Revised employment data according to ILO Employment by econmic activity 2015.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-3.xlsx

Figure 5.2-4 Share of individuals who have basic or above basic digital skills in the population, 2015 and 2017



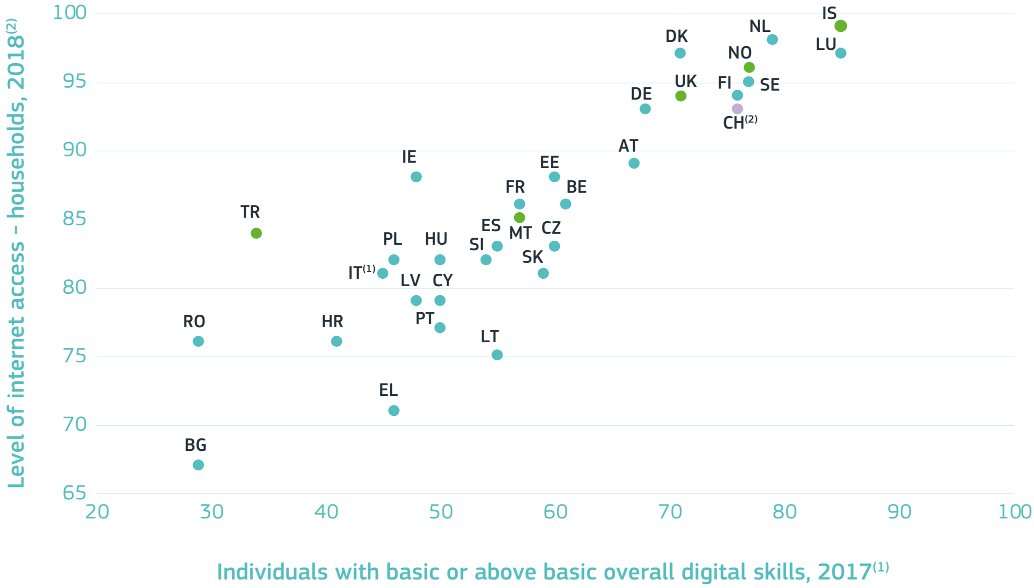
Science, research and innovation performance of the EU 2020

Source: Eurostat (online data code: TEPSR_SP410)

Note: [1]IT: 2016.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-4.xlsx

Figure 5.2-5 Individuals with basic or above basic digital skills and level of internet access in households, 2017 and 2018



Science, research and innovation performance of the EU 2020

Source: Eurostat (online data code: TEPSR_SP410 and isoc_ci_in_h)

Notes: (1)IT: 2016. (2)CH: 2017.

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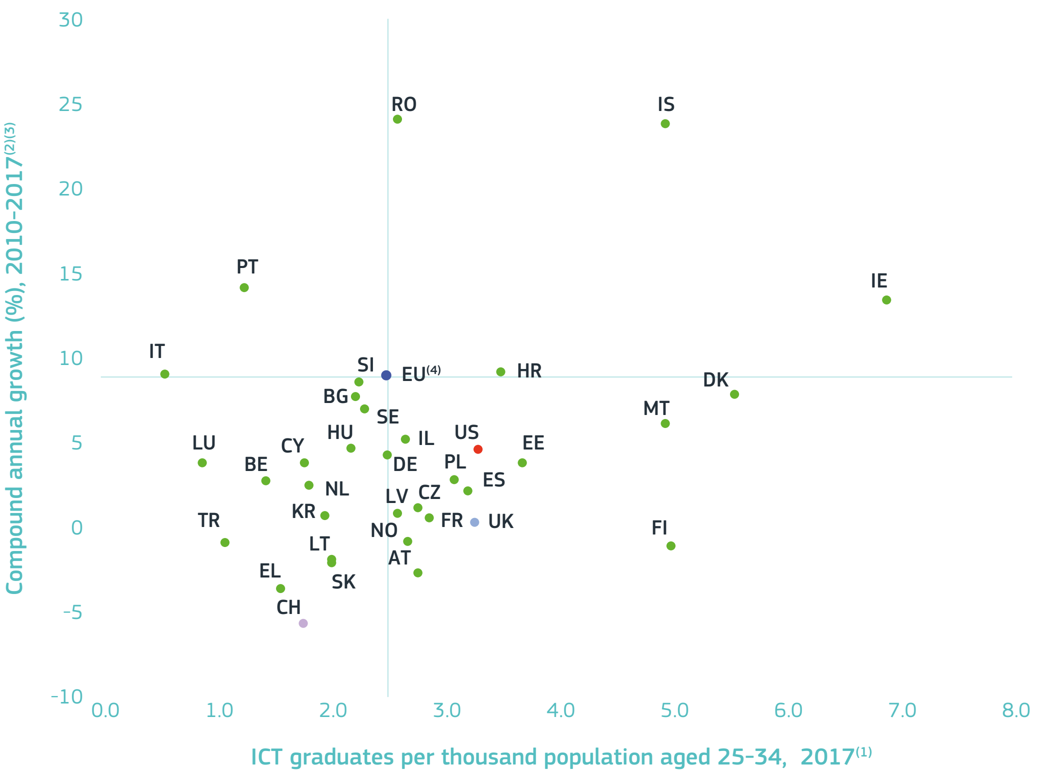
Within the last decade or so, the steep increase in the share of Europeans who use the internet resulted in 85% of Europeans having online access in 2018 (based on internet use in the last three months). In many European countries, almost the entire population is active on the internet. However, the data show that there is a wide gap between basic internet usage and the development of advanced digital skills. While 70% of Europeans go online for information about goods and services, only 7% have used the internet to follow an online course. The share of individuals with digital skills in the EU population is growing slowly. As regards individuals with more than the basic overall digital or software skills, Europeans have recently improved to reach population shares of about 30% and 40%, respectively. Greece and Sweden have shown the greatest progress in digital skills over the last three years. On the other hand, the lack of at least basic digital skills appears on the labour market in several member states and the 'use of computer' ranks as a number one demanded skill on the job market in Poland and Slovakia[6]. The increasing levels of digital skills is important to ensure a broad range of opportunities to enter and remain in the labour market. At the same time, with the rise in e-government, online shopping, banking and smart mobility, acquisition of these skills will prevent individuals not only from being locked out of work but also out of society (EPSC, 2019).

6 Cedefop project Skills-OVATE - skills sorted by their frequency across all online job vacancies.

In the period 2014-2017, the number of ICT graduates in the EU rose on average by about 4% per year. However, much lower growth in previous years and stagnation or even decline in several Member States resulted in a gap in the labour market (Figure 5.2-6). Member States with a high number of computing graduates per 1 000 population aged 25-34 include Ireland (where many US digital giants have their European headquarters), Malta (where an online gaming cluster has developed), Finland (with its important video-game sector) and Denmark. Italy, the worst European performer seems to be on a growing trajectory, although one reason for concern is the continuous decline in the number of graduates from computing studies in countries like Greece, Lithuania and Slovakia.

Figure 5.2-6 Graduates in the field of ICT per thousand population aged 25-34, 2017 and compound annual growth, 2010-2017[1]



Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: educ_uoe_grad02), OECD (Graduates by field) and United Nations data

Notes: [1]US, KR, IS, CH, IL: 2016. [2]US, KR, IS, CH, IL: 2010-2016; NL: 2010-2012; EU, FR, HR: 2014-2017. [3]Break in series between 2013 and the previous years due to change of classification (ISCED97 / 11 replaced by ISCED-F 2013). US, KR, IL: data based on ISCED11. [4]EU was estimated from the available data.

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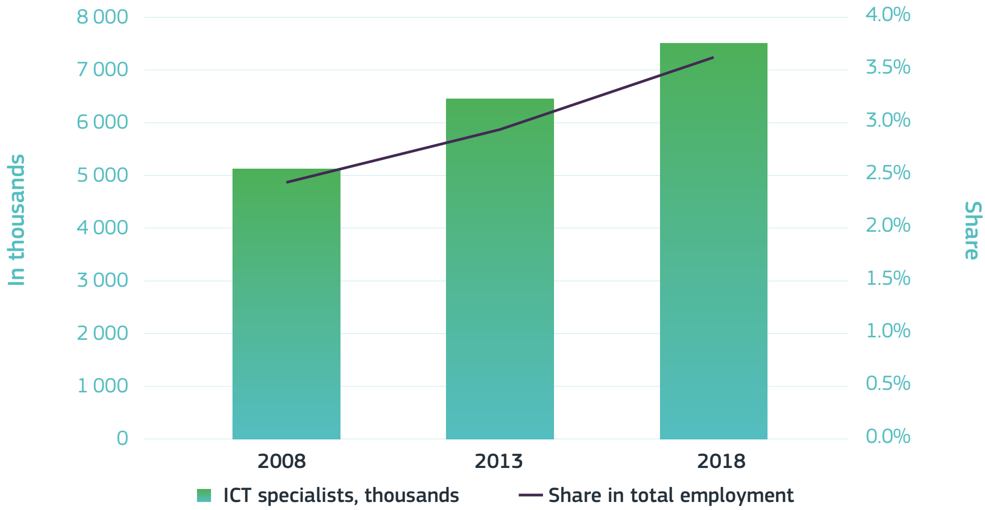
Although the number of ICT graduates has increased, it is not keeping pace with continuous growth in employment in ICT and is not meeting market demand. While the population's basic ICT skills are improving, there is a growing need for practitioners with a solid base in ICT skills. In 2018, the share of such professionals was 3.9 % of total European employment, and their total number has been increasing by more than 3 % annually over the last decade (Figure 5.2-7). Sweden, Finland, Estonia, Luxembourg and the Netherlands maintain the highest shares. Growth in these jobs is fuelled by new developments such as big data, the Internet of Things, the cloud, and the expanding app economy. In Bulgaria in particular, together with Belgium Cyprus and Ireland, the number of such jobs has increased significantly in the last ten years. Looking at the performance over the last five years, strong growth in Bulgaria is followed by Lithuania, Estonia, Romania and Greece. The lack of graduates to fill such vacancies is, to a certain extent, reflected by 56.8 % of companies facing difficulties when trying to recruit ICT specialists – and there are already over 1 million vacancies for ICT specialists in the EU[7].

Aligning the provision of education and training with changing labour market and social needs is a persistent issue facing every country, in particular as regards coordinating investment strategies with the private sector. It is well accepted that general investment in education and training together with investment in R&D are complementary (Cedefop, 2012; OECD, 2013) and that investment in human capital leads to more innovation at the firm level, including on-the-job training (Dostie, B., 2018). However, challenges persist in aligning the role and actions of public-sector actors with the actions of the private sector. This is difficult enough even in a single sector – as testified by challenges faced in aligning public investment priorities and fundamental research with the needs and applied research carried out by enterprises. At the European level, despite evolving statistical instruments, actually tracking investment levels (particularly as regards skills investment) faces significant barriers due to the misalignment of available data sources in their timing, scope and definitions. Nevertheless, recent assessments by the Commission (EC, 2019a) enables a more comprehensive picture to be drawn. Total investment in skills for labour market and social purposes – which would probably have the most direct link to companies' skills needs and innovation performance in the EU in reference year 2015 – totalled EUR 203 billion, which is less than the total investment in R&D at EUR 259 billion that same year. The private share in this expenditure varies significantly from 72 % in Slovenia to 22 % in Finland. Only about 20 % of these investments at the EU level represent publicly funded formal adult education, which depicts the complex nature of adult learning and its funding sources. See more information on the importance of economic competencies and investment in Chapter 5.3 - Investment in economic competencies.

7 An assessment by IDC and Empirica estimated a shortage of 749 000 by 2020 (2018); the estimation, based on the European Commission's VICTORY project (2019), refers to currently available vacancies.

Figure 5.2-7 Employment of ICT specialists in the EU28, 2008, 2013 and 2018

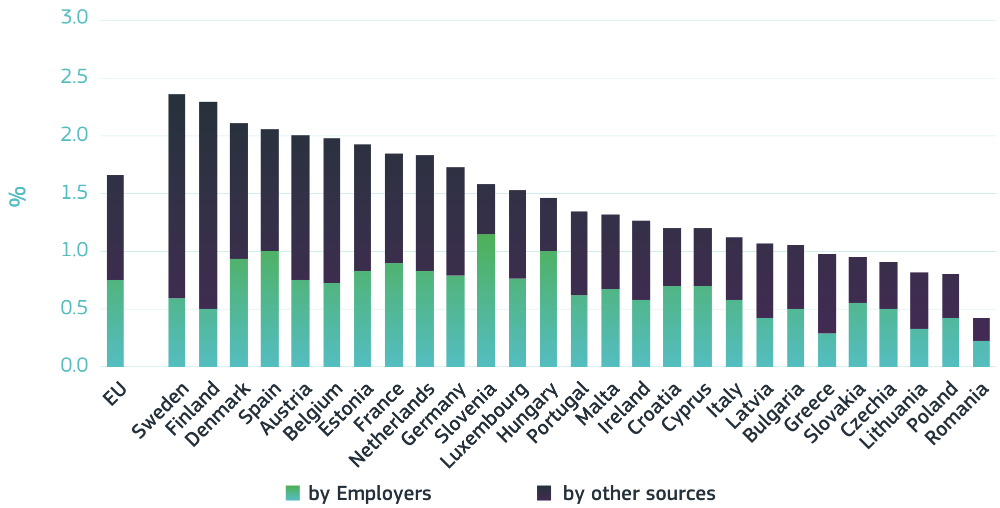


Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: isoc_sks_itspt)

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-7.xlsx

Figure 5.2-8 Investment in adult learning (estimated) across EU in 2015[1] as % of GDP



Science, research and innovation performance of the EU 2020

Source: European Commission, DG Employment, Social Affairs & Inclusion based on Eurostat - EU Adult Education Survey (reference year - 2016), special data extraction for DG EMPL; Eurostat - EU Continuing Vocational Training Survey (reference year – 2015), special data extractions for DG EMPL; Eurostat - UOE data (reference year 2015)

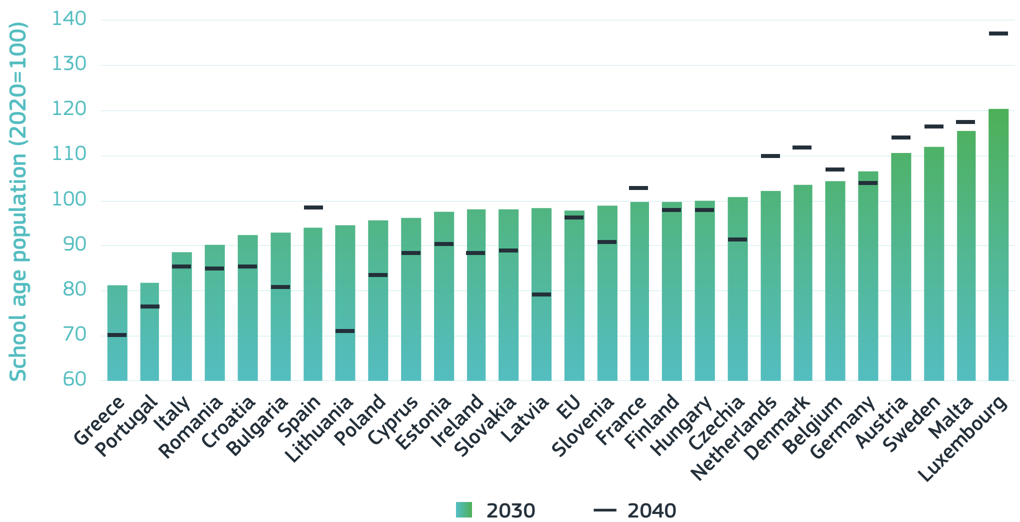
Note: [1]Investment in skills by Employers includes all economic sectors, data for the public sector employers was estimated using AES participation data and CVTS cost data per country per participant. Investment in Formal VET includes public and private expenditure on formal vocational education and training at ISCED 3 and ISCED 4 education levels. Investment in skills also includes spending on training as part of ALMPS and spending by individuals for non-formal education and training.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-8.xlsx

2. Education will face demographic change and other challenges

Investment in tertiary education in the EU lags behind that of the United States and South Korea, despite significant public efforts. With only a marginal share of private investment and the bulk of public expenditure centred on school education, the EU invests much less in tertiary education than its competitors. a closer look at EU demographic predictions reveals that public funding of education must equip students for the future. Although we can assume that low levels of spending on school education are somewhat reflected in educational outputs, as evidenced by an international skills test in compulsory education, non-financial factors play an important role, too. High levels of spending per pupil do not necessarily translate into corresponding educational outcomes, although there is a consensus that investment in higher participation rates (a higher number of learners) has both social and economic benefits. Thus, any assessment of education expenditure must consider the main features of the funding system and demographic developments which affect the number of students in the system and the expenditure per student. As we can see in Figure 5.2-9, the size of school-age population is expected to decline in most Member States in the next two decades. Such a development will force many governments to reassess how to handle the teaching staff mismatch, ensure an adequate school network with a proper infrastructure and deploy new technologies for educational purposes.

Figure 5.2-9 School-age population predictions, 3 to 18-year-olds (index 2020 = 100)



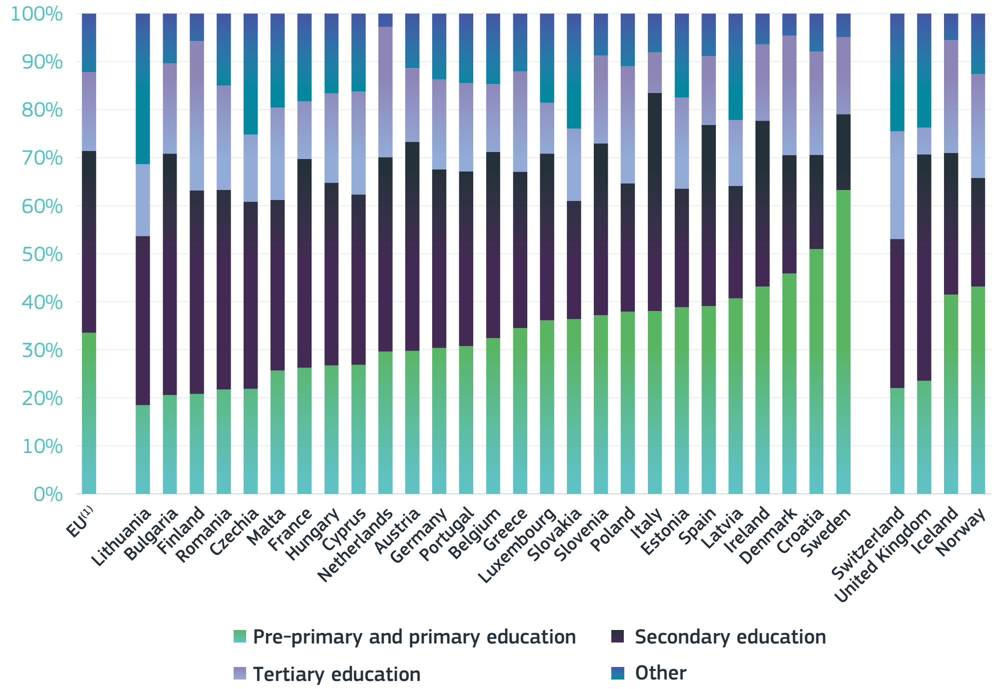
Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: proj_18np)

Note: Baseline projections.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-9.xlsx

Total investment in education in the EU is at a similar level to that in the United States and South Korea but 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. European public investment in education is driven by two major trends. First, non-tertiary education (mostly pre-primary, primary and secondary) absorbs the bulk of expenditure on education across the EU (Figure 5.2-10). The second point is that public funding is shaped by expenditure on teaching staff which accounts for 60 % of total expenditure in the EU and exceeds 70 % in countries such as Greece, Belgium, Italy and Bulgaria.

Figure 5.2-10 Share of public expenditure on education by level (%), 2017



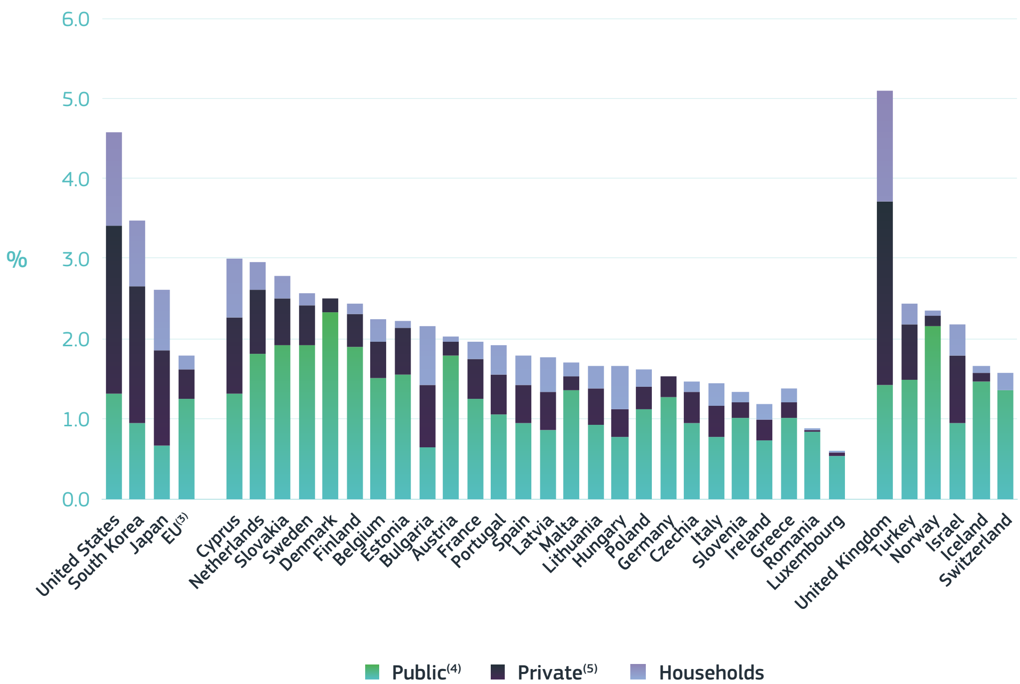
Source: Eurostat (online data code: gov_10a_exp)
Note: (1)EU was calculated by DG Research and Innovation.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-10.xlsx

There is general consensus among education economists that early investment in education gives the highest returns, since outcomes from the 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 upper secondary level and have an impact on the take-up of science and technology studies at the tertiary level – fields of study where there is a potential gap in the future supply of graduates.

While spending on school education in the EU is comparable to the levels found in North America and East Asia, there is a remarkable gap in tertiary education. The EU is spending less on tertiary education compared to all of its competitors and the gap is not closing over time. The spending gap compared to international competitors seems to be driven primarily by private sources of funding. With the exception of a few European countries (Bulgaria, Cyprus, Hungary and Latvia), public expenditure constitutes most tertiary education expenses (Figure 5.2-11).

Given the fact that European countries invest predominantly in earlier levels of education (pre-primary, primary and secondary, see Figure 5.2-10) and demographic developments in many states suggest lower numbers of children entering early levels of education, certain countries may have to reassess the structure of their expenditure on education.

Figure 5.2-11 **Total educational expenditure on tertiary education[(1)] from public and private sources as % of GDP, 2016[(2)]**



Source: Eurostat (online data code: educ_uoe_fine01) and OECD (Educational expenditure by source and destination)

Notes: [(1)]ISCED 2011 levels 5-8. [(2)]US, JP, KR, EU, CZ, DK, EL, LU, MT, PT, RO, SK, IS, TR, IL: 2015. [(3)]EU was estimated and does not include HR. Other estimations were done for some countries. [(4)]Public sources include General government and International organisations. [(5)]Private sources include Non-educational private sector and Other non-educational private entities.

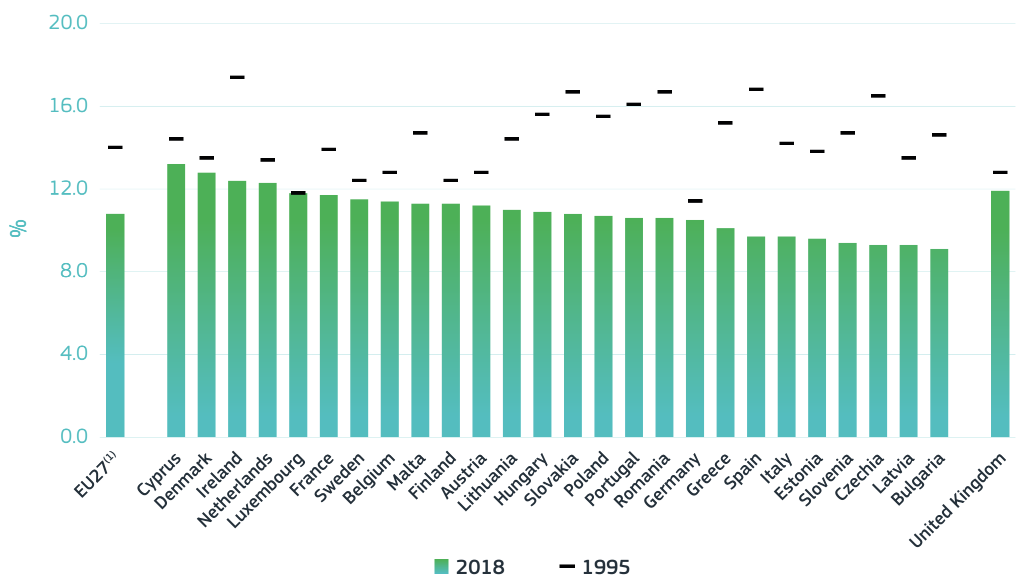
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-11.xlsx

The absolute number of students in EU tertiary education remains rather stable despite the gloomy demographic outlook in many countries. This anticipates a decline in the number of tertiary graduates in the medium term, especially in central and eastern European countries. As tertiary participation rates have increased in Member States and the size of younger cohorts has shrunk, the number of tertiary students in the EU started to decline in 2014 and could continue to do so due to demographic developments in the near future. The decline in tertiary students is strongest in central and eastern European countries where the small cohorts of the post-1990 demographic crisis have now reached tertiary student age. In addition, other Member States in southern Europe have observed a declining share of the young population (Figure 5.2-12), although these have not translated into fewer tertiary students since there participation in tertiary education has increased. Based on favourable participation rates combined with a reduction in early leavers, in 2018, Member States hit the 40.7 % share, thereby exceeding the Europe 2020 target (Figure 5.2-13 with EU headline target).

While a scientific debate continues 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 from tertiary education in terms of average earnings and the risk of unemployment are high. Various explanations are possible, such as mismatches in the fields of expertise being demanded, or a general oversupply of tertiary graduates, etc. 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 levell.

The latest statistics reveal that the number of students is shrinking faster in Estonia (-26.3 %), Slovakia (-25.5 %), Lithuania (-21.2 %), Hungary (-20.1 %), Slovenia (-18.6 %), Poland (-18.5 %), Czechia (-17.4 %), Romania (-14 %), Latvia (-12.2 %) and Bulgaria (-12 %). In the EU15, since 2013, the decline has been strongest in Finland (-4.4 %) and Portugal (-3.8 %). The number of tertiary students continues to increase in the majority of the EU15 Member States and in Cyprus (+41.6 %) and Malta (+14.7 %). In both these countries, the relatively new higher education systems are still in the expansion phase. Despite an unfavourable demography, student numbers are still rising in Germany (+11.2 %) as the result of a growing number of foreign students and an ongoing increase in participation rates.

Figure 5.2-12 Proportion of population aged 15-24 years old (%), 1995 and 2018



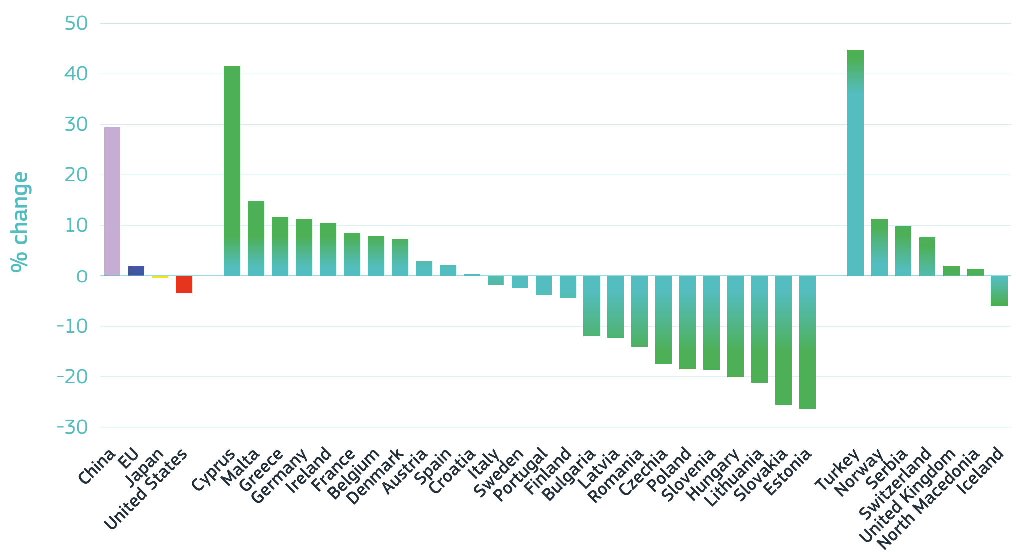
Science, research and innovation performance of the EU 2020

Source: Eurostat (online data code: demo_pjanind)

Note: [(1)]EU27 includes UK, but excludes Croatia.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-12.xlsx

Figure 5.2-13 % change in the number of tertiary students between 2013 and 2017[(1)]



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: educ_uoe_enrt02) and UNESCO data

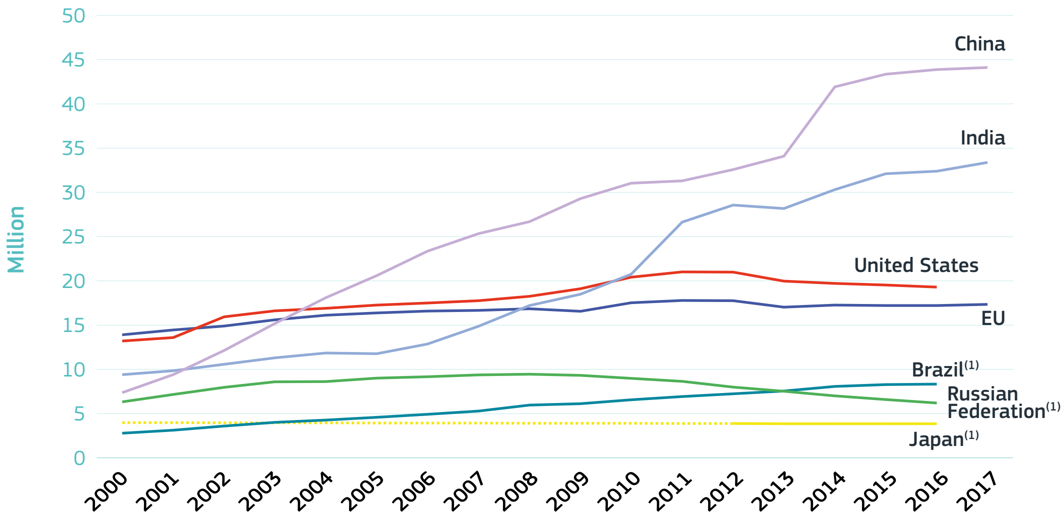
Note: [(1)]US, JP: 2013-2016; IE: 2014-2017.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-13.xlsx

Recently, in terms of the absolute number of tertiary students, the EU and the United States have shown similar levels of participation in tertiary education. The steep growth in China and India over the last decade means a growing pool of well-educated individuals coming from these emerging economies. While the EU had 16% of the world's tertiary student population at the beginning of the millennium, the share dropped to 9% in 2017. In the period 2000 to 2016, the shares of China and India increased by 6 and 13 percentage points, respectively, to reach 15% for India and 20% for China. In terms of the absolute number of tertiary graduates, China overtook the EU in 2005 and India in 2010. The United States and EU demonstrated growth in the noughties followed by stagnation over the last decade.

As in the United States, the European student population has become progressively more international, showing to some extent that European universities are attractive on the global stage. However, Europe could better capitalise on pools of talent outside of Europe, and come closer to the 5.5% of international students in the United States' higher education system[8]. The number of mobile students from abroad increased in Europe from 992000 in 2013 to 1.21 million in 2016 (+22%), although only about half of these international students came from outside Europe. In 2017, the largest groups of non-European students came from Asia (267000) and Africa (180000)[9]. The highest numbers of international students are in Germany and France. The United Kingdom seems to be particularly popular among Asian students, educating some 220000 coming from Asia, which is almost the same as the number of Asian students in the EU.

Figure 5.2-14 **Total number of tertiary students, 2000-2017**



Science, research and innovation performance of the EU 2020

Source: Eurostat (online data code: educ_uoe_enrt02) and UNESCO data

Note: (1)EU, Brazil: 2006 value, Russian Federation: 2010 value and Japan: period 2000-2012 estimated by DG Research and Innovation.

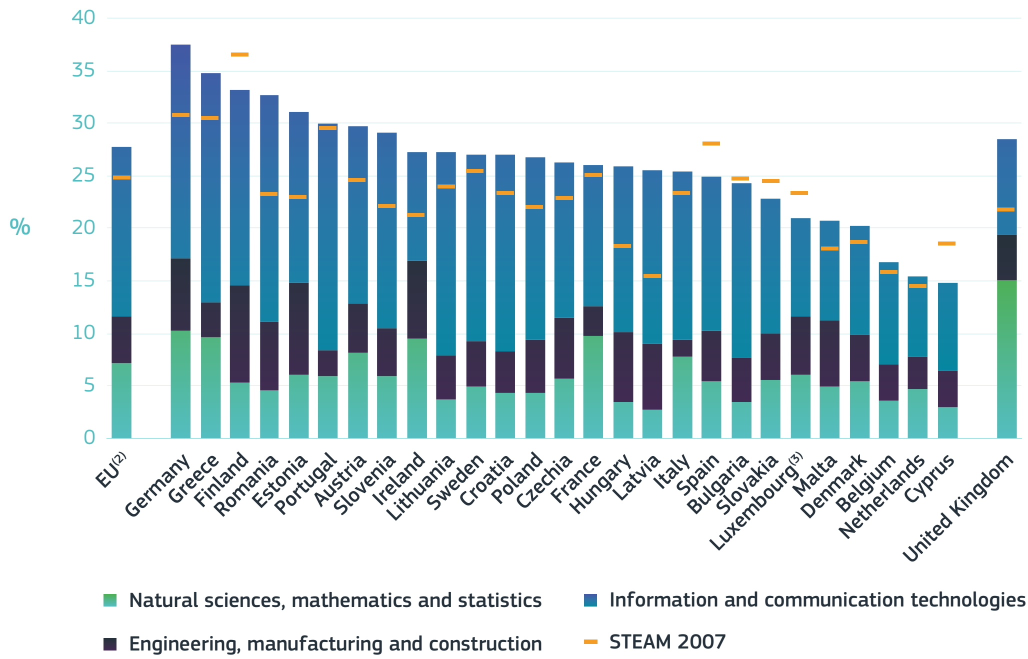
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-14.xlsx

8 US higher education enrolment data from 2018/19 based on the National Center for Education Statistics (NCES).

9 Furthermore, there were 220000 Asian, 30000 African and 23000 Northern American students in the United Kingdom in 2017.

The share of STEM (science, technology, engineering and mathematics) students has increased since 2007, with strong improvements in many central and eastern European states. Between 2007 and 2017, the share of STEM students grew from 22% to 28%, with particularly high shares in Germany, Greece, Finland, Estonia, Romania and Portugal (Figure 5.2-15). With more attention being given to the role of design in product marketing and product innovation, arts and design students are becoming an important asset in modern economies as these are contributing to the emergence of 'creative industries'. Correspondingly, STEM education often uses the STEAM approach, i.e. teaching STEM in environmental, economic and cultural contexts with the infusion of the arts, humanities and social sciences. The intention is to apply more creative thinking in the design of innovative products and, in general, to involve new insights and perspectives in scientific progress. The enhanced STEAM approach to STEM education also raised expectations that graduates utilise their artistic talents to generate innovative thinking, while the definition of 'art' education in STEAM often spreads across visual arts to liberal arts and humanities. Ongoing research is seeking more conceptual clarity in STEAM terminology (Colluci-Gray et al., 2017) and investigating different methods for merging STEAM methodologies (Perignat and Katz-Buonincontro, 2019).

Figure 5.2-15 Tertiary students in science, technology, engineering and mathematics (STEM) as % of total tertiary students, 2017[1] (and for 2007 without breakdown)



Science, research and innovation performance of the EU 2020

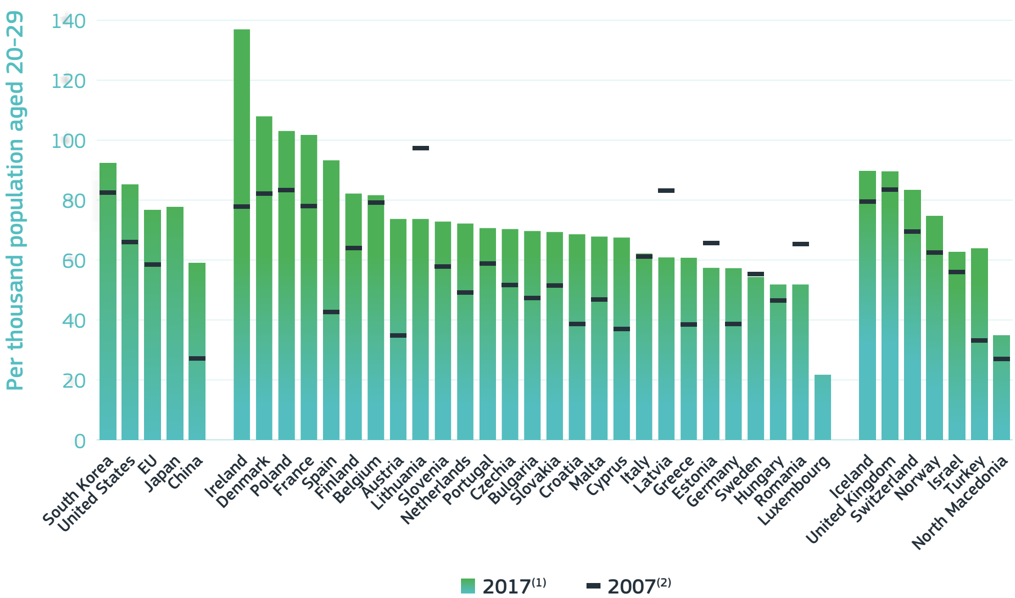
Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: educ_uoe_enrt03)

Notes: [1]SI: 2016. [2]EU estimated and does not include IT and NL. EU: 2016. IT, NL: 2014. [3]LU: 2006. EU average does not include LU.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-15.xlsx

The shares of new graduates among young populations only increased because of the shrinking EU population of 20- to 29-year-olds. The stagnating numbers of tertiary graduates in the EU population suggest that the EU will not reach the levels of its competitors, the United States and South Korea, in the short term. As regards new tertiary graduates per thousand population (Figure 5.2-16), the EU performs at a similar level to Japan, but below the United States and South Korea. While figures in China and the United States continue to increase, in the EU, the number of new tertiary graduates per population has hardly grown over the last decade and has fallen in South Korea and Japan. Ireland's outstanding performance can be explained by a 20 % increase in 2017 on the previous year. Combined with a decline in the young population since 2007, Ireland shines as an outlier. a group of leading Member States is following Ireland with trends that are more genuine and with overall improvements that are comparable to Ireland. While many central and eastern European countries experienced high growth rates in the past, the number of graduates in these countries has fallen – dramatically in some of them – within a few years. This is due to demographic developments, occasionally reinforced by students' preferences. For example, 17 % of Slovak students enrolled abroad[10]. Most went to Czechia where the trend is growing: the share of Slovak students among all the students at Czech universities rose from 5 % in 2007 to 7 % in 2017.

Figure 5.2-16 New graduates from tertiary education per thousand population aged 20-29, 2007 and 2017



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: educ_uoe_grad01) and UNESCO data

Notes: [1]US, JP, KR, IS, IL: 2016. [2]LU, IL: 2011; JP: 2013.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-16.xlsx

10 The percentage of national tertiary students enrolled abroad, 2016; OECD (2018), Education at a Glance.

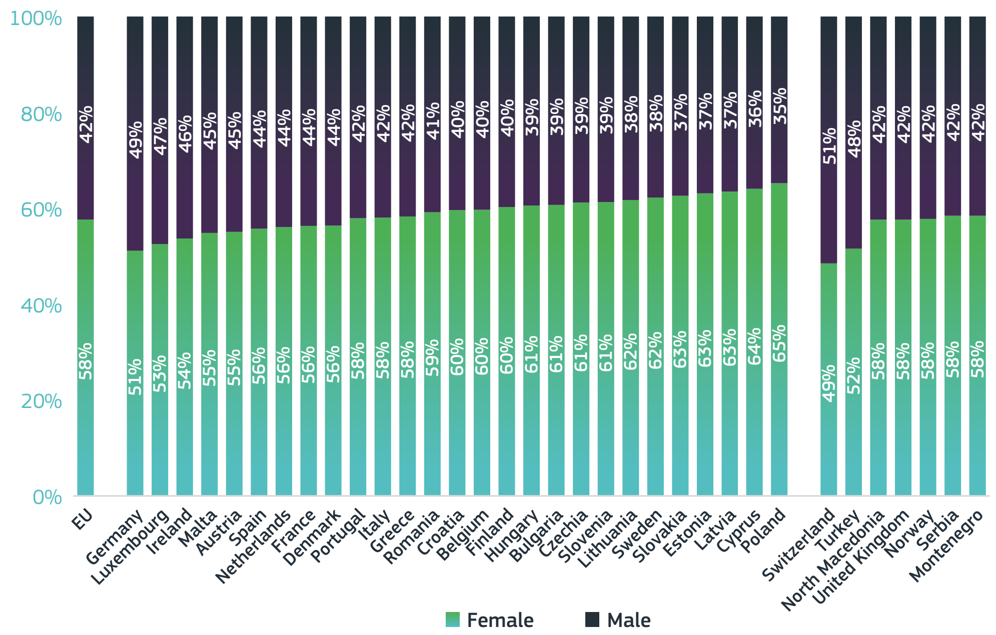
Gender imbalances among graduates are greater compared to the number of enrolled students as 54% of students in higher education were women. In 2017, the share of women reached 57.6% when considering tertiary graduates in the EU (Figure 5.2-17). Germany is the EU country with the most equal gender balance (female share of tertiary graduates is 51.1%), while men represent fewer than 40% of tertiary graduates in many central and eastern European countries. At the level of enrolled students, female students outnumbered men by about 1.3 million and represented 54% of the EU tertiary student population following a rather stable trend over the last five years.

Women represent only about one third of all STEM graduates in the majority of EU countries. More precisely, they represent only about 33% of all science, technology, engineering and mathematics graduates in the EU, a share which has not changed in recent years. In 2017, there were remarkable differences within the main STEM areas with a higher share of female graduates (53%) in natural sciences, mathematics and statistics, but a significantly lower share (19%) in information and communication technologies. The European share of female science and technology graduates reaches comparable values in Canada (32%) and the United States (37%), while South Korea only achieved 26% of female graduates.

The under-representation of women in certain STEM occupations as well as in related study areas has persisted over time. The proportion of males interested in STEM grew from 2006 to 2015, but not of females. Dedicated studies in STEM-related vocational plans demonstrate that adolescent plans are broadly segregated by gender. Earlier data from PISA-participating countries[11] show that, across all the OECD and partner countries, a much higher proportion of males express an interest in engineering and computing occupations than females, whereas the opposite trend exists in the preference for health careers (Han, 2017). The low participation of women observed across STEM occupations contributes to talent loss and limits the beneficial effects of social diversity. The persistence of women's under-representation in particular fields of STEM also contributes to reproducing economic gender inequalities, as STEM occupations represent some of the best paid and most prestigious jobs in the labour market (Blasko et al., 2018

11 PISA is the OECD's Programme for International Students Assessment.

Figure 5.2-17 Share of tertiary graduates by sex (%), 2017



Science, research and innovation performance of the EU 2020

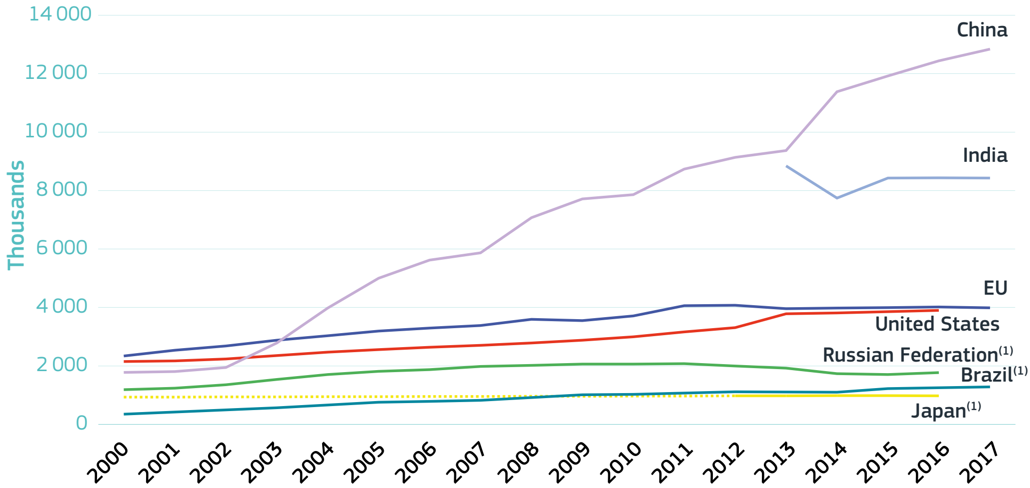
Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: educ_uoe_grad01)

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-17.xlsx

The numbers of tertiary graduates are very similar in the EU and the United States, while China is reinforcing its position as the world's largest producer of tertiary graduates (Figure 5.2-18).

The EU has a worse performance in the share of science and technology (S&T) graduates than several years ago, remaining roughly at 2005 levels. In 2015, although there was a higher share of S&T students at over 25 %, the following years showed a deterioration in these values. As regards science and technology graduates (Figure 5.2-19), the EU countries now reach approximately the same level as in 2005. South Korea has seen shares which continue to decline, although it still has a much higher share of science and technology graduates among all tertiary graduates. As regards the number of tertiary graduates per thousand population, South Korea has almost been caught up by the United States, while Canada is also climbing to similar levels. Data from years 2014-2017 suggest that the share of EU graduates stagnated at a level considerably lower than these three listed competitors.

Figure 5.2-18 Total number of tertiary graduates, 2000-2017



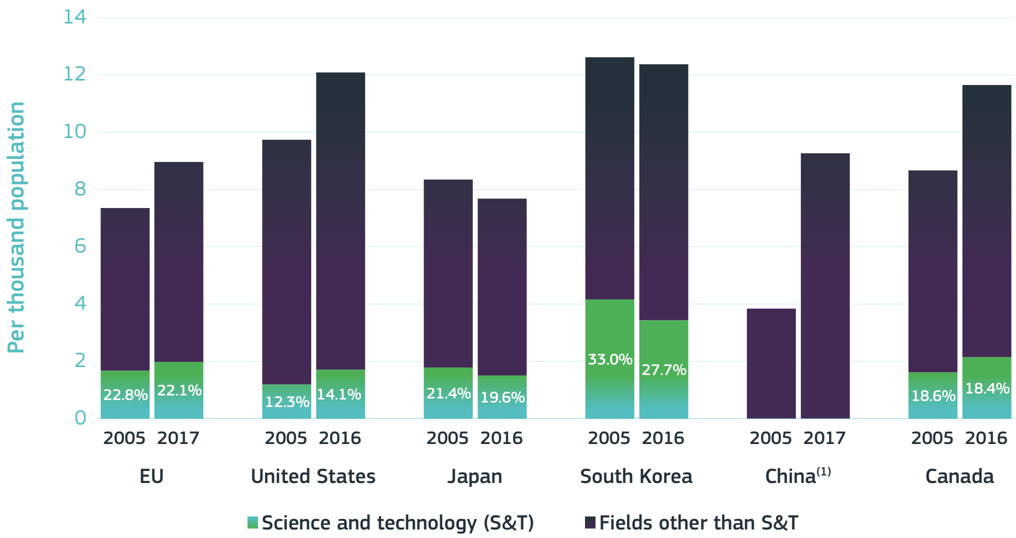
Science, research and innovation performance of the EU 2020

Source: Eurostat (online data code: educ_uoe_grad01) and UNESCO data

Note: [1]EU, Brazil: 2006 and 2013 values, Russian Federation: 2008 and 2010 values and Japan: period 2000-2012 estimated by DG Research and Innovation.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-18.xlsx

Figure 5.2-19 Tertiary graduates per thousand population broken down by science and technology and other fields, 2005 and 2017



Science, research and innovation performance of the EU 2020

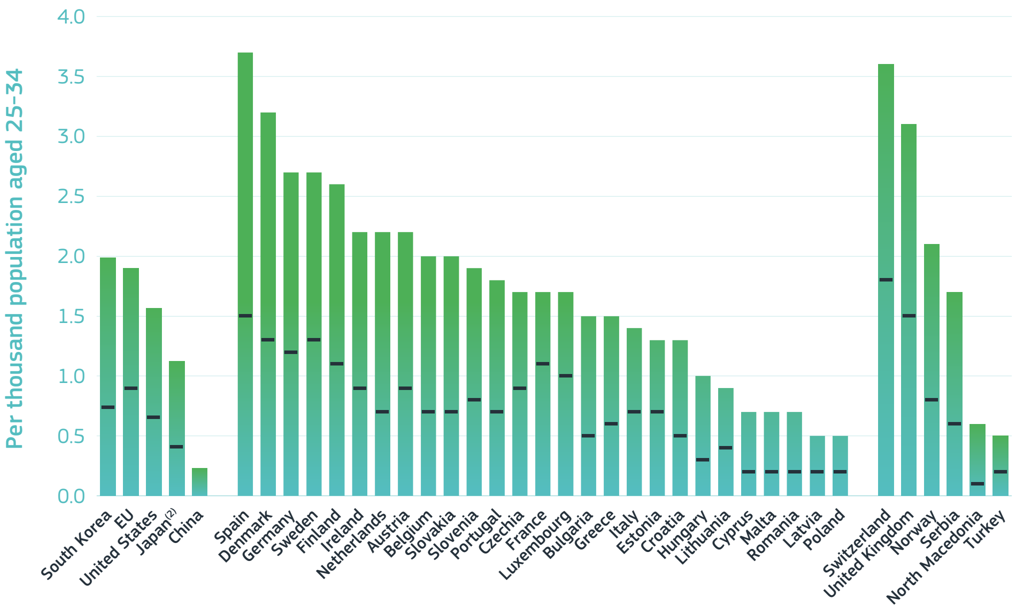
Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: educ_uoe_grad02), OECD (Graduates by field), UNESCO and World Bank data

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/2020/parti/chapter52/figure-52-19.xlsx

The EU performs well in the education of new doctoral graduates, including in science and technology. Some EU countries are among the best performers worldwide, together with Switzerland. As regards new graduates at the doctoral level, the EU achieves at the same level as South Korea in general but maintains a higher share of science and technology graduates. Other competitors, such as Japan and the United States have lagged behind with little progress in recent years. Spain, the UK, Germany and the Nordic countries perform well, but smaller countries tend to have a high share of doctoral students being awarded their degrees abroad, thus the available data could understate their performance. Many eastern and southern European countries produce a relatively low number of doctoral graduates, where a mixture of factors could contribute to the lower attraction of academic careers perceived (EC/EACEA, 2017)[12].

Figure 5.2-20 New doctoral graduates per thousand population aged 25-34, 2017



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: educ_uoe_grad06 and educ_uoe_grad07), OECD, UNESCO and World Bank data

Notes: (1)US, JP and KR: 2016. (2)Share of science and technology graduates of Japan does not include Information and Communication Technologies graduates.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-20.xlsx

12 Characterised through a combination of factors, such as employment conditions in academia, duties and working time of academic staff, remuneration of academic staff, or continuing professional development.

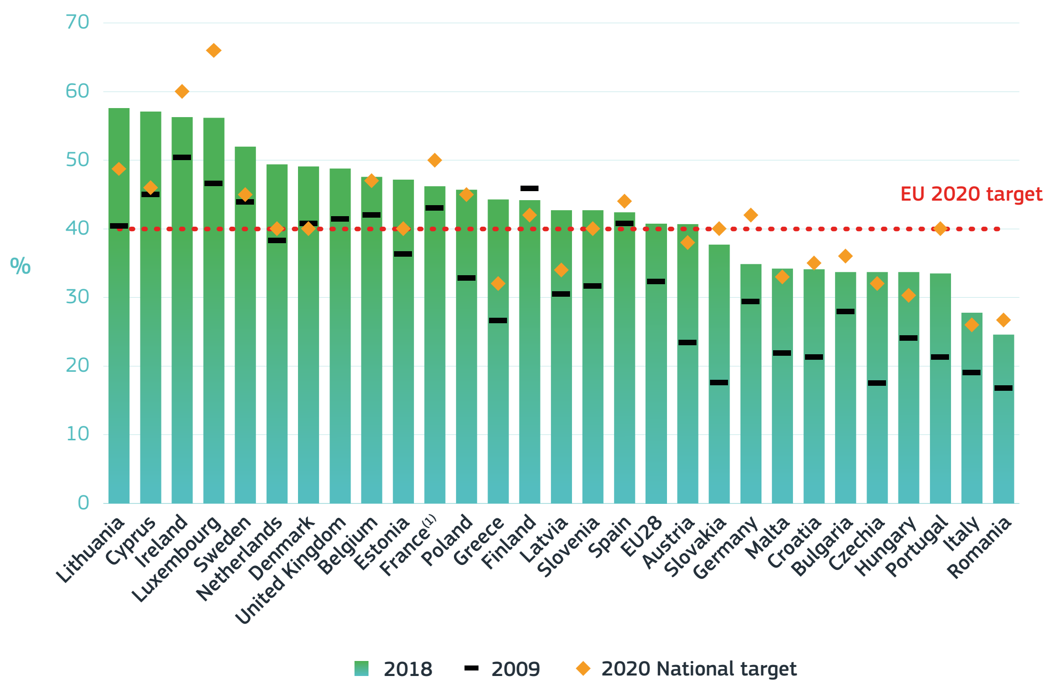
In 2018, the EU reached its target for the share of people with tertiary attainment, and also made progress in achieving the target for early leavers from education and training. Progress in the number of tertiary graduates (with some time lags) contributed to achieving the EU's headline target for tertiary attainment (Figure 5.2-21). The Europe 2020 strategy's target demands that at least 40 % of 30- to 34-year-olds in the EU should have completed tertiary education by 2020 (EC, 2019c). Reaching the level of 40.7 %, the EU crossed this threshold in 2018. With the initial level at 23.6 % in 2002, there was a steady increase to 32.3 % in 2009 and beyond. This growth pattern was even more significant for women (from 24.5 % in 2002 to 45.8 % in 2018) than for men (from 22.6 % to 35.7 %), meaning that there is a gender gap with women above and men still below the overall Europe 2020 target.

Lithuania, Cyprus, Ireland, Luxembourg and Sweden already have tertiary education attainment rates of over 50 %. Italy and Romania still show relatively low tertiary attainment rates. After Mexico, Italy has the lowest tertiary attainment rate among OECD countries (based on the population of 25- to 34-year-olds from 2017). Despite the progress achieved, the EU still lags behind the tertiary attainment levels of the United States (48 %), Japan (60 %), Canada (61 %) and South Korea (70 %).

Although tertiary attainment has become more accessible, some challenges remain relevant. Studies, such as the OECD PIAAC survey[13], show big differences between the skill levels of tertiary graduates in EU countries and hence the need to focus more on the quality of education in some countries. Although the EU reached its target for educational attainment rates at the tertiary level, other challenges, such as the quality of education and the acquisition of skills relevant to the labour market, remain relevant. Furthermore, reducing dropout rates from education and training would help to mitigate difficulties early leavers have in joining the labour market and improve the efficiency of public investment in education. As set out by the EU 2020 strategy, the share of early leavers from education and training in the EU should not exceed 10 %. With 10.6 % reported in 2018, the EU was 0.6 percentage points away from its target.

13 Programme for the International Assessment of Adult Competencies (PIAAC) is an OECD programme of assessment and analysis of adult skills based on international survey conducted in over 40 countries/economies.

Figure 5.2-21 EU headline target on the tertiary attainment of population aged 30-34, 2009 and 2018



Science, research and innovation performance of the EU 2020

Source: Eurostat (online data code: edat_lfse_03)
Note: (1)FR: the 2020 national target includes persons aged between 17 and 33 years.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-21.xlsx

3. Research personnel and gender equality show low dynamics

Although the number of researchers and R&D personnel in Europe grew to 1.77 million in 2018, business R&D employment remains at low levels. In 2018, the EU's active population reached around 213 million of whom 198 million were employed[14]. Human resources in science and technology (HRST) accounted for 110 million people in the EU, or 56% of total employment, a share that has been increasing constantly. People employed in science and technology who had successfully completed tertiary-level education accounted for 23% of total employment and over the last decade their shares have been growing, in particular, in Austria, Malta, Portugal and Luxembourg.

The retiring baby boomer generation and the potential risk of sectoral and regional bottlenecks in the supply of skilled workers could aggravate the demographic challenges, which were described earlier,

14 Active population includes the total labour force of 20- to 64-year-olds which includes both employed and unemployed people. Source: Employment - annual data [lfsi_emp_a].

in the coming decades when small young cohorts enter the labour market. An adequate supply of skilled human resources is vital for knowledge absorption and for the development of science and technology-intensive economic sectors. However, rapid technological progress and a change in workplace requirements, growing interdisciplinarity and the resulting low predictability of future skills needs in combination with fluctuating migration levels make planning and foresight difficult. To better grasp and capitalise on the latest developments, the European Institute of Innovation and Technology plays an important bridging role between the European R&I framework and education policies and programmes. The Institute contributes to reshaping innovative and entrepreneurial education at both master and doctoral levels, although its Skills for the Future initiative intends to rethink approaches to education programmes at lower educational levels, too. Their higher-education partners focus on developing innovative curricula that provide students, entrepreneurs and business innovators with the knowledge and skills anticipated for a knowledge and entrepreneurial society. Any broader response is limited by interacting forces of growing internationalisation of the labour markets and greater competition for highly skilled people. While the first tends to make regional or national skill gaps less severe, the growing international and intersectoral demand for highly trained professionals, including scientists and researchers, lacks regions or countries that are further developing their R&I systems.

Figure 5.2-22 Key data on human resources in science and technology in the EU

	Total (000s) 2018	As % of total employment 2018	Compound annual growth (%) 2007-2018[(1)]
Active population	213 624	108	0.32
Total employment (LFS)	198 032	100	0.34
HRST - Human Resources in Science and Technology	110 473	55.8	2.23
HRSTE - Human Resources in Science and Technology - Education	85 764	43.3	3.10
HRSTO - Human Resources in Science and Technology - Occupation	69 959	35.3	1.68
HRSTC - Human Resources in Science and Technology - Core	45 250	22.8	2.94
SE - Scientists and engineers	14 759	7.5	2.52
Total R&D personnel (FTE)	2 795	1.4	2.97
Researchers (FTE)	1 773	0.9	3.57

Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: hrst_st_ncat and rd_p_persocc)

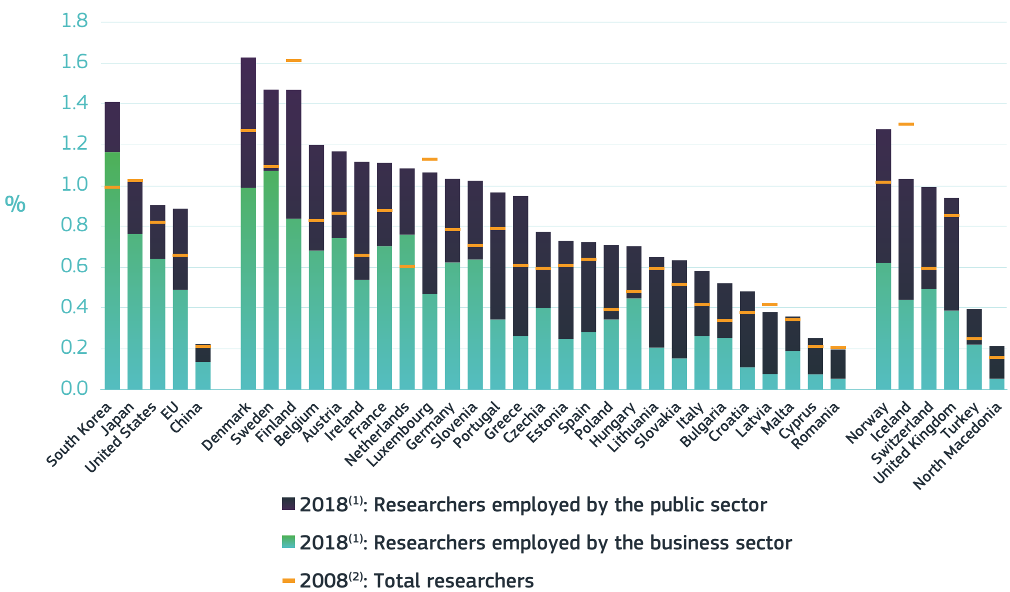
Note: [(1)]Breaks in series occur between 2014 and the previous years and between 2011 and the previous years for HRST data.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-22.xlsx

Human resources in science and technology have grown faster than total employment in the past and jobs in this area were more resilient during the crisis. Whilst total employment increased on average by 0.3 % each year between 2007 and 2018, HRST increased annually by 2.2 %, or by nearly 20 million over the whole period, research personnel by 3 % and the number of researchers by 3.6 %. This reflects the labour force's rising educational attainment, as well as the shift to 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. As yet, there is no evident overall skills gap although the situation might change in the future and there are already bottlenecks in certain regions and sectors, such as ICT.

The share of researchers in the workforce reflects countries' economic structures and shows dynamic developments. 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 still lags behind the United States, Japan and, in particular, South Korea. The share remains worryingly low when it comes to researchers employed in the business sector (see Figure 5.2-23). However, the percentage of researchers employed in the EU has outpaced the growth rates of China, the United States and Japan's stagnating values. None of the international competitors have been able to keep pace with South Korea, where the share is pulling further ahead.

Figure 5.2-23 Total researchers (FTE) as % of total employment, 2008 and 2018



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: rd_p_persocc), OECD and Statista based on National Bureau of Statistics of China

Notes: (1)US: 2016; JP, KR, CN, CH, TR: 2017. US value for public sector estimated. (2)EL: 2011.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-23.xlsx

EU countries keep increasing the number of researchers (in relative and absolute terms), as do their global competitors. In the EU, the highest share of researchers in total employment as well as those employed by the business sector are in the Nordic countries. While Cyprus and Romania show relatively low levels of researchers (roughly on the same level as China), the group of low performers extends to Croatia and Latvia, when looking only at researchers in the business sector. The good news is that many EU countries are showing a positive trend in the employment of researchers. These are in central and eastern European countries (notably Croatia and Poland) plus Greece and Portugal, which seem to have recovered from the crisis and have increased the number of researchers significantly since 2007. However, the picture changes when comparing the total number of researchers worldwide. Since 2015, China has had the largest number of business researchers in absolute terms and is competing with the EU in the total number of researchers; in 2017, there were 1.68 million in the EU and 1.74 million in China.

Although females represented 48 % of EU graduates at the doctoral level in 2017, they represent about a third of all EU researchers and only about a quarter of those in the business sector. The share of female researchers is still far from balanced, depending to a large extent on the sector of activity, with relatively higher shares of female researchers in education – 46 % in 2016 – while the business enterprise sector is performing worse with female researchers still severely under-represented with a share of about a quarter of researchers. Previously, as the number of women researchers in the EU increased at a higher rate on average than men, the situation improved slightly, although this was not the case for all Member States. Czechia has one of the lowest numbers of female researchers in the EU with their share in 2017 (23.1 %) reaching 2 percentage points lower than in 2007 (25.4 %). The best EU performers, such as Latvia and Bulgaria, show values for equal gender splits in the research population.

Figure 5.2-24 Total researchers (Full-Time Equivalent)

	2018 (thousands)[1]	Compound annual growth (%) 2007-2018[2]	% of female researchers, 2007[3]	% of female researchers, 2017[3]	As % of total employment, 2018[1]
EU	1773	3.57	:	30.2	0.90
Belgium	58	4.29	31.1	34.8	1.21
Bulgaria	16	3.58	47.8	46.4	0.52
Czechia	41	3.61	25.4	23.1	0.78
Denmark	46	3.99	29.3	35.5	1.64
Germany	433	3.69	18.6	22.6	1.03
Estonia	5	2.74	41.5	40.7	0.75
Ireland	25	6.46	30.3	35.4	1.12
Greece	37	5.81	36.7	37.8	0.96
Spain	140	1.22	37.9	38.8	0.72
France	306	2.89	18.9	28.6	1.13
Croatia	8	2.43	47.2	47.7	0.48
Italy	140	3.54	33.8	34.6	0.60
Cyprus	1	2.95	34.0	38.0	0.27
Latvia	4	-1.08	49.6	50.8	0.41
Lithuania	9	0.32	48.6	46.1	0.64
Luxembourg	3	5.22	22.3	27.3	1.07
Hungary	31	5.53	31.7	26.8	0.70
Malta	1	5.11	25.0	29.4	0.36
Netherlands	96	3.59	25.5	27.1	1.09
Austria	51	4.42	20.6	23.7	1.18
Poland	118	6.10	39.4	35.4	0.71
Portugal	47	2.91	43.9	43.1	0.96
Romania	17	1.19	43.8	46.3	0.20
Slovenia	10	2.60	33.7	30.9	1.03
Slovakia	16	2.57	41.4	40.1	0.64
Finland	38	0.06	31.5	33.2	1.49
Sweden	75	2.33	29.4	28.6	1.47
United Kingdom	309	1.85	36.8	38.7	0.96
Iceland	2	3.65	37.8	46.4	1.03
Norway	35	3.22	33.5	38.1	1.29
Switzerland	46	6.97	30.2	34.9	0.99
North Macedonia	2	4.39	52.5	56.4	0.22
Turkey	112	8.46	34.1	32.8	0.40
United States	1 371	2.11	:	:	0.91
China	1 740	6.00	:	:	0.22
Japan	676	0.10	13.0	16.2	1.04
South Korea	383	5.61	14.9	20.1	1.43

Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: rd_p_persocc and rd_p_femres), OECD and Statista based on National Bureau of Statistics of China

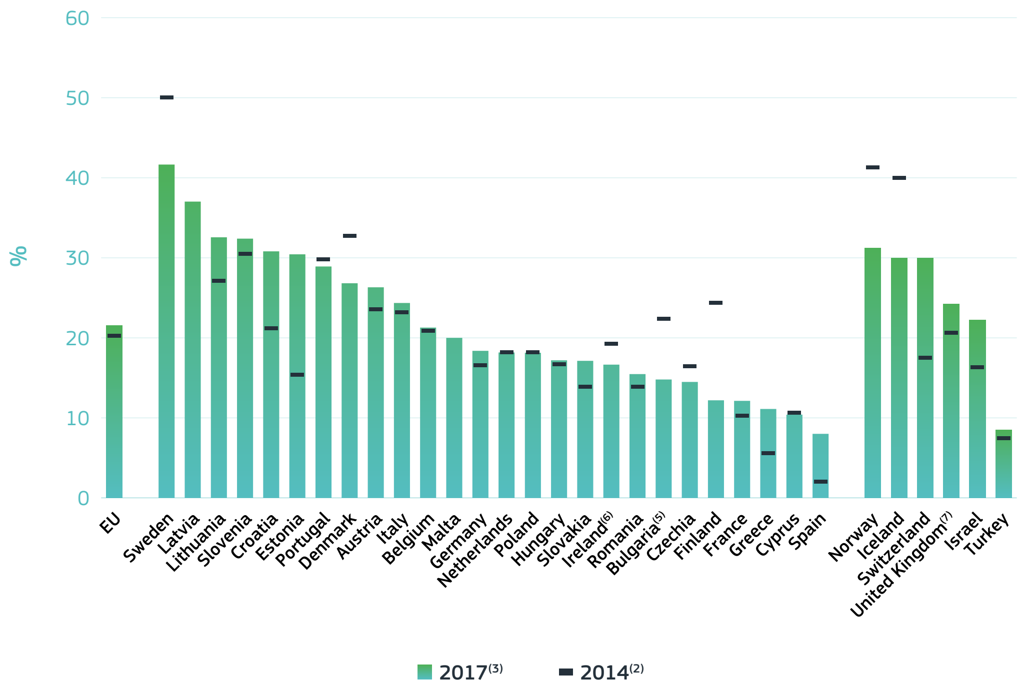
Notes: [1]US: 2016; JP, KR, CN, CH, TR: 2017. [2]US: 2007-2016; JP, CH: 2008-2017; KR, CN, TR: 2007-2017; PT, SI: 2008-2018; EL: 2011-2018. JP, CN, FR, IT, LU, NL, PT, RO, SI, FI, SE, IS: show break in series between 2007-2018. [3]CH: 2008; LU: 2009; FR: 2010 EL, NL: 2011. [4]EU aggregate estimated and does not include BE and FI. [5]JP, KR, BE, EL, FI, UK, IS, NO, CH - head counts (HD) for share of females.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-24.xlsx

Women are in a minority in the top academic grade and in recent years their position has only improved slightly. Across the EU, the proportion of women among heads of institutions in the higher-education sector rose from 20.2% in 2014 to 21.7% in 2017 although, at the same time, several countries experienced a fall in the number of women heading up institutions (Figure 5.2-25). The under-representation of women in leadership positions has wide implications for both scientific advancement and for industries with a strong need for a technologically educated workforce (EC, 2018). In recent years, growing numbers of scientific institutions have adopted a variety of measures to make improvements, such as leadership training, implicit bias training, and broader gender equality plans (Cameron et al., 2015).

In recent decades, the ratios of women to men in senior academic and decision-making positions have fallen below expectations given the growing number of women among higher-education graduates. For example, in the life sciences at the EU level, women make up the majority of graduates up to doctoral level but are less successful than men in securing research grants (ERC, 2018), and their numbers progressively decline at each progressive career stage (Helmer, 2017).

Figure 5.2-25 Share of females as heads of institutions in the higher education sector (HES)[(1)], 2014 and 2017



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Women in Science database

Notes: [(1)]Data are in headcounts (HC). [(2)]BE (French speaking community universities), BG, SI: 2013. FR: 2012. [(3)]BE (French speaking community universities), CZ, PT, RO, SI, UK: 2016. CY: Academic Year 2015-2016. ES: 2015. [(4)]LU excluded due to lack of data. [(5)]BG: Data about heads of scientific organisations are not available. [(6)]IE: Private colleges and other smaller institutions are not included. [(7)]UK: Figures rounded to the nearest multiple of 5.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-25.xlsx

4. Conclusions

Investment into human capital is important as it is one of the main factors influencing the competitiveness of European R&I systems. R&I are systemically linked processes within the framework of a larger, knowledge-driven socio-economic system (EC, 2009). The accumulation and transformation of knowledge provides input for R&I activities and, within that context, it is of key importance that R&I are well connected to a number of other areas, such as the **education system**.

The education system **provides the knowledge base** and can **foster creativity**, both of which support the ability to perform high-quality research. It is the interpretation, the combination and recombination of information into new knowledge, and the upgrading of the existing knowledge base that make our R&I systems competitive. In addition to scientific excellence, education is an important way to **transfer knowledge** derived from R&I to society and equip young people with **the right skills** for their future professional development.

The supply of **human resources in science and technology** ranks among the most important factors determining the competitiveness of the EU in the long term. The demand can vary depending on concrete industry or technology sectors and thus the focus on 'R&D expenditure' must be complemented by indicators such as 'R&D personnel' and 'researchers' to fully understand the EU's comparative advantage. In that context, the **under-representation of women** in both public and private research presents an unused potential of talents and deprives women of the opportunity to contribute towards R&I on an equal footing. Given the negative effects of gender imbalance in all scientific fields and the necessity to accelerate the progress towards gender equality in R&I, there must be more tangible role models for potential women scientists to encourage more women to pursue a **scientific career** and presence in scientific **decision-making bodies**.

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CHAPTER 5.3

INVESTMENT IN ECONOMIC COMPETENCIES

KEY FIGURES

2 %
of EU investments in economic competencies as a % of GDP

5/30
most valuable brands are in the EU

What can we learn?

- **Economic competencies, such as management quality, organisational structure and workforce training, are essential ingredients** to reap the full productivity benefits from investments in both tangible and other intangible assets, especially in a fast-changing world.
- **Economic competencies are contributing to economic and labour productivity growth** in Europe.
- **The EU underinvests in economic competencies relative to the United States**.
- **Intra-EU differences in investments in economic competencies persist** which may exacerbate inequalities in innovation.
- **Brand strength and recognition is increasingly bringing value to companies**. Over time, there has been an enormous rise in brand value especially in technology and disruptive digital industries where Europe has a 'weaker' presence. Today, the 'top 30 brands' are mainly found in the United States and China.
- **Many software and digital applications behind the widespread success of digital disruptive industries have some 'EU origin'**.

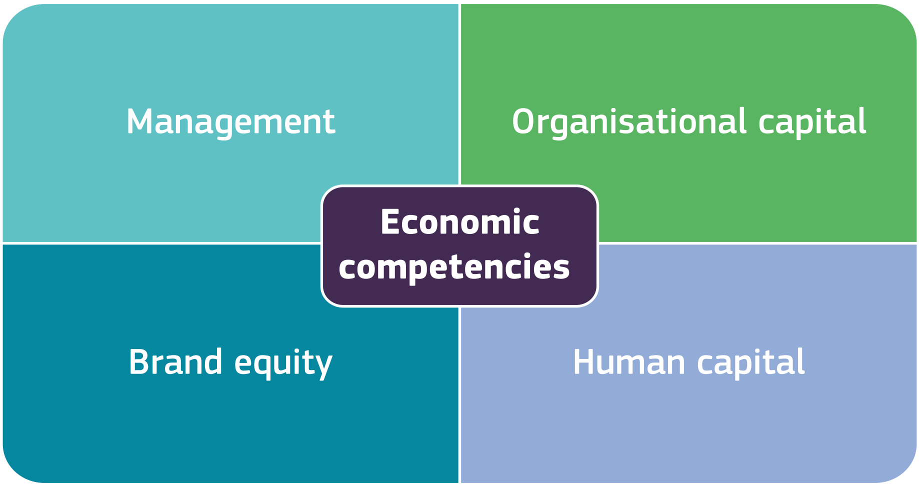
What does it mean for policy?

- **Incentivise investments in training, mentoring, coaching and other activities that promote lifelong learning and soft skills**, such as the capacity to adapt and adopt new technologies in a fast-changing world.
- **Support the strength of the 'made in EU' technological brand on the global scene**, including the communication of successful EU innovations that underpin widespread software and tech applications in the digital age.
- **Produce further cross-country and cross-sector evidence** as well as analytical work **on management quality and its impact** on business productivity.

Economic competencies, such as management quality, organisational structure and workforce training, are essential ingredients for reaping the full productivity benefits from investments in both tangible and other intangible assets, especially in a fast-changing world. As highlighted in Chapter 2 - Changing innovation dynamics in the age of digital transformation, because of digitalisation, innovation is moving at an unprecedented speed. In such a fast-changing world, organisations need to increasingly adapt and create structures that are flexible enough to accommodate new market and technology trends that could put them in the lead in the new era. This includes building a company culture that promotes 'resilience in discomfort', allowing for experimentation, collaboration, creativity and critical thinking and, if necessary, acquiring new competences to cope with change. Managers play a key role in shaping just how strategic and agile an organisation is. In other words, good management provides a vision for the company, defines strategic objectives and the right incentive structure to guide and motivate the workforce. In this context, higher management quality has been documented to be productivity-enhancing for a company (see, for example, Bloom, Sadun and Van Reenen, 2016). In addition, management quality correlates positively with both larger ICT adoption rates and productivity resulting from using ICT capital (see, for example, Andrews et al. (2018)). Furthermore, the uptake of advanced technologies affects the production process workflow and the relative costs of acquiring or communicating information, which implies that implementing such technologies often needs organisational innovations that match technological innovation (OECD, forthcoming). In this respect, skills and competences should be aligned with the production process and the changes it may be subject to. Thus, training and preparing the workforce is essential.

The so-called 'economic competencies' include brand aspects (advertising and market research), knowledge embedded firm-specific human capital and organisational capital following the framework in Corrado et al. (2005), as represented in Figure 5.3-1. This chapter highlights the importance of exploring complementarities between economic competencies and other intangible and tangible assets for firm performance and productivity. These competencies relate to the resilience and agility of teams and companies to recognise and embrace the opportunities brought by new technologies. Stehrer et al. (2019) analysed the role of these supplementary intangibles and found that economic competencies (which are outside the boundaries of national accounts) have a statistically significant impact on growth, which is robust both before and after the crisis and more visible in business services than in manufacturing.

Figure 5.3-1 Visual representation of different economic competencies



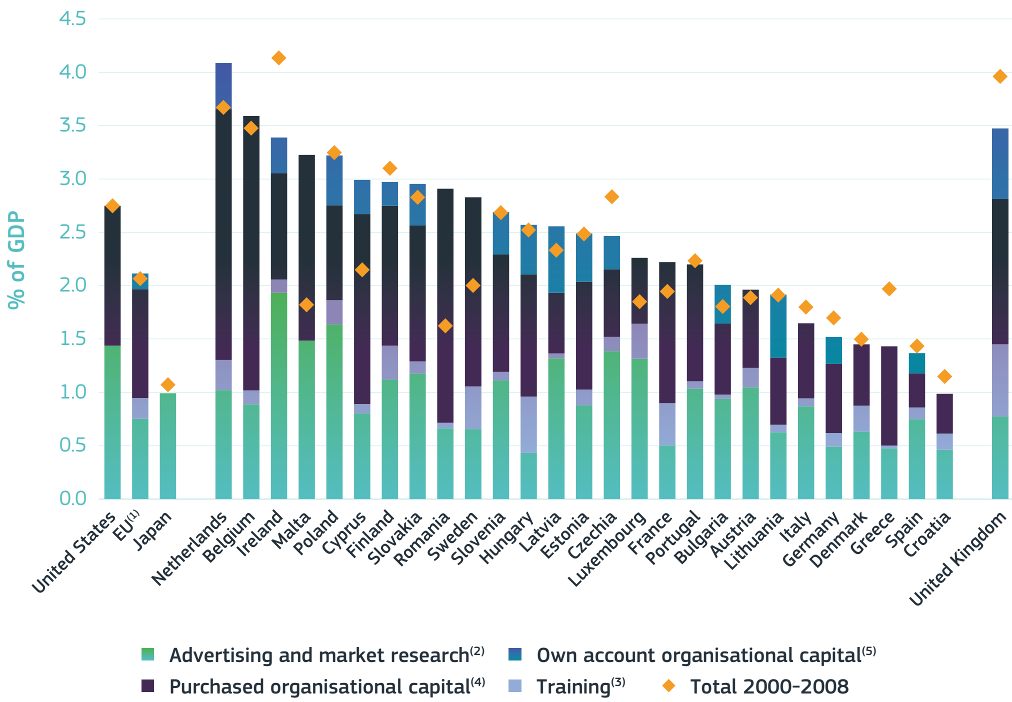
Science, research and innovation performance of the EU 2020
Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Corrado et al. (2015)
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter53/figure-53-1.xlsx

1. Europe appears to underinvest in economic competencies relative to the United States despite the positive contribution of these intangibles for growth

The United States appears to outperform the EU in investing in economic competencies. Moreover, intra-EU differences persist which may hinder future productivity developments and exacerbate innovation inequalities. Figure 5.3-2 compares countries in terms of gross fixed capital formation in economic competencies – purchased and own-account organisational capital, brand aspects (advertising and market research) and (vocational) training – as a percentage of GDP over the periods 2000-2008 and 2009-2017. Overall, relative investments in these supplementary intangibles seem to have slightly increased in the EU as a whole, although this only appears to be the case in half of the EU Member States. Despite this increase, the United States still outperforms the EU with aggregate investments in advertising and market research and organisational capital of 2.8 % of GDP compared to only 2.1 % in the EU in the period 2009-2018. Heavier investments in relative terms by US companies to promote their brands contribute to this gap.

Within the EU, the highest shares of investments in economic competencies are in the Netherlands, Belgium, Ireland, Malta and Poland where investments were higher than 3 % of GDP between 2009 and 2017. The United Kingdom also stands out as a top investor in economic competencies in Europe, investing 3.5% of GDP. On the contrary, the shares of investments were lowest (below 1.5% of GDP) in Croatia, Spain, Greece and Denmark. Relative investments in brand equity were the largest in Ireland where large multinational companies are also present. In addition, Hungary had the largest relative investments in training, while purchased organisational capital investments were the highest in relative terms in Belgium. These intra-EU disparities call for an assessment of the bottlenecks to firm investments in the lowest-investing countries. This is crucial to boost both absorption capacity and the uptake of new, productivity-enhancing technologies.

Figure 5.3-2 Investment in economic competencies as a percantage of GDP, 2009-2017 with breakdown and total for 2000-2008



Science, research and innovation performance of the EU 2020

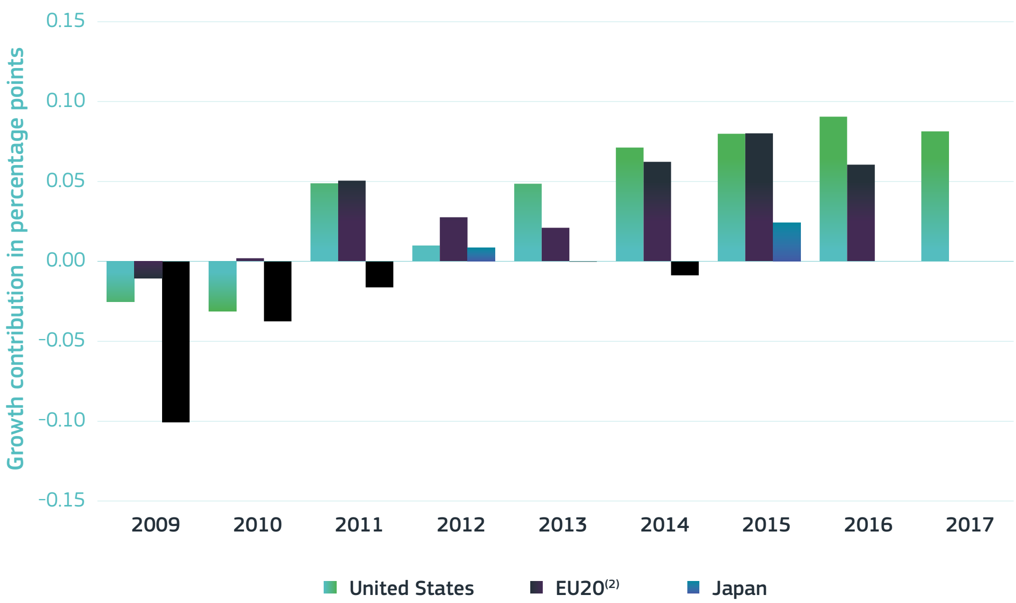
Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on EU KLEMS 2019 (analytical database)

Notes: [1]EU was estimated by DG Research and Innovation. [2]JP: 2009-2015; HR: 2009-2016. [3]Data not available for US, JP and MT. HR, UK: 2009-2016. [4]Data not available for JP. HR: 2009-2016. [5]Data not available for US, JP, BE, DK, EL, FR, HR, IT, LU, MT, AT, PT, RO and SE. UK: 2009-2016.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter53/figure-53-2.xlsx

Overall, the contribution of economic competencies to both economic growth and productivity growth has increased over time in Europe. When looking at the contribution of economic competencies as a whole to value-added growth as well as labour productivity growth per hour worked, it is possible to observe that overall it has increased since 2009 (Figure 5.3-3 and Figure 5.3-4, respectively) even though the contribution remains small when compared to other assets (see, for example, Chapter 3.1. Productivity puzzle and innovation diffusion). Stehrer et al. (2019) found a statistically *significant role tangible ICT and intangible economic competencies play in facilitating both value-added growth and labour productivity growth*. In 2015, a one percentage point increase in economic competencies resulted in almost a 0.1 percentage point increase in value added and productivity growth in the EU. Moreover, when compared to the United States and Japan, it seems that the contribution of economic competencies to labour productivity growth remained more resilient and stable in Europe as the post-crisis period appears to have had a less favourable effect in the United States and Japan than in Europe.

Figure 5.3-3 Contribution of intangible economic competencies[(1)] to value-added growth in the EU, United States and Japan in percentage points, market economy, 2009-2017

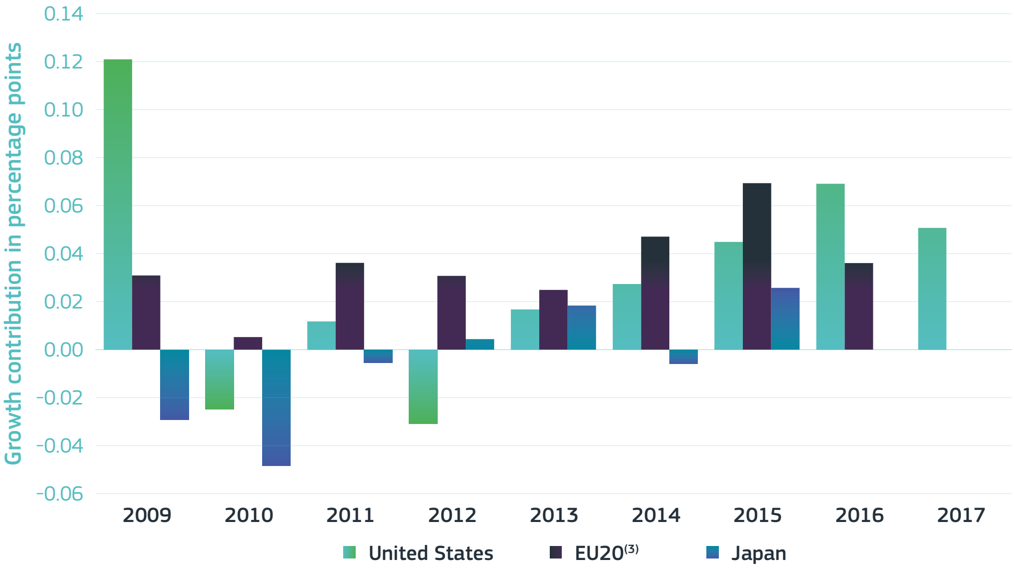


Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on EU KLEMS 2019 (analytical database)

Notes: [(1)]Economic competencies include: advanced and market research, purchased organisational capital, and (vocational) training. [(2)]EU20 average includes BE, CZ, DE, DK, EE, ES, FR, IT, LV, LT, LU, HU, NL, AT, RO, SI, SK, FI, SE and UK.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter53/figure-53-3.xlsx

Figure 5.3-4 Contribution of intangible economic competencies[1] to labour productivity growth[2] in the EU, United States and Japan in percentage points, market economy, 2009-2017



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on EU KLEMS 2019 (analytical database)

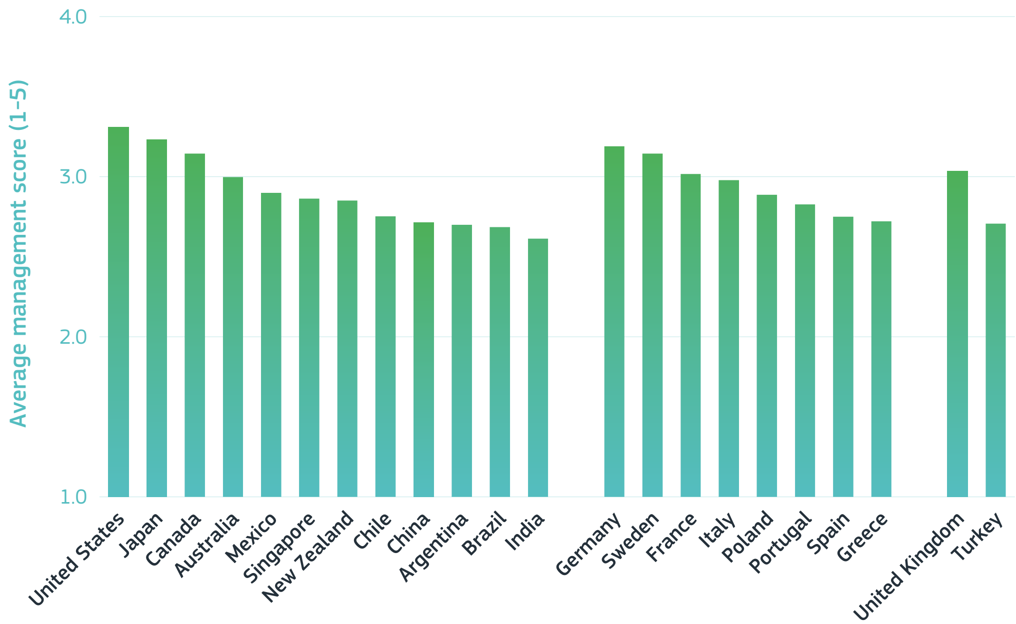
Notes: [1]Economic competencies include: advanced and market research, purchased organisational capital, and (vocational) training. [2]Labour productivity growth is measured as value added per hour growth. [3]EU20 average includes BE, CZ, DE, DK, EE, ES, FR, IT, LV, LT, LU, HU, NL, AT, RO, SI, SK, FI, SE and UK.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter53/figure-53-4.xlsx

Stronger management capabilities can foster the adoption of new productivity-enhancing technologies and thus help to cope faster with change within an organisation. Research points to the existence of differences in management quality across countries, although more recent and wider cross-country coverage is needed. Bloom and Van Reenen (2016) put forward the idea that some forms of management practices can be seen as a '*technology*', since they can be instrumental in increasing total factor productivity (TFP). OECD (forthcoming) lists other studies that have found that the *dispersion in managerial practices can account for up to one third of TFP differences between countries and across firms within countries*. Bloom et al. (2019) investigated management practices in US manufacturing plants and found a large dispersion of management across plants. In addition, the authors concluded that these management practices explained more than 20 % of the variation in productivity, *a similar, or greater, percentage than that accounted for by R&D, ICT, or human capital*. Finally, right-to-work laws and learning spillovers were found to improve management scores.

Overall, management quality in the manufacturing sector was found to be higher in the United States, Japan, Canada, Germany and Sweden. At the same time, there seems to be room for improvement in how businesses are managed in southern Europe, notably in Greece, Spain and Portugal (Figure 5.3-5). Unfortunately, the availability of cross-country and comparable data on management practices is still limited, which means more research is needed to identify and address bottlenecks in management quality in Europe.

Figure 5.3-5 Average management scores in manufacturing by country, 2004-2014



Science, research and innovation performance of the EU 2020

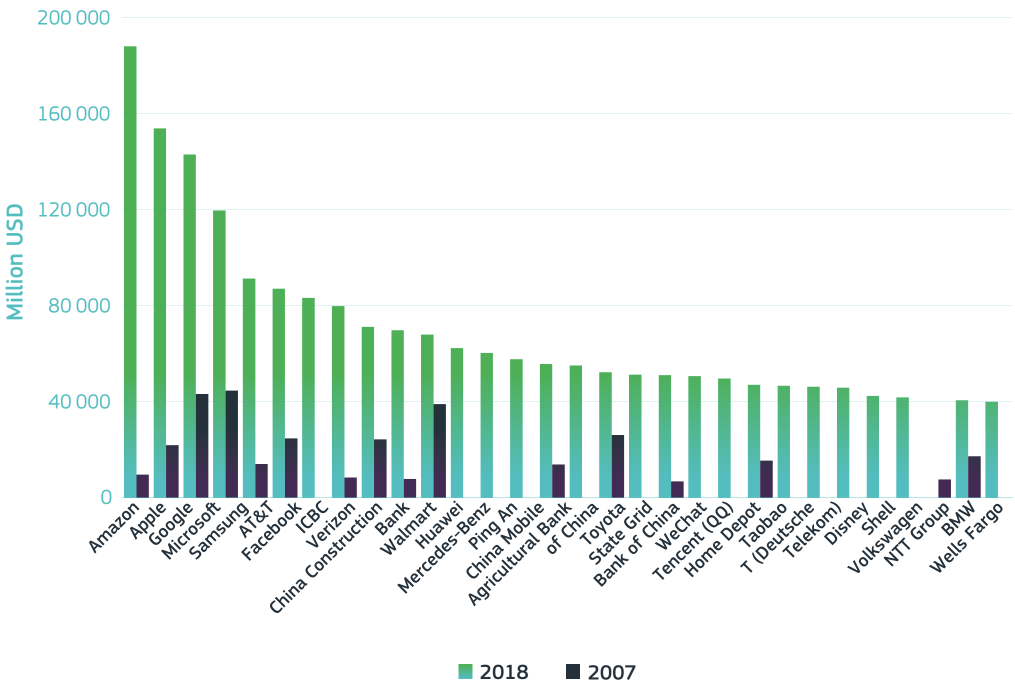
Source: Bloom, N., Sadun, R., & Van Reenen, J. (2016)
Note: Unweighted average management scores; all waves pooled (2004-2014): management scores are between 1 and 5.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter53/figure-53-5.xlsx

2. Efforts to promote 'made in EU' brands on the global scene lag behind international competitors

Brand strength and recognition is increasingly bringing value to companies by boosting customers' loyalty and attracting new ones. As indicated in Corrado (2005), firms can increase their brand equity by advertising their brands or by researching the market. This is an important strategy to ensure consolidation of the customer' base and to work towards expanding it. In addition, digital firms care as much (if not more) about their brand since the pace of change is unprecedented due to digitalisation. As noted in Blix (2015), speed in building brand recognition and consumer loyalty is essential for the survival of digital firms especially because services in some areas may be very similar and the need to stand out from the competition may therefore be even stronger.

Over time, there has been an enormous rise in brand value, especially among companies operating in the digital and tech space. Figure 5.3-6 highlights the remarkable increase in brand value between 2007 and 2018, in this case in the top 30 most valuable brands. In particular, it is interesting to see that some companies like Amazon were not in the top 30 in 2007, while the company's brand was the leader in value in 2018, with the brand value increasing by 1 856% in just one decade. Moreover, Facebook was created in 2004 and has made it into the top most-valuable brands. Others, such as Huawei, were not in the list of most valuable brands in 2007 but became highly valuable in 2018. The EU is mainly represented in the rankings by companies in the automotive and oil industry from Germany and the Netherlands.

Figure 5.3-6 **Brand value change in the top 30 most valuable brands in 2018 relative to their value in 2007**



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Brand Finance- Global 500 2019 and Brand Finance - Global 500 2008

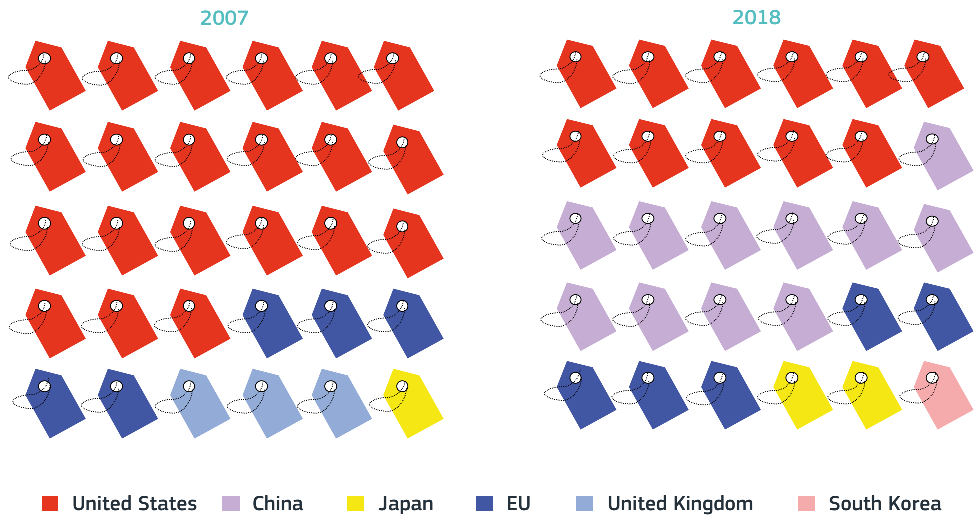
Note: Brand value is the net present value of the estimated future cash flows attributable to the brand. Brands are ranked by brand value according to Brand Finance methodology.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter53/figure-53-6.xlsx

When focusing on the European market only, the EU's top 20 most valuable brands only include two technology companies. Statista (2019)[1] shows that besides the automotive and oil industries which dominate the top 10 EU most valuable brands, only Bosh and Siemens (both from Germany) represent technology companies in the top 20. This contrasts with the reality in the United States where tech companies such as Apple, Google, Amazon, Microsoft, Facebook and IBM dominate the top 10[2].

Today, most of the 'top 30 brands' are found in the United States and China. Figure 5.3-7 shows the distribution of the top 30 brands by brand value in 2007 and in 2018, according to Brand Finance. While in 2007 the top valuable brands were found in the United States (21 out of 30), in 2018, Chinese brands were also leading in brand value. In particular, in 2018, both the United States and China each had 11 brands in the top 30, compared to only five in the EU (Mercedes-Benz, Deutsche Telecom, Shell, Volkswagen, BMW) – i.e. four from Germany and one from the Netherlands. Tech companies dominate the top 10 brands, most coming from the United States.

Figure 5.3-7 **Geographical distribution of the 'top 30 brands'(1), 2007 and 2018**



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Brand Finance- Global 500 2019 and Brand Finance - Global 500 2008

Note: (1)Brand value is the net present value of the estimated future cash flows attributable to the brand. Brands are ranked by brand value according to Brand Finance methodology.

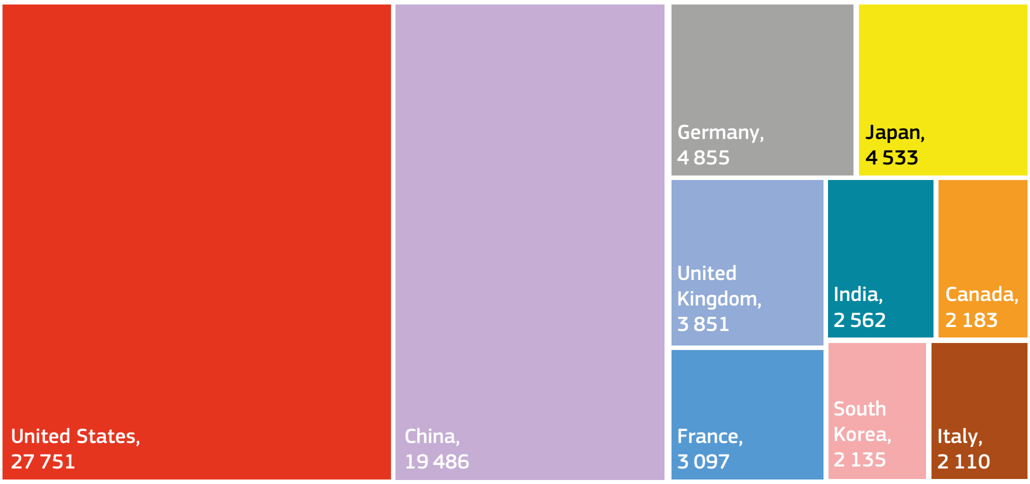
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter53/figure-53-7.xlsx

1 https://www.statista.com/statistics/643747/brand-value-of-the-leading-20-most-valuable-euro-brands/

2 https://www.statista.com/statistics/259061/10-most-valuable-north-american-brands/

The combined nation brand value is the largest in the United States, followed by China. In the EU, the brand value of German, French and Italian brands positions these three Member States in the top 10 most valuable nation brands. Cumulatively, US brands are worth more than USD 27 trillion, the largest value worldwide. This compares with around USD 19 trillion in China and USD 10 trillion in the EU which aggregates the brand value in Germany, France and Italy.

Figure 5.3-8 Most valuable nation brands worldwide in 2019, USD billion



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit, based on Statista and Brand Finance Nation Brands 2019, (https://www.statista.com/statistics/322423/most-valuable-nation-brands/)
Note: Brand Finance measures the strength and value of the nation brands of 100 leading countries using a method based on the royalty relief mechanism employed to value the world's largest corporate brands.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter53/figure-53-8.xlsx

Better communicating Europe's excellent science and innovation not only improves the public perception of science and technology but also contributes to a stronger 'EU identity' and the upgrade of the 'EU brand' on the global scene. As discussed in Chapter 6.1 - Scientific performance, Europe produces excellent science. In this context, communicating scientific results and their impact on society is key. Box 5.3-1 describes how the live showcase of the first-ever image of a black hole mobilised European and international attention. The image was taken by the Event Horizon Telescope, a global scientific collaboration involving EU-funded scientists. The Community Research and Development Information Service (CORDIS)[3] is the European Commission's primary source of results from the projects funded under the EU's Framework Programmes for Research and Innovation (FP1 to Horizon 2020). In this way, impactful projects and success stories of EU-funded research projects can be shared around the world. Horizon Europe will build upon the many achievements of its predecessors.

3 https://cordis.europa.eu/en

BOX 5.3-1 Communicating science: the first-ever image of a black hole taken by Event Horizon Telescope, unveiled live to the world by the European Commission

Extract from EC press release – First-ever image of a black hole, 10 April 2019

'(On 10 April 2019), the Commission revealed the **first-ever image of a black hole taken by Event Horizon Telescope, a global scientific collaboration involving EU-funded scientists**. This major discovery provides visual evidence for the existence of black holes and pushes the boundaries of modern science.

Black holes are extremely compressed cosmic objects, containing incredible amounts of mass within a tiny region. Their presence affects their surroundings in extreme ways, by warping spacetime and super-heating any material falling into it. The captured image reveals the black hole at the centre of Messier 87, a massive galaxy in the constellation of Virgo. This black hole is located 55 million light-years from Earth and has a mass 6.5-billion times larger than our sun.

This major scientific achievement marks a paradigm shift in our understanding of black holes, confirms the predictions of Albert Einstein's General Theory of Relativity and opens up new lines of enquiry into our universe. The first image of a black hole successfully captured was unveiled in six simultaneous press conferences across the globe today.

EU funding through the European Research Council (ERC) has provided crucial support to the EHT. In particular, the EU has provided funding for three of the leading scientists and their teams involved in the discovery, as well as supported the development and upgrading of the large telescope infrastructure essential to the success of the project.'

Many software and digital applications behind the widespread success of digital disruptive industries have some 'EU origin'. Box 5.3-2 illustrates three examples – Linux (open source programme), MP3 (audio and media format) and Python (programming language).

BOX 5.3-2 Communicating innovation: examples of EU innovations behind widespread digital products and services – Linux, MP3, Python

LINUX: created by Linus Torvalds (Finland)

Extract from https://en.wikipedia.org/wiki/History_of_Linux, hyperledger.org and https://opensource.com/article/19/8/everyday-tech-runs-linux

'In 1991, while studying computer science at **University of Helsinki**, Linus Torvalds began a project that later became the **Linux kernel**. He wrote the program specifically for the hardware he was using and independent of an operating system.

The **largest part of the work on Linux is performed by the community**: the thousands of programmers around the world that use Linux and send their suggested improvements to the maintainers. **Various companies have also helped not only with the development of the kernels, but also with the writing of the body of auxiliary software**, which is distributed with Linux. Some examples are Dell, IBM and Hewlett-Packard.

The **Open Source Development Lab** (OSDL) was created in 2000, as an independent non-profit organization which pursues the goal of optimizing Linux for employment in data centers and in the carrier range. On 22 January 2007, OSDL and the Free Standards Group merged to form The Linux Foundation, narrowing their respective focuses to that of promoting Linux in competition with Microsoft Windows.

Many companies, organizations and technologies run on Linux: NASA's Pleiades supercomputer, Amazon's services – from Amazon Elastic Compute Cloud (Amazon EC2) to Fire TV – SteamOS (gaming), Instagram, Facebook, YouTube, Twitter, New York Stock Exchange, the Pentagon, Apple's iCloud, Google's Chrome OS, Android, and many others.'

The Linux Foundation is also pioneering important developments in the field of blockchain. In particular, the Foundation hosts the 'Hyperledger' project – an open source and global collaborative effort created to advance cross-industry blockchain technologies.

Figure 5.3-9 Examples of software and applications running on Linux

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit, based on opensource.com and Wikipedia.org
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter53/figure-53-9.xlsx

MP3: developed by the Fraunhofer Institute (Germany)

Extracts from https://www.mp3-history.com/

'mp3 encodes and stores music. An mp3 file takes up just 10 percent of the storage space of the original file, meaning music can be quickly transferred over the Internet and stored on mp3 players.

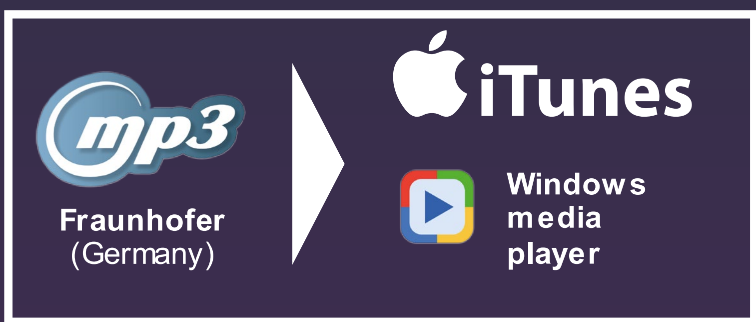
The idea for audio encoding and initial basic research in the field arose at Friedrich-Alexander University Erlangen-Nuremberg. Starting in 1987, a large team drawn from the university and the Fraunhofer Institute for Integrated Circuits IIS in Erlangen worked on developing the mp3 standard.

Marketing the new technology was just as important as its development in the late 1980s and early 1990s. Developers at **Fraunhofer** searching for mp3 technology applications came up with the **vision of portable music players that would allow music fans to store their entire music collections**. Though their ideas were initially ridiculed, the Fraunhofer team overcame the established industry's resistance and turned mp3 into a global success.

Fraunhofer does not sell any mp3 products to end users and does not provide end user support for mp3 devices and software. **iTunes (Apple) and Windows Media (Microsoft) integrate the Fraunhofer mp3 software**. In 2017, Technicolor's mp3 licensing program for certain mp3 related patents and software of Technicolor and Fraunhofer IIS has been terminated.

mp3 is more than a technology; mp3 is a cultural phenomenon and an example for successful research, development and marketing in Germany.'

Figure 5.3-10 Examples of audio and media applications running on MP3



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit, based on Fraunhofer

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter53/figure-53-10.xlsx

PYTHON: designed by Guido van Rossum (Netherlands)

Extracts from https://medium.com/@johnwolfe820/a-brief-history-of-python-ca2fa1f2e99e, https://en.wikipedia.org/wiki/Python_(programming_language

'Python is an interpreted, high-level, **general-purpose programming language**. It was originally conceptualized by Guido van Rossum in the late 1980s as a member of the **National Research Institute of Mathematics and Computer Science situated in the Netherlands**. Initially, it was designed as a response to the ABC programming language that was also foregrounded in the Netherlands. The language was released in 1991. Rather than having all of its functionality built into its core, Python was designed to be highly extensible. This compact modularity has made it particularly popular as a means of adding programmable interfaces to existing applications.

Since 2003, **Python has consistently ranked in the top ten most popular programming languages** in the TIOBE Programming Community Index where, as of December 2018, it is the third most popular language. It was selected **Programming Language of the Year** in 2007, 2010, and 2018. An empirical study found that scripting languages, such as Python, are more productive than conventional languages, such as C and Java, for programming problems involving string manipulation and search in a dictionary.

Large organisations that use Python include Wikipedia, Google, Yahoo!, CERN, NASA, Facebook, Amazon, Instagram, Spotify. The social news networking site Reddit is written entirely in Python.'

Figure 5.3-11 Examples of organisations using Python

Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit, based on medium.com and Wikipedia.org

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter53/figure-53-11.xlsx

3. Conclusions

Economic competencies are important complementary intangible assets to other intangibles, such as R&D, and to tangible assets like investments in machinery. For example, strategic management can lead to the uptake of novel technologies that can make a company lead in the future. Moreover, investing in the workforce's cognitive and soft skills makes organisations more resilient when coping with change. At the macro level, evidence shows that **economic competencies are indeed contributing to both labour productivity and economic growth**. As regards that growth-enabling role, the fact that the **EU underinvests in economic competencies relative to the United States** may limit its productivity growth.

Furthermore, the era of globalisation and digitalisation means fiercer competition than ever. Hence, companies better at boosting their reputation and marketing their products, services and business models are likely to attract a larger market share. For this reason, **the United States' clear leadership position in brand value, particularly in technology companies, means that the EU needs to step up its game and become better at promoting its brands on the global scene**. At the same time, it needs to reinforce its technology and digital leadership by enabling the right business environment for EU digital companies to flourish, which are also very R&D-intensive.

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CHAPTER 5.4

INVESTMENT IN ICT

KEY FIGURES

2%
share of ICT investments in GDP estimated in the EU

4%
share of the ICT sector in total value added in the EU

3%
share of employees in the ICT sector in the EU

17%
share of ICT patents in total EU patents

1 in 10
enterprises performs big data analytics in the EU

What can we learn?

- **Europe underinvests in ICT** compared to other major economies.
- The **ICT-producing sector's contribution to productivity growth in the EU has declined**. However, the **contribution from the most-intensive ICT-using industries to labour productivity growth has picked up** in recent years and is **above that of the United States**.
- **The weight of the ICT sector in the European economy has stabilised at around 4 %** of total value added, which is below other international players.
- Overall, **ICT employment has slightly increased in Europe** and ICT services are the key component.
- The **share of ICT patents in the EU patenting landscape is considerably smaller** than among its international competitors.
- Although an **intra-EU gap persists in digital competitiveness, laggard countries are catching up**.
- **Company size seems to matter for firms' digital transformation** and differences are striking in some EU Member States.
- **ICTs can provide solutions to address climate change**. At the same time, R&I is key to reducing the global footprint of ICT – R&I for 'green ICT'.

What does it mean for policy?

- **Boost the level of investments in ICT** and the convergence of ICT with other 'physical' technologies.
- **Accelerate ICT diffusion**, including digital competencies, skills, technologies, and access to infrastructure across sectors, firms and individuals, in an inclusive manner.
- **Prioritise funding for R&I solutions to improve the energy** efficiency of data centres, high-performance computers, infrastructure of telecommunications, etc.

The expansion of ICT has enabled the digital revolution and contributed to productivity and economic growth. ICTs can also provide solutions for sustainable growth. At the same time, there is still room to improve ICT diffusion across sectors, firms and individuals in an inclusive way. Information and communication technologies (ICTs) play an important role in economic growth and in transforming societies by connecting ideas and people all over the world. ICT boosts firms' productivity by improving communication, enabling knowledge management and reducing production costs. Moreover, the use of ICT may create network effects across sectors, lower transaction costs and increase the speed of innovation, which can boost overall economic efficiency and thus total factor productivity (Pilat, 2004). In addition, technological progress leading to new ICT goods and services can also enhance productivity growth in the ICT sector. Furthermore, ICT can bring social benefits by allowing generalised access to information and knowledge, while bringing people together even if they are geographically apart. The use of ICTs can also be determinant for achieving the Sustainable Development Goals (SDGs) in areas such as energy efficiency, water management and in supporting the overall transition to a low-carbon economy. ICT-related projects are also an important part of EU Framework Programmes to spur R&I in ICT[1] in Europe.

However, ICT diffusion has not happened at the same pace across firms and individuals. The gap between frontier and laggard companies remains large (although there is some catching-up), which is partly explained by the insufficient diffusion of innovation, notably digital technologies (see Chapter 3.1- Productivity puzzle and innovation diffusion). At the same time, the access, adoption and uptake of digital technologies has yet to become widespread across individuals which illustrates the need to continue the efforts to make the access to ICT more inclusive. Skills and, in particular, digital skills are crucial to navigate this new paradigm. Chapter 5.2 - Investment in education, human capital and skills analyses differences across the EU in this respect.

In this chapter, we look at trends in ICT investment and its contribution to growth. Moreover, an analysis of the evolution of the ICT-producing sector, notably its value-added contribution, employment, innovation and R&D intensity, is provided alongside some reflections for policy.

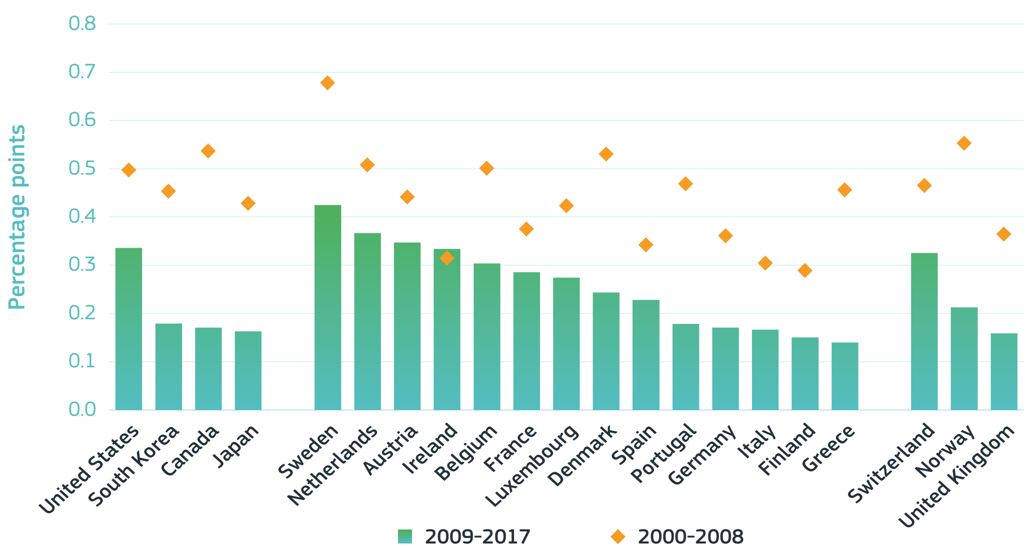
1 https://ec.europa.eu/digital-single-market/en/research-development-scoreboard

1. Europe underinvests in ICT

ICT capital deepening contributes to economic growth, although its contribution seems to have decreased in the last decade. The OECD (2016) points to the drop in ICT price relative to GDP price. Moreover, research shows a significant contribution from ICT to growth; the major impact on productivity occurred between 1995 and 2005 but the diffusion of ICT seems to have stabilised now. van Ark (2016) put forward the idea that we currently live in the 'installation phase' of the new digitalisation wave, which may imply that its impact on productivity may be 'on hold' until we effectively enter the 'deployment phase' of these digital technologies. Figure 5.4-1 provides a comparison between the contribution of ICT capital-deepening to GDP growth between 2000 and 2008, and 2009 and 2017. Overall, its contribution has declined worldwide. Similarly, Adarov and Stehrer (2019) found a declining role of ICT assets in growth across Japan, the United States and the EU15 as a whole.

In the EU, over the period 2009-2017, the contribution was the highest in Sweden, the Netherlands and Austria, and the lowest in Italy, Finland and Greece (of those Member States with available data). Ireland was the only EU Member State where the contribution from ICT capital has actually increased in recent years. Within the major economies listed below, the United States seems to be the economy where the slowdown was least pronounced, which could be evidence of greater ICT diffusion in the country in line with the OECD (2016).

Figure 5.4-1 Contribution of ICT capital[1] to GDP growth (percentage points), average over 2000-2008 and 2009-2017



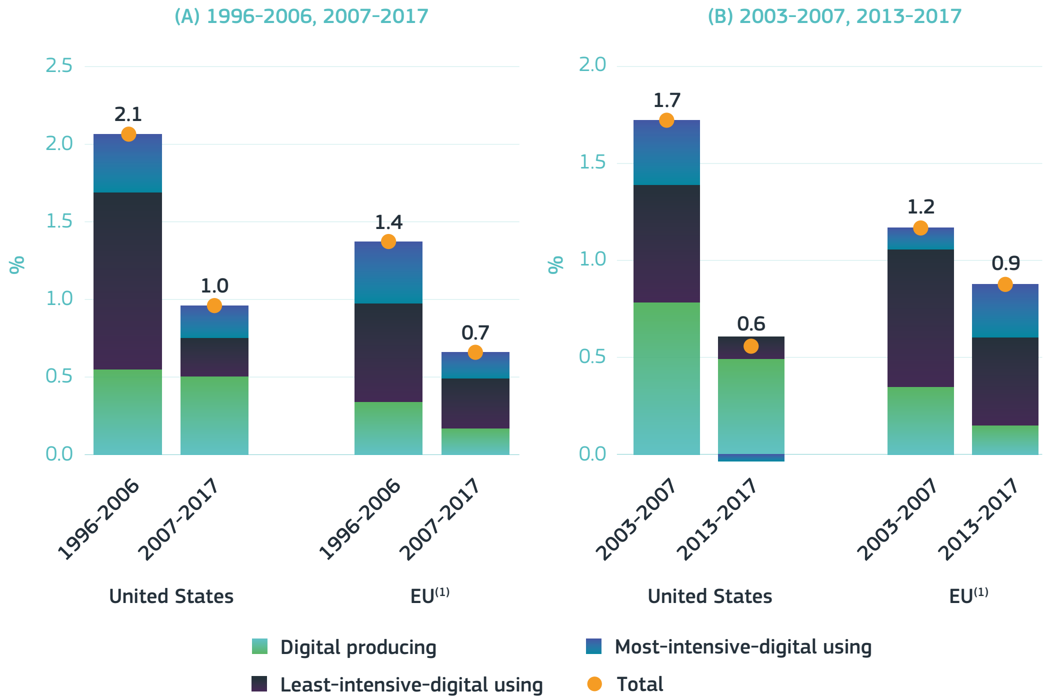
Source: OECD Productivity Database

Note: [1]ICT capital includes computer hardware, telecommunications equipment, and computer and software databases.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter54/figure-54-1.xlsx

However, new research shows that Europe appears to have an advantage compared to the United States in the most-intensive ICT-using sector, which accounts for the largest contribution to labour-productivity growth in recent years. van Ark et al. (2019) look at the contributions of ICT-using and ICT-producing sectors to labour-productivity growth over time in 19 EU Member States and in the United States. Overall, the authors found that the contribution from the digital-producing sector to productivity growth has declined in the EU and, to a lesser extent, in the United States (Figure 5.4-2). However, in recent years in the EU, the contribution to growth in labour productivity in ICT-using sectors seems to have picked up, notably over the period 2013-2017. In fact, the most-intensive digital-using sectors make the largest contribution to labour-productivity growth in the EU. On the contrary, in the United States, the role of ICT-using sectors for productivity has declined in a very pronounced way, while the ICT-producing sector has not seen a marked decline (as is the case in the EU). Thus, the authors suggest that Europe has an opportunity from its ICT-using sectors to boost productivity growth while, in the United States, the ICT-producing sector, including the big 'tech' companies, may be making use of many of the available resources that could be limiting extending productivity benefits to the ICT-using sectors in the country.

Figure 5.4-2 Labour productivity growth and contributions from digital-producing and most- and least-intensive-using sectors, in %



Science, research and innovation performance of the EU 2020

Source: van Ark et al. (2019), Conference Board calculations using data from Eurostat; BEA; BLS

Notes: [1]EU aggregate is based on 19 countries and euro area aggregate on 16 countries, as data for BG, EE, IE, HR, CY, LV, LT, LU and MT were not available for the entire period. Taxonomy for the identification of sectors defined as in Bart van Ark et al. (2019). Labour productivity growth concerns the growth of output per hour.

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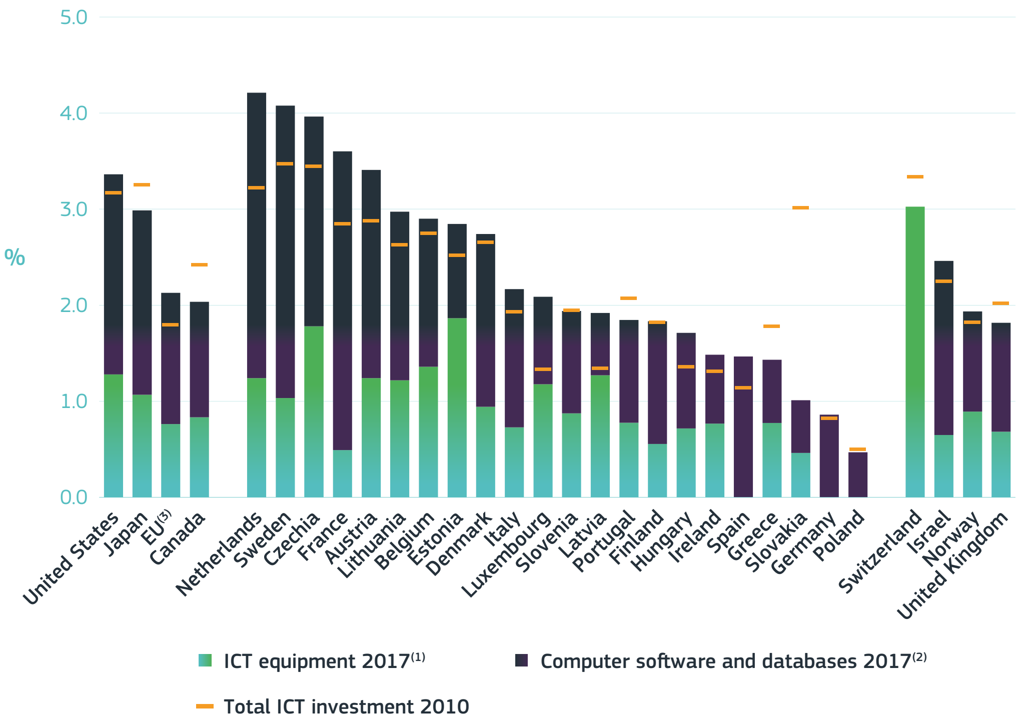
The EU underinvests in ICT in comparison with other major economies such as the United States and Japan, even though estimates point to an increase in the share of ICT investments in GDP more recently. Figure 5.4-3 depicts the evolution of ICT investments by country – i.e. the sum of ICT equipment and computer software and databases. Estimates for the EU aggregate show that Europe invests less as a percentage of GDP than its international competitors, notably the United States and Japan. Indeed, in 2017, the EU invested around 2% of GDP in ICT compared to almost 3.5% in the United States and 3% in Japan. However, it is important to mention that compared to 2010, there has been an increase in the share of ICT investments in GDP in the EU while, for example, there has been a relative decline in Japan and Canada.

Member States that invested the most are the Netherlands, Sweden and Czechia, at around 4% of GDP. Overall, the share of ICT investments in GDP increased between 2010 and 2017 in most EU Member States, the exceptions being Portugal, Greece and Slovakia.

Figure 5.4-3 Investment in ICT as % of GDP by country, 2010 and 2017



Science, research and innovation performance of the EU 2020

Source: OECD (Capital formation by activity ISIC Rev4) and Eurostat (online data code: nama_10_gdp)

Notes: (1)DK: 2015. LV, NO: 2016. (2)DK, EE, EL, PL: 2015. IE, ES, LV, PT, SE, NO: 2016. (3)EU value estimated with the available countries. The number of countries is not the same in both categories.

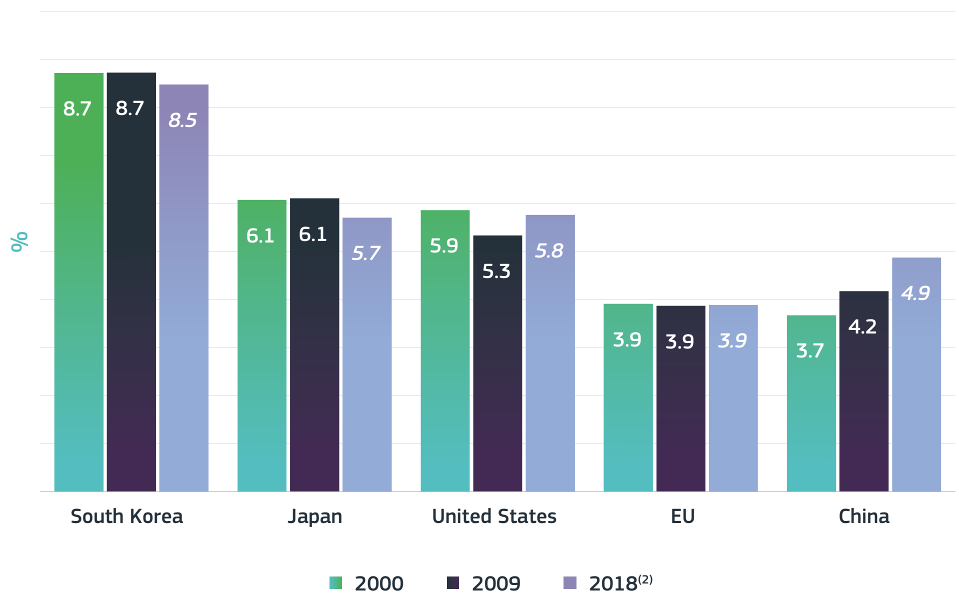
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter54/figure-54-3.xlsx

2. The ICT sector in Europe: weight stable over time, increasing employment share, less R&D-intensive, less productive, and lower patenting activity than other global players

Value added

Since 2000, the weight of the ICT sector in the European economy has stagnated at close to 4% of GDP, a much lower contribution than in South Korea, Japan and the United States. Whilst in most major economies ICT value added has more or less stabilised, in China it has been on the rise since 2000. In the EU, the weight of the ICT sector stabilised at 3.9% of GDP between 2000 and 2018, compared to a much higher share of over 8.5% in South Korea and around 6% in Japan and in the United States (Figure 5.4-4). The value added in ICT in China increased remarkably from 3.7% of GDP in 2000 to 4.9% in 2018.

Figure 5.4-4 Value added in ICT as % of GDP by region[1], 2000, 2009 and 2018



Science, research and innovation performance of the EU 2020

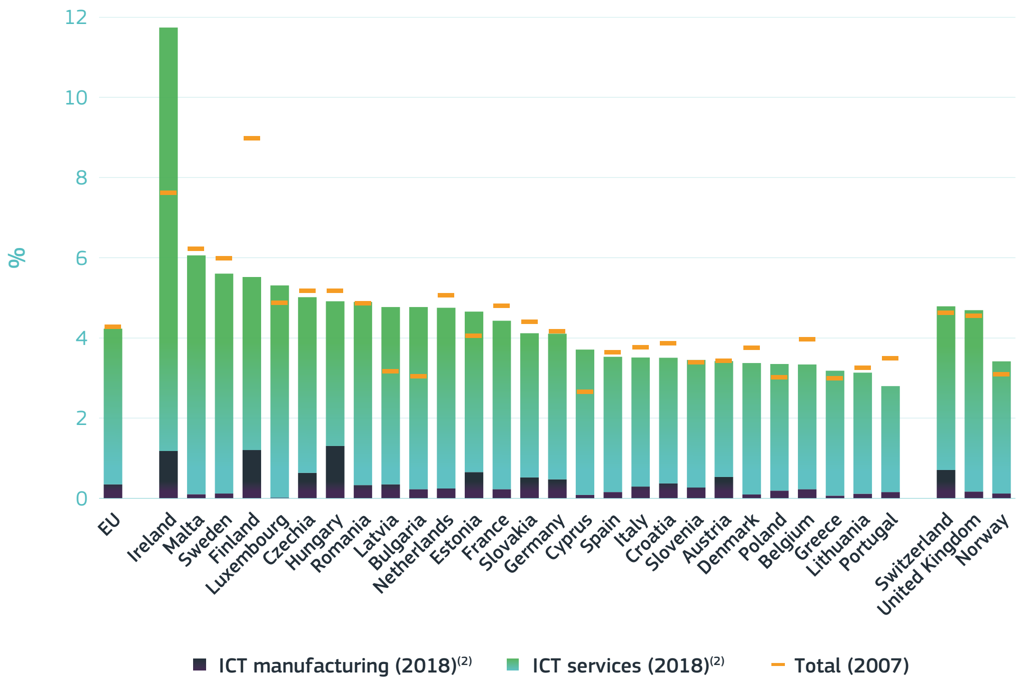
Source: DESI report ICT Sector and its R&D Performance, PREDICT project

Notes: [1]The operational definition of ICT, as defined in the PREDICT project, was used. The operational definition of ICT allows for international comparison with non-EU countries. [2]CN: 2016, JP: 2017.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter54/figure-54-4.xlsx

In most EU Member States, the share of value added in ICT as a share of GDP has slightly declined over the last decade. ICT services are the key components of the ICT sector. Figure 5.4-5 shows the evolution of the ICT sector (manufacturing and services) by country between 2007 and 2018. Ireland stands out as the EU Member State with the highest ICT share – of almost 12% of GDP – in the country. The Member States with the lowest share of ICT were Greece, Lithuania and Portugal. ICT services is the most important component of the ICT sector in all countries. ICT manufacturing had the highest share in Hungary, Ireland and Finland.

Figure 5.4-5 Value added in ICT[1] as % of GDP broken down by manufacturing and services, 2018 (and for 2007 without breakdown)



Source: DESI report ICT Sector and its R&D Performance, PREDICT project

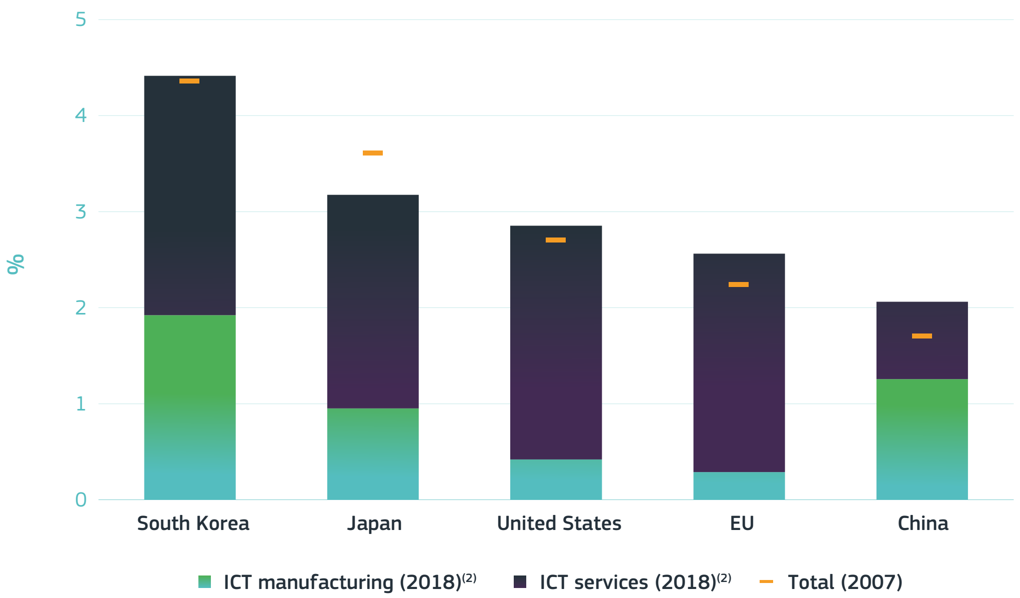
Notes: [1]The comprehensive definition of ICT, as defined in the PREDICT project, was used. [2]IE: 2014; NO, CH: 2015.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter54/figure-54-5.xlsx

Employment

The ICT sector employs the most people in South Korea, followed by Japan, the United States, the EU and, finally, China. In the EU, the share of employment in the ICT sector rose between 2007 and 2018. The relevance of ICT value added in the economy was previously demonstrated as being highest in South Korea and, in 2018, was also visible in terms of employment contribution of around 4.5% of the country's total employment (Figure 5.4-6). It is also important to note the relevant size of ICT manufacturing. Japan comes next with slightly more than 3% of its active population employed in the ICT sector, although the share has declined relative to 2007. The United States, the EU and China have seen increases in the importance of the ICT sector in employment over the last decade. In 2018, the EU's ICT share in employment was around 2.5% compared to around 2.8% in the United States and slightly more than 2% in China. In both the EU and the United States, ICT services are the leading employer within the ICT sector, while in China, ICT manufacturing stands out as the top sector.

Figure 5.4-6 Employment in ICT[1] as % of total employment broken down by manufacturing and services, 2018 (and for 2007 without breakdown)



Science, research and innovation performance of the EU 2020

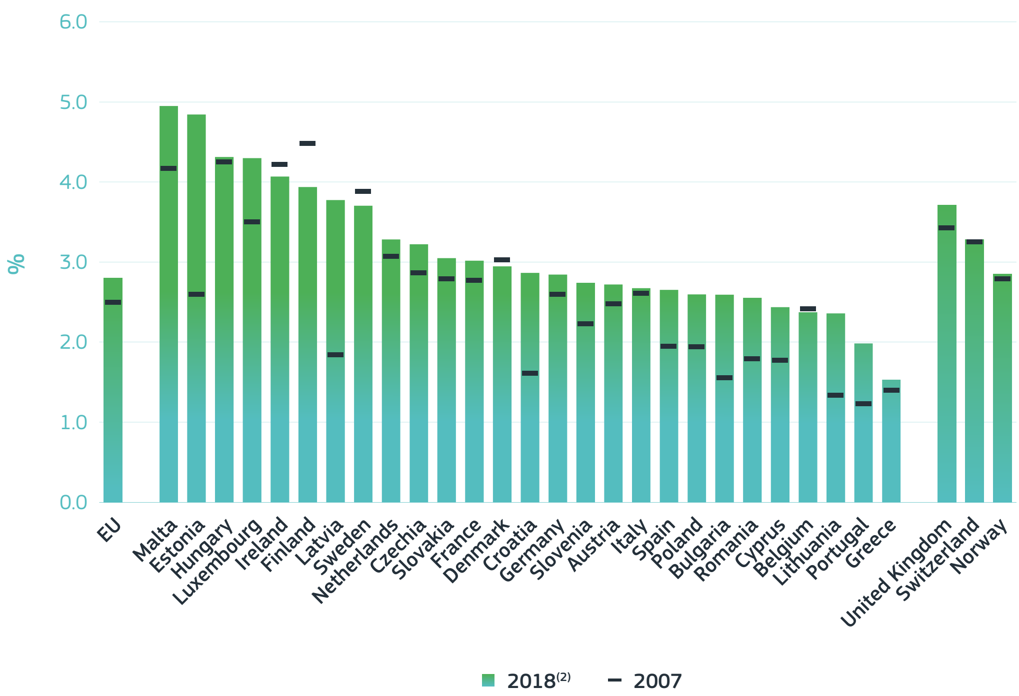
Source: DESI report ICT Sector and its R&D Performance, PREDICT project

Notes: [1]The operational definition of ICT, as defined in the PREDICT project, was used. [2]CN: 2016; JP: 2017.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter54/figure-54-6.xlsx

Employment in the ICT sector increased in most EU Member States between 2007 and 2018. Malta, Estonia, Hungary, Luxembourg and Ireland have the highest shares of ICT employment, at above 4% of total employment (Figure 5.4-7). On the other hand, in 2018, in Greece, Portugal, Lithuania and Belgium the role of the ICT sector in employment was the lowest, with less than 2.5% of employment. This is partly correlated with the economic structure, as previously noted that the size of the ICT sector in terms of value added in these economies was also smaller in relative terms. With the exception of Ireland, Finland, Sweden, Denmark and Belgium, all the other EU Member States maintained or even increased their employment shares in the ICT sector between 2007 and 2018.

Figure 5.4-7 Employment in ICT[1] as % of total employment, 2007 and 2018



Science, research and innovation performance of the EU 2020

Source: DESI report ICT Sector and its R&D Performance, PREDICT project

Notes: [1]The comprehensive definition of ICT, as defined in the PREDICT project, was used. [2]NO, CH: 2016.

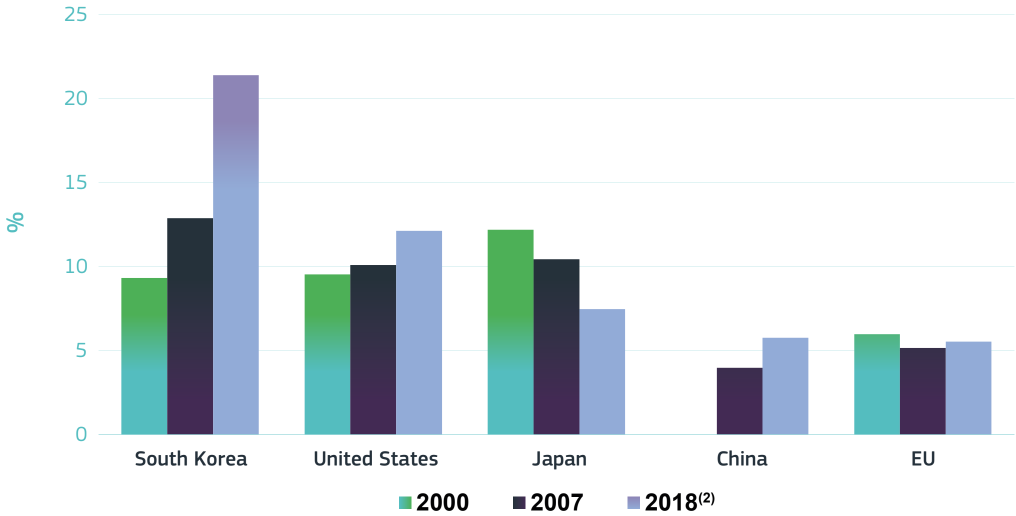
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter54/figure-54-7.xlsx

R&D intensity

The ICT sector is considerably less R&D intensive in the EU than among other international players, notably South Korea but also the United States and Japan. Figure 5.4-8 presents the evolution of business enterprise expenditure on R&D as a percentage of the value added of the ICT sector in 2000, 2007 and 2018 by major economy. The ICT sector is the most R&D intensive in South Korea where R&D intensity has been on the rise since 2000. The United States comes next, also showing slight increases in the R&D intensity of the ICT sector over time. In Japan, R&D intensity has been on the decline since 2000, although it was still above that of the EU in 2018.

In the EU, the R&D intensity of the ICT sector was the highest in Finland, Austria and Sweden. 'Innovation leaders', namely Finland, Sweden and Denmark, and 'strong innovators', such as Austria and France, rank highest in terms of their ICT industries' R&D intensity in 2018. At the lower end of the spectrum are Latvia, Luxembourg, Croatia, Lithuania and Romania (Figure 5.4-9). Norway stands out an H2020 associated country with a very high R&D intensity in the ICT sector (for which data are available), close to that of Finland.

Figure 5.4-8 Business R&D intensity of ICT[(1)], 2000, 2007, 2018



Science, research and innovation performance of the EU 2020

Source: DESI report ICT Sector and its R&D Performance, PREDICT project

Notes: [(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 definition of ICT allows for international comparison with non-EU countries. [(2)]CN: 2016; JP: 2017.

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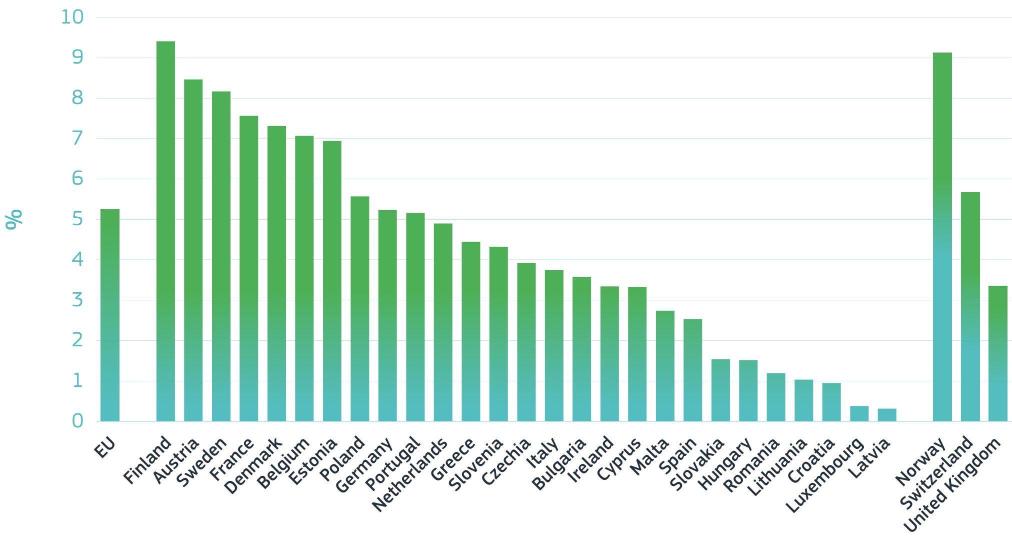
Figure 5.4-9 Business R&D intensity of ICT[(1)], 2018[(2)]



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Source: DESI report ICT Sector and its R&D Performance, PREDICT project

Notes: [(1)]Business enterprise expenditure on R&D as % of value added. The comprehensive definition of ICT, as defined in the PREDICT project, was used. [(2)]CH: 2015; IE: 2014; NO: 2016.

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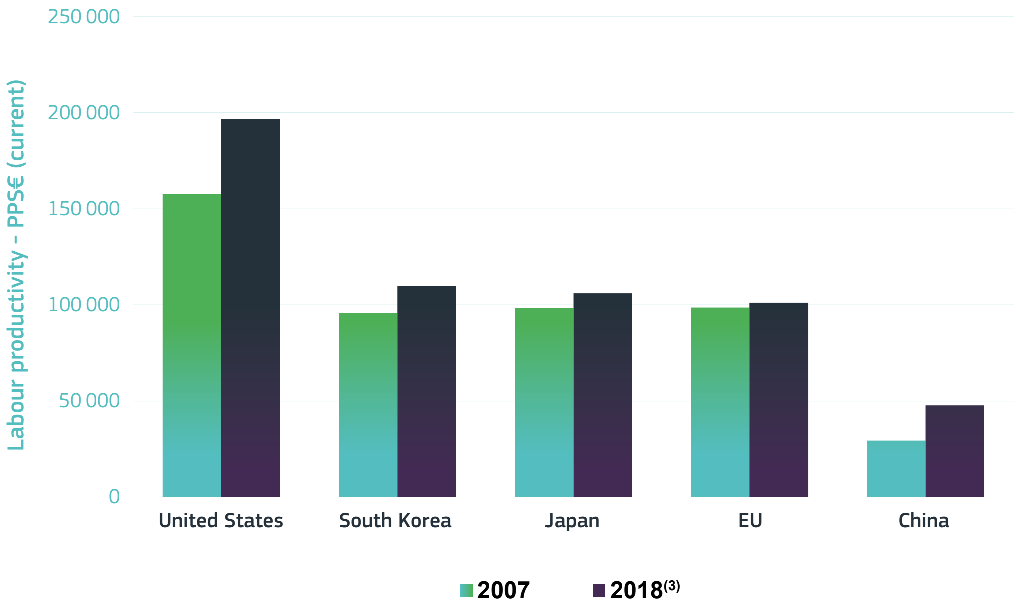
Productivity

The ICT sector is more productive in the United States, South Korea and Japan than in the EU. Figure 5.4-10 compares the evolution of labour productivity in the ICT sector between 2007 and 2018 by major economy. Relative to 2007, all economies have increased productivity levels in this sector, except for the EU where it seems to have stabilised. In 2018, labour productivity was the highest in the United States, followed by South Korea, Japan, and the EU. China seems to have the least-productive ICT sector (from the economies presented in the graph) even though labour productivity has risen considerably in just over a decade.

Figure 5.4-10 Labour productivity (GDP per person employed)[1] in ICT[2], 2007 and 2018



Science, research and innovation performance of the EU 2020

Source: DESI report ICT Sector and its R&D Performance, PREDICT project

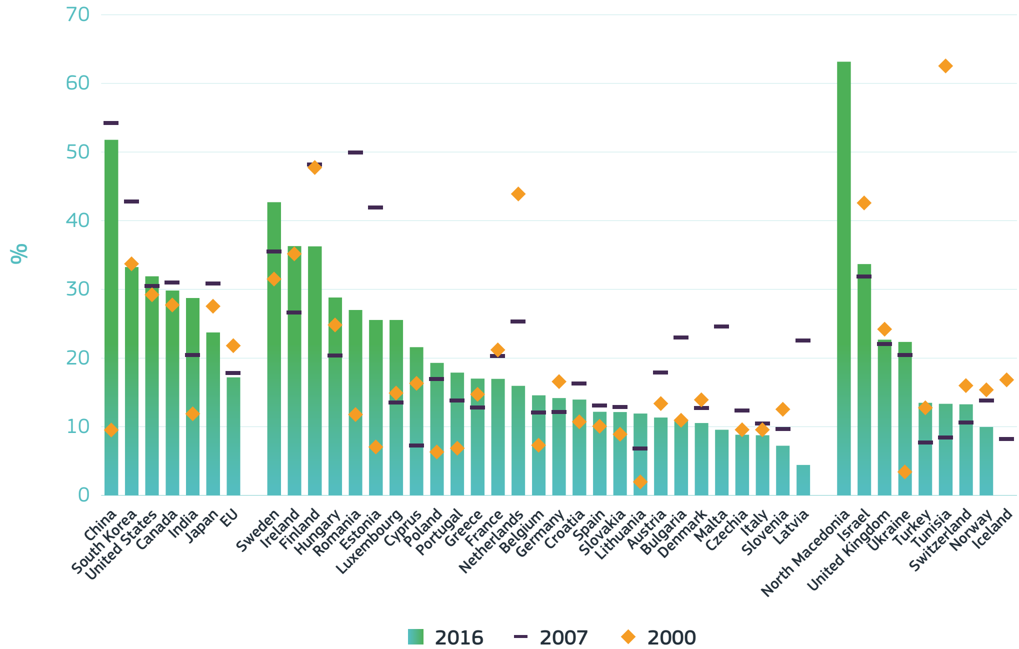
Notes: [1]GDP per person employed in current PPS€. [2]The operational definition of ICT, as defined in the PREDICT project, was used. The operational defintion of ICT allows for international comparison with non-EU countries. [3]CN: 2016; JP: 2017.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter54/figure-54-10.xlsx

Patenting activity

The EU seems to trail behind other major economies when it comes to the relative innovativeness of the ICT sector. Figure 5.4-11 illustrates a means of representing the innovativeness of the ICT sector by looking into the evolution of the share of ICT-related patent applications, although there are certainly other ways. Major economies, such as China, South Korea, the United States, Canada, India and Japan, clearly outperform the EU in this respect. For example, 52 % of Chinese patents were ICT-related, compared to a much lower share of 17 % in the EU in 2016. Moreover, the share of ICT patents in the EU overall seems to have stabilised, while in China and India the share has been on the rise since 2000. In 2016, in the EU, the weight of ICT-related patents was the most pronounced in Sweden (43 %), Ireland (36 %) and Finland (36 %). Of course, the economic structure also plays an important role here, as we have seen before that these EU Member States also have high ICT value-added shares. Conversely, the share of ICT patents was the lowest in Latvia (4 %), Slovenia (7 %), Italy and Czechia (9 %).

Figure 5.4-11 ICT-related(1) PCT patent applications as % of total PCT patent applications(2), 2000, 2007 and 2016



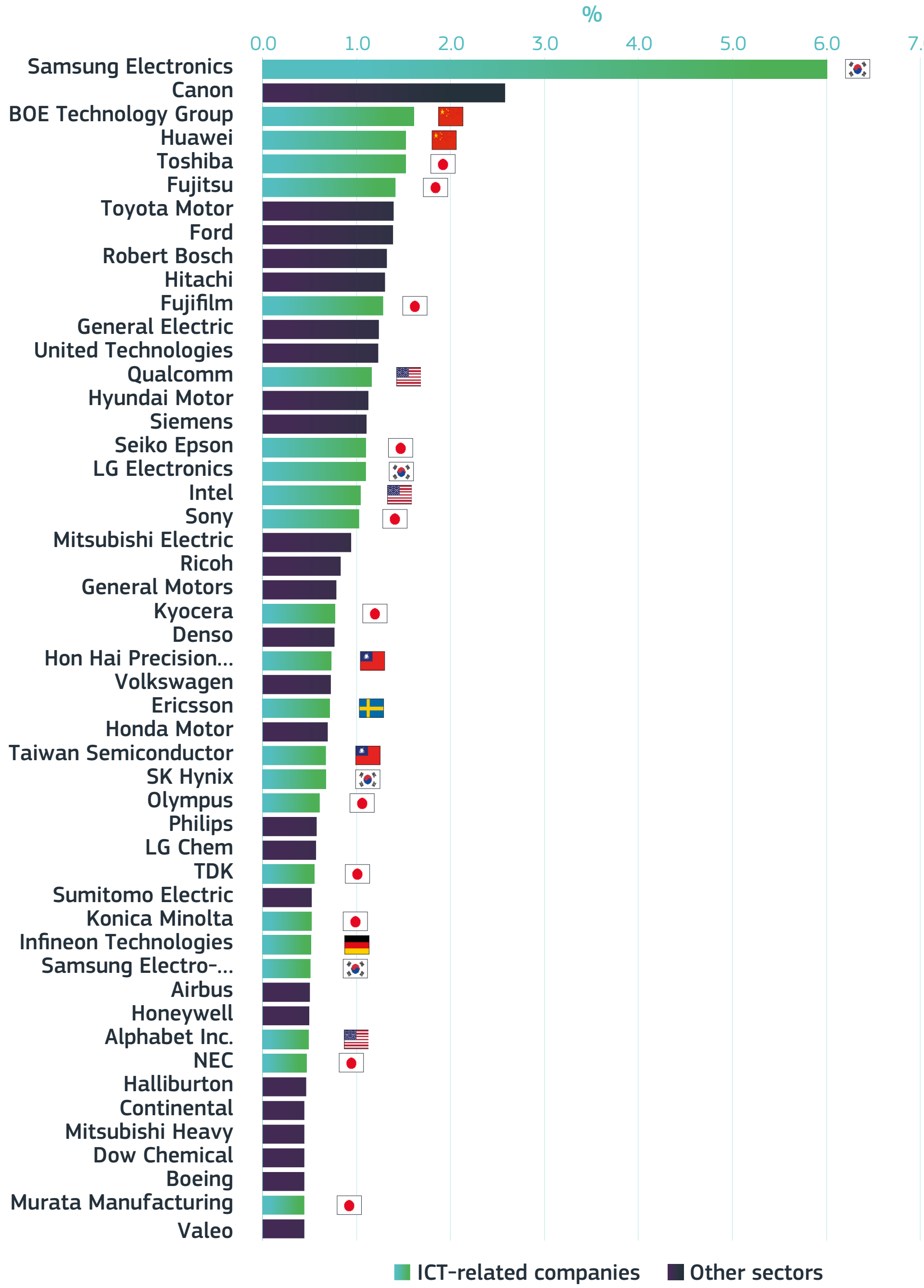
Source: OECD (Patents by technology)

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 data and the inventor's country of residence.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter54/figure-54-11.xlsx

Almost half of the 'top 50 patenting companies' operate in the ICT sector and are mainly found in Asia, while the EU is represented by two companies. Figure 5.4-12 shows that within the most R&D-intensive investors active in patenting worldwide, ICT-related companies emerge as very active patenting companies, notably in computers and electronics. In particular, of the top 50 patenting companies, close to half are ICT-related. Asian companies (with headquarters in Japan, South Korea, China and Taiwan) are in the lead, while Ericsson (Sweden) and Infineon Technologies (Germany) represent Europe.

Figure 5.4-12 Share in patenting of the 'top 50 patenting companies' by sector and country for ICT-related companies, 2014-16



Source: OECD and Joint Research Centre-OECD, COR&DIP© database v.2., 2019

Note: Data concerns IP5 patent families.

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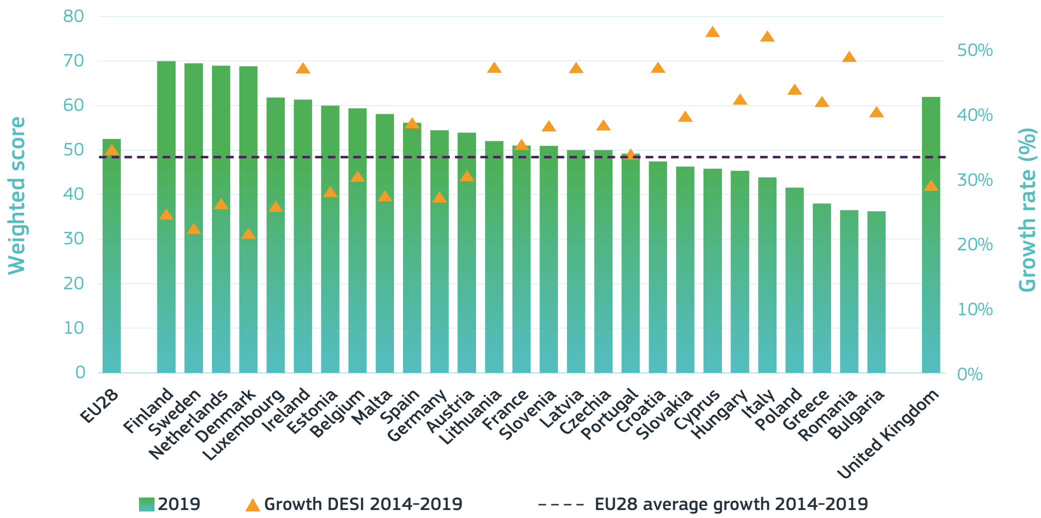
3. An EU digital divide remains, although there is some catching up

Digital competitiveness seems to be highest among the EU's 'innovation leaders' which demonstrates the import-ance of developing a country's digital capacity to innovate. At the same time, the digital divide between the most-advanced and least-digitally-advanced nations seems to be closing. Since 2014, the European Commission has issued the Digital Economy and Society Index (DESI) to monitor and benchmark the evolution of digital competitiveness in EU Member States across different digitalisation pillars. These include the dimensions of connectivity, human capital, use of internet, integration of digital technology, and digital public services.

The results of DESI 2019 show that the EU's 'digital leaders' are Finland, Sweden and the Netherlands (Figure 5.4-13). On the other hand, Bulgaria, Romania and Greece are the least-digitally-advanced Member States. Nevertheless, all EU Member States seem to have increased their digital performance between 2014 and 2019. More importantly, some catching-up from the laggards seems to have taken place, as shown by growth rates higher than the EU average. Hence, all EU Member States are improving their digital capacities and the digital divide has become less nuanced, although further efforts are needed to continue in this positive path towards digital convergence[2].

Figure 5.4-13 Digital Economy and Society Index (DESI)(1), 2019 and growth rate 2014-2019



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on European Commission, DG CNECT (Digital Economy and Society Index 2019)

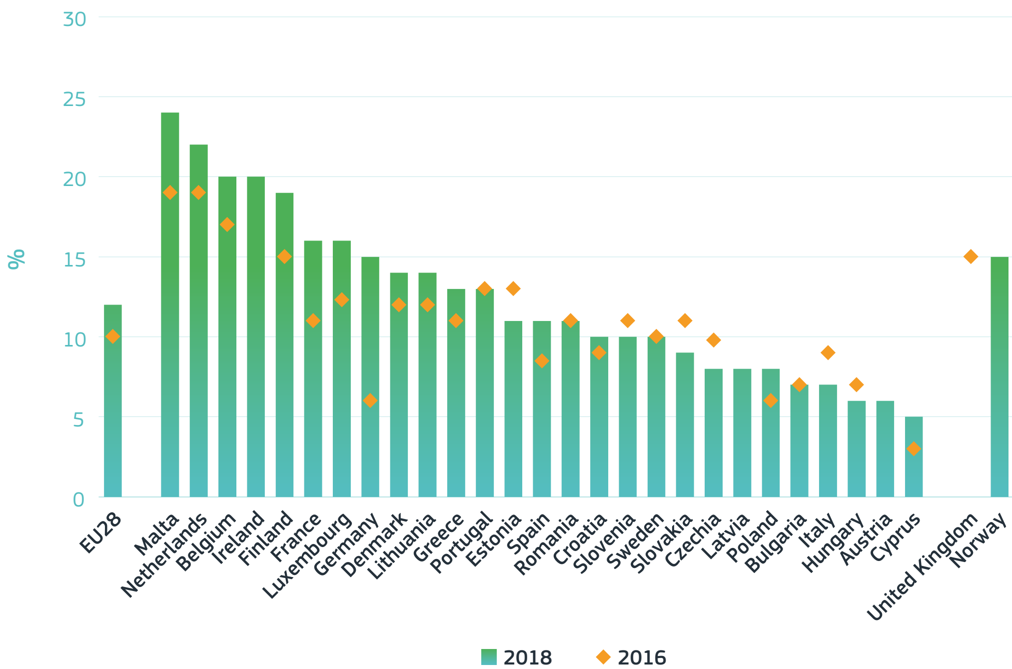
Note: (1)The Digital Economy and Society Index (DESI) is a composite index that tracks the evolution of digital competitiveness. The index is the average of the five main dimensions: connectivity, human capital, uses of internet, integration of digital technology, and digital public services.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter54/figure-54-13.xlsx

2 Indeed, in absolute terms substantial differences remain especially between top and lower performers.

Slightly more than 1 in 10 enterprises in the EU performed big data analyses as part of their work. However, in some countries, the gap in the uptake of this practice by firm size is considerable. Due to the huge amounts of data created every day, companies often need to have the capacity to process all the information produced digitally. Big data is usually characterised by its '3 Vs' – namely, *volume*, *variety* and *velocity*. Overall, the percentage of enterprises performing big data analytics increased in most EU Member States between 2016 and 2018 (Figure 5.4-14). In Malta, the Netherlands, Belgium and Ireland, 20 % or more of all enterprises performed some sort of big data analysis, while in Cyprus, Austria and Hungary, less than 7 % of enterprises did so.

Figure 5.4-14 Share of enterprises analysing big data in total enterprises[(1)], 2016 and 2018



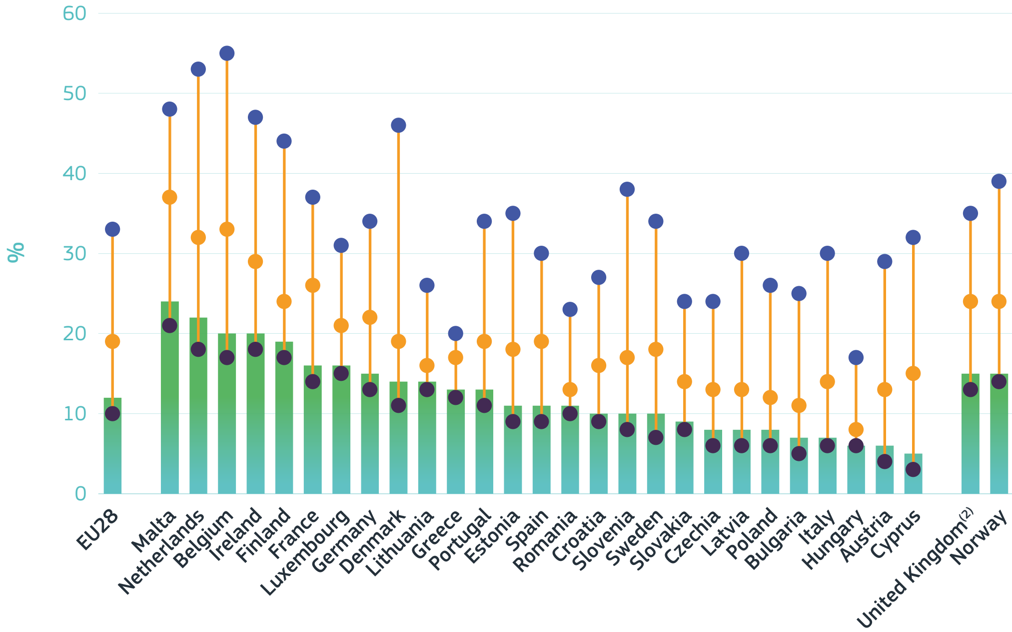
Source: Eurostat (online data code: isoc_eb_bd)

Note: [(1)]All enterprises, without the financial sector (10 or more people employed).

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter54/figure-54-14.xlsx

There are intra-EU differences in terms of big data uptake by firm size. Figure 5.4-15 depicts the difference by firm size in terms of the uptake of big data by country. While in Greece and Hungary there is not a very substantial difference in the use of big data by large, medium and small firms, in most Member States, big data practices seem less diffused across firms with large companies clearly making more use of big data analytics than medium-sized and, in particular, small firms. This is particularly true in countries such as Belgium and Denmark.

Figure 5.4-15 Share of enterprises[(1)] performing big data analysis by size, 2018



Science, research and innovation performance of the EU 2020

Source: OECD (2019) "Measuring the digital transformation" and Eurostat (online data code: isoc_eb_bd)

Notes: [(1)]Enterprises without financial sector. [(2)]UK: 2016.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter54/figure-54-15.xlsx

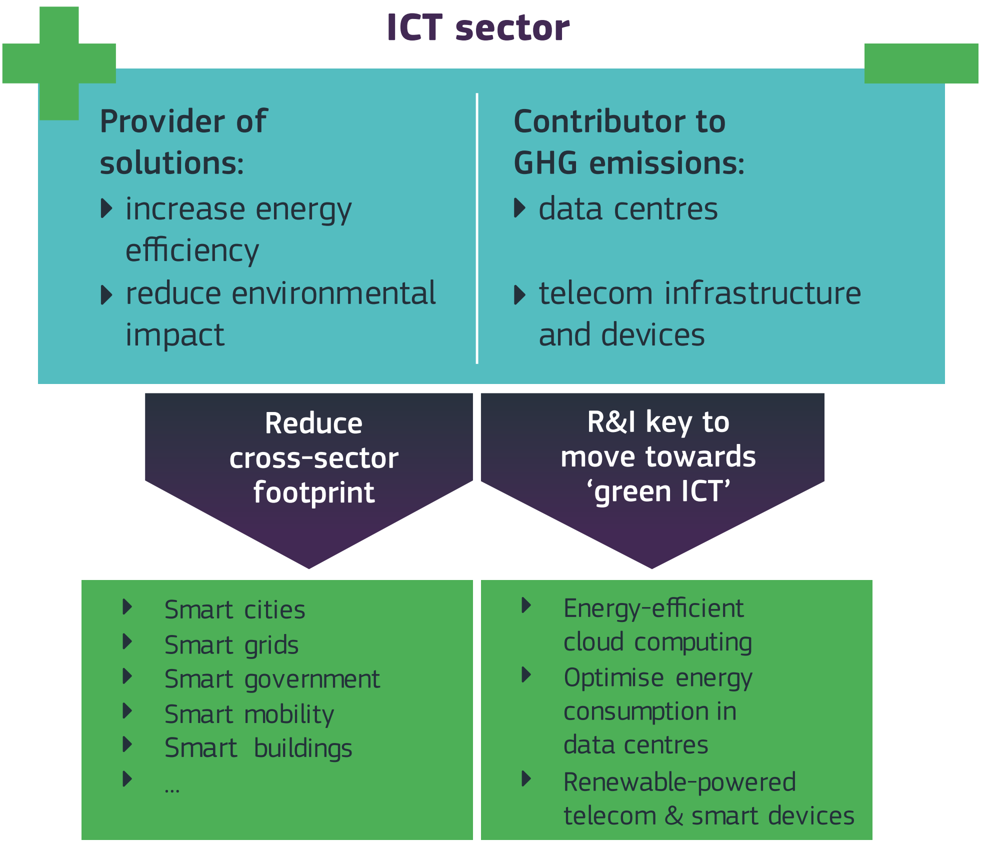
4. R&I essential to move towards 'green ICT'

ICTs can provide solutions to address climate change. At the same time, there is a need to reduce the global footprint of ICT which is being fostered by the digital transformation of the economy. In its 2009 Recommendation[3], the European Commission outlines a framework to 'mobilise ICTs to facilitate the transition to an energy-efficient, low-carbon economy', considering the potential of ICT to enhance energy efficiency. Indeed, ICTs can act as enablers of a low- (or even zero-) carbon economy. The Global e-Sustainability Initiative (2015) argues that ICT has the potential to cut global carbon emissions by approximately 15 % by promoting the efficiency of processes and energy use. As a result, ICTs can enable the 'smartification' of many aspects of our economies – i.e. smart cities, smart grids, smart mobility, smart governments, smart businesses, smart buildings, etc. – which reduce the environmental impact across sectors.

3 https://ec.europa.eu/information_society/activities/sustainable_growth/index_en.html

However, with the exponential growth of data, more storage and computing capacity is needed. Moreover, the use of sophisticated telecoms equipment, infrastructure and mobile devices is also consuming increasing amounts of energy. The new EU Digital Strategy[4] explains that today the ICT sector accounts for 5-9% of electricity use and more than 2% of global greenhouse gas emissions (as much as all air traffic). If unchecked, the footprint could increase to 14% of global emissions by 2040. R&I can be fundamental in the move towards 'green ICT' – i.e. by exploring and creating new ways of making cloud computing and data centres energy efficient, telecom operations powered by renewables, and by generating smart devices. Figure 5.4-16 is a simplified representation of ICT's potential impact on greenhouse gas emissions. While ICT is an important enabler of green growth (left-hand side), there is also substantial energy consumption by using ICTs and the need to increase computing capacity. Nevertheless, R&I solutions could address some of the pitfalls of digital technologies in terms of environmental impact. This matter is further explored in Chapter 7 - R&I enabling artificial intelligence.

Figure 5.4-16 Visual representation of the impact of ICT on greenhouse gas emissions



Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Global e-Sustainability Initiative (2015) and presentation by Richard Labelle (2014)
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter54/figure-54-16.xlsx

4 EU Digital Strategy: https://ec.europa.eu/commission/presscorner/detail/en/fs_20_281

5. Conclusions

Investments in ICT capital remain important within the range of intangible assets for economic growth, despite a decline in recent years in its contribution to GDP growth. The EU appears to underinvest in ICT compared to the United States, so boosting the levels of investment in ICT equipment and software in Europe seems fundamental to ride the next innovation wave.

When it comes to the ICT sector, our analysis shows that ICT services in the EU are clearly the largest component within the sector. Moreover, the role of the ICT sector has remained relatively stable over time in the EU, at around 4% of GDP. The share of employment in the EU's ICT sector has also risen over the last decade. However, the sector appears less R&D intensive, less productive and less active in ICT patenting than other major economies.

At the same time, this chapter shows that ICT diffusion is not happening at an appropriate rate. Some countries are still lagging behind in providing their workforces with the right digital skills, or in the uptake of digital technologies by companies of all sizes, and governments. **This calls for further accumulation and diffusion of ICT capital throughout Europe to ensure the adoption of digital technologies that will bring productivity gains across the economy**.

Another important consideration relates to securing network and information systems. In fact, securing ICT products and services may probably contribute to fostering their uptake by the market, society which, ultimately, could help the ICT sector in the EU. The EU Cybersecurity plan focuses on five priorities, including achieving cyber- resilience, drastically reducing cybercrime, developing cyberdefence policies and capabilities related to the Common Security and Defence Policy (CSDP), developing industrial and technological resources for cybersecurity, and establishing a coherent international cyberspace policy for the EU and promoting the EU's core values[5].

Finally, while on the one hand ICTs can provide solutions to address climate change by leading to smart grids, smart buildings and smart cities (to name but a few), **on the other hand, there is a need to reduce ICT's global footprint from the energy-intensive use** of data centres as well as infrastructure for telecommunications. In this context, **investing in R&I to generate solutions for energy-efficient cloud computing, or the optimisation of energy consumption in data centres, can lead to green ICT**.

5 https://ec.europa.eu/commission/presscorner/detail/en/IP_13_94

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