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].

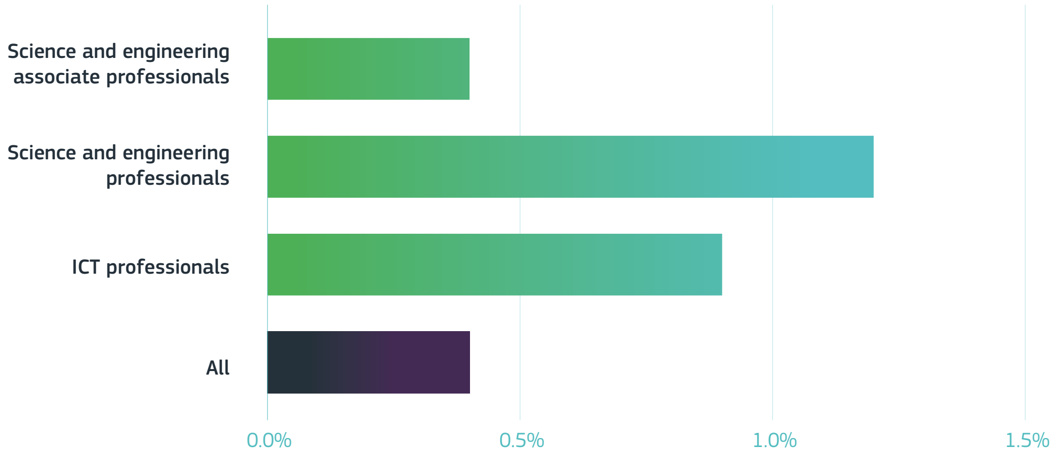
1 Jobs classified under the ISCO-88 major groups, based on Cedefop Skills Forecast 2021-2030, EU28, annual percentage rate.

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



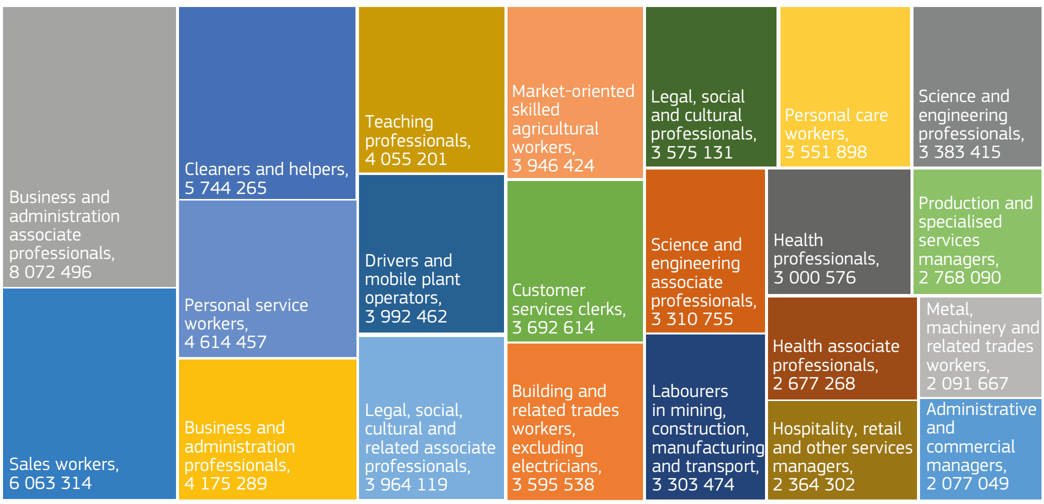
Science, research and innovation performance of the EU 2020

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

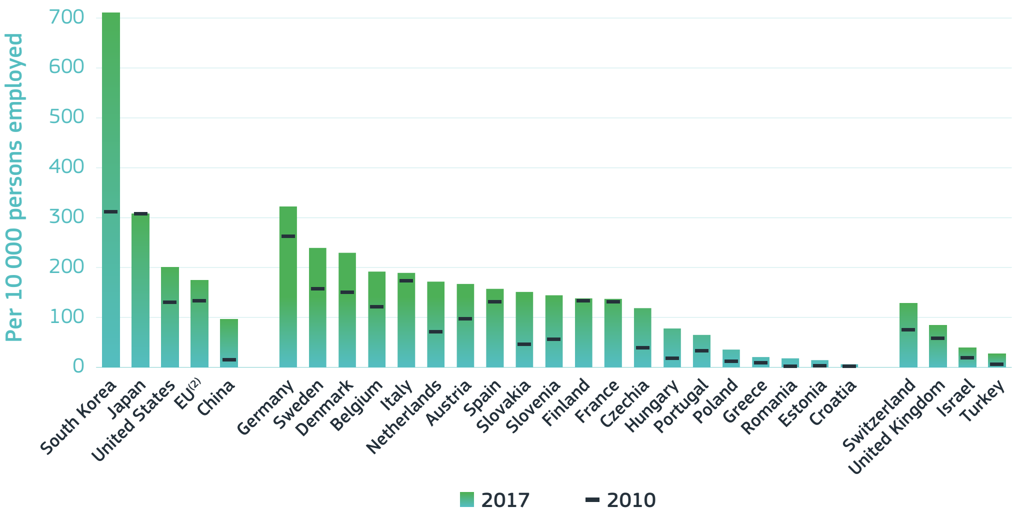
The manufacturing sector is characterised by a growing use of industrial robots. European countries with a large car industry tend to have high numbers of industrial robots per person employed. The ongoing debate on the impact of technical progress on employment concentrates on the levels of robots in 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



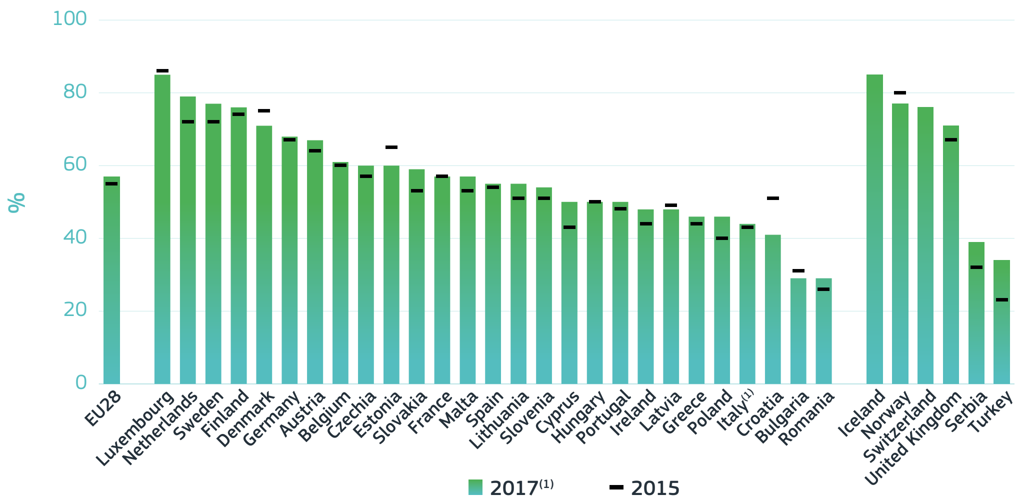
Science, research and innovation performance of the EU 2020

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



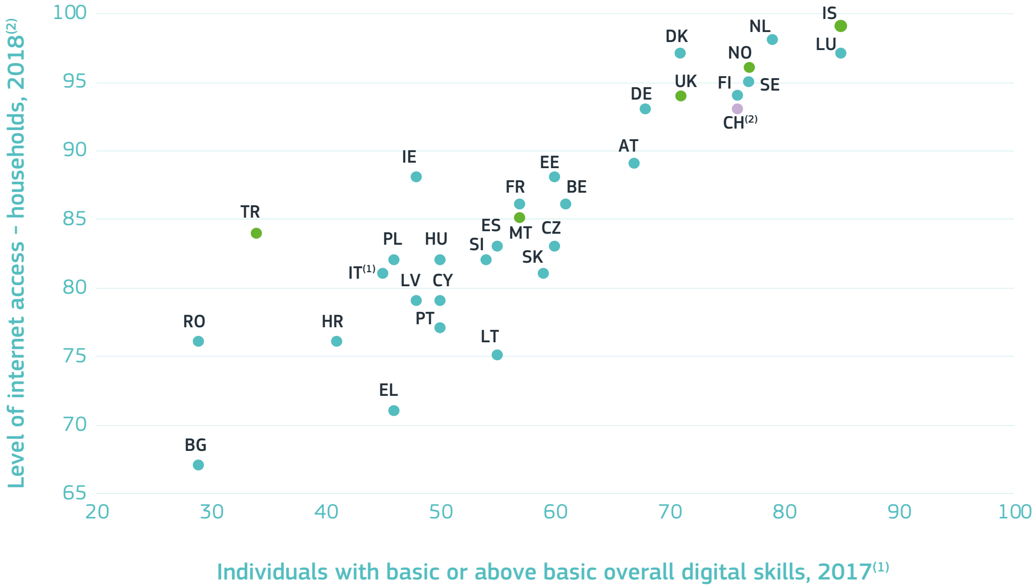
Science, research and innovation performance of the EU 2020

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

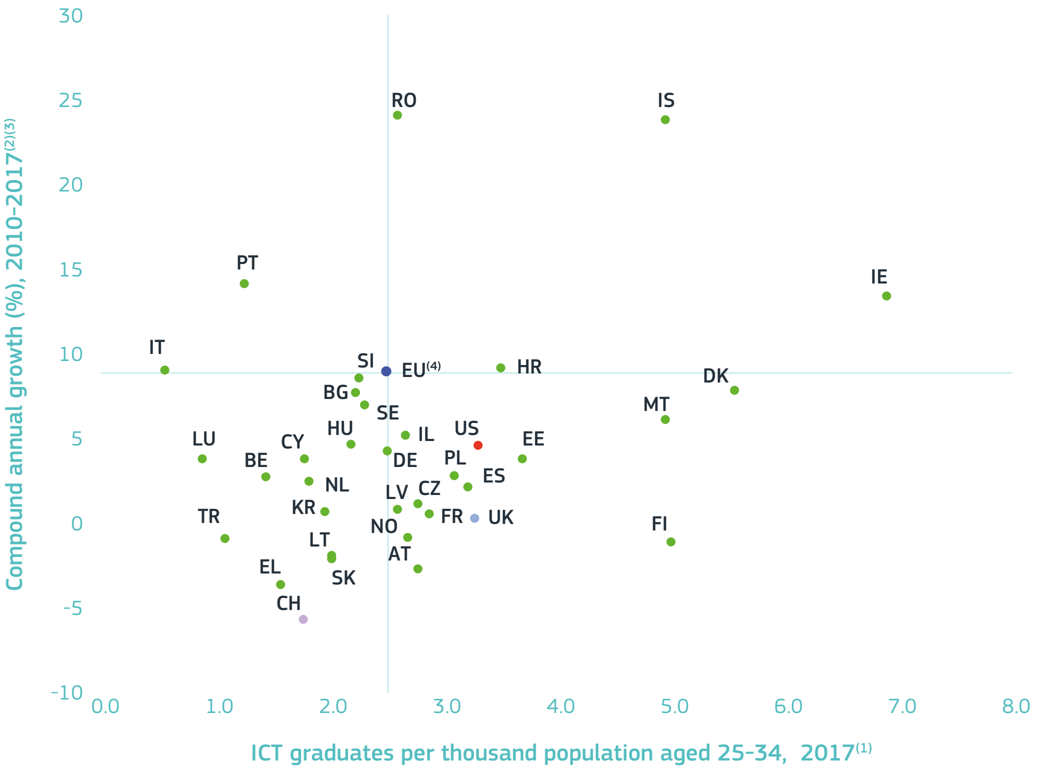
Source: Eurostat (online data code: TEPSR_SP410 and isoc_ci_in_h)
Notes: [1]IT: 2016. [2]CH: 2017.
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-5.xlsx

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]



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) 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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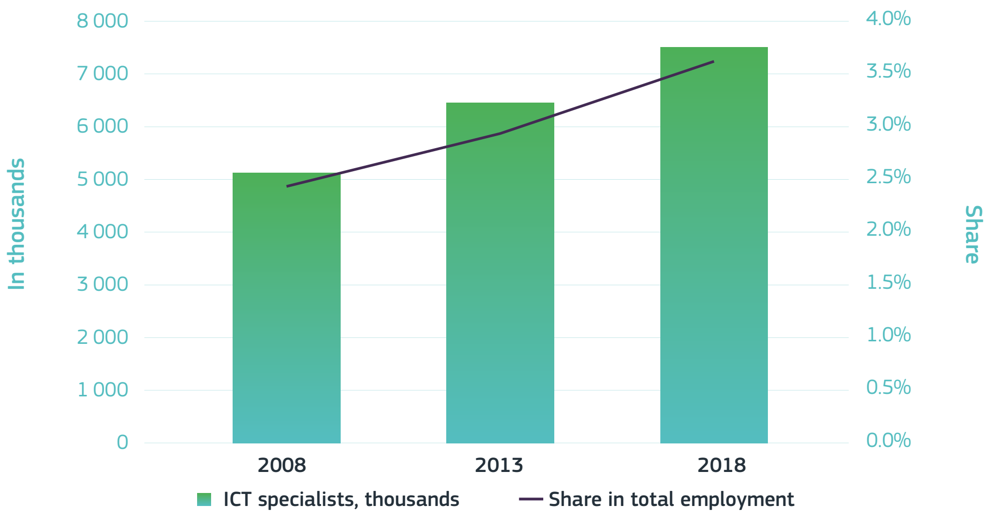
Although the number of ICT graduates has increased, it is not keeping pace with continuous growth in employment in ICT and is not meeting market demand. While the population's basic ICT skills are improving, there is a growing need for practitioners with a solid base in ICT skills. In 2018, the share 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

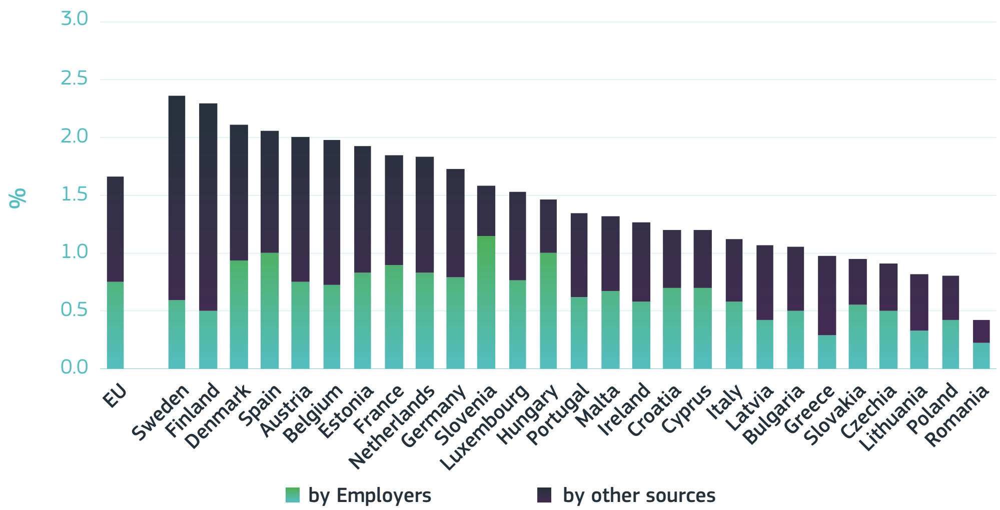


Science, research and innovation performance of the EU 2020

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)

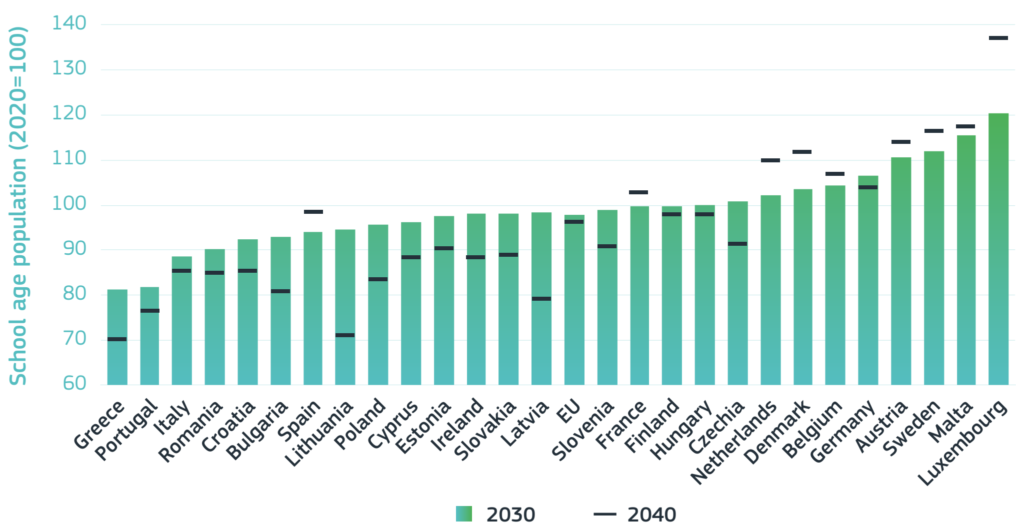
Note: [1]Investment in skills by Employers includes all economic sectors, data for the public sector employers was estimated using AES participation data and CVTS cost data per country per participant. Investment in Formal VET includes public and private expenditure on formal vocational education and 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)



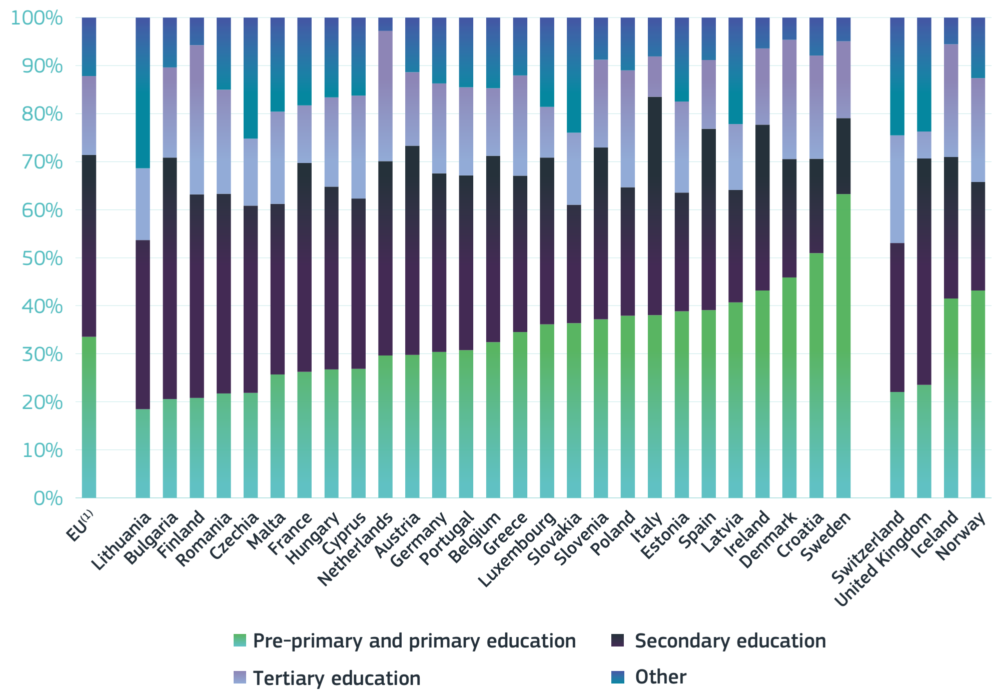
Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: proj_18np)

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



Science, research and innovation performance of the EU 2020

Source: Eurostat (online data code: gov_10a_exp)

Note: [1]EU was calculated by DG Research and Innovation.

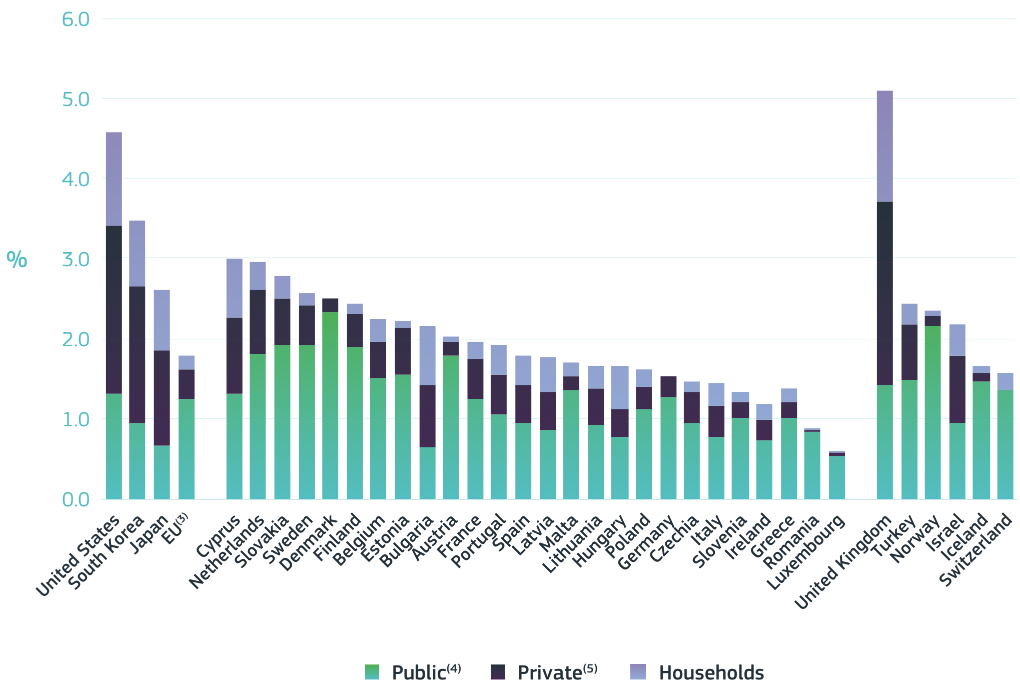
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-10.xlsx

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)]



Science, research and innovation performance of the EU 2020

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.

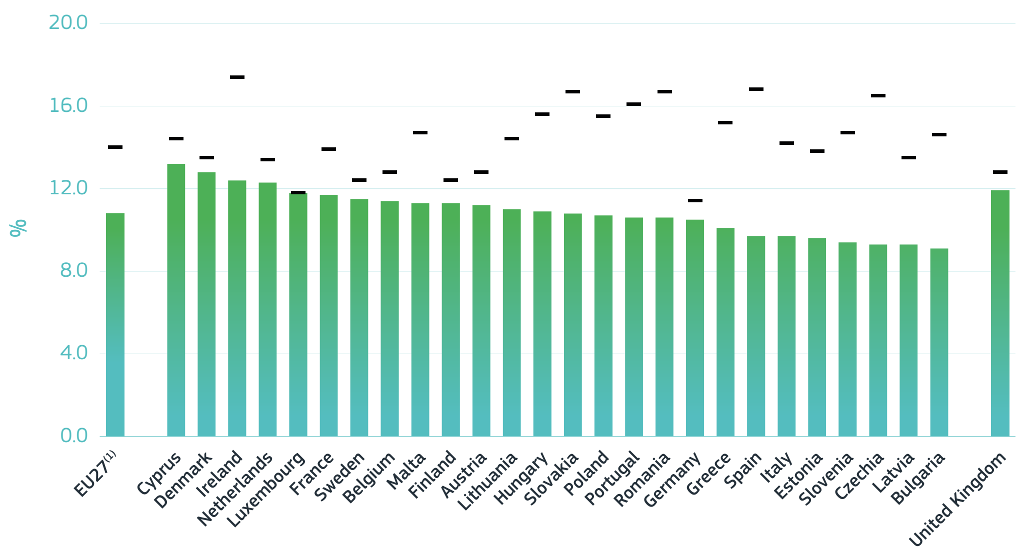
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-11.xlsx

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



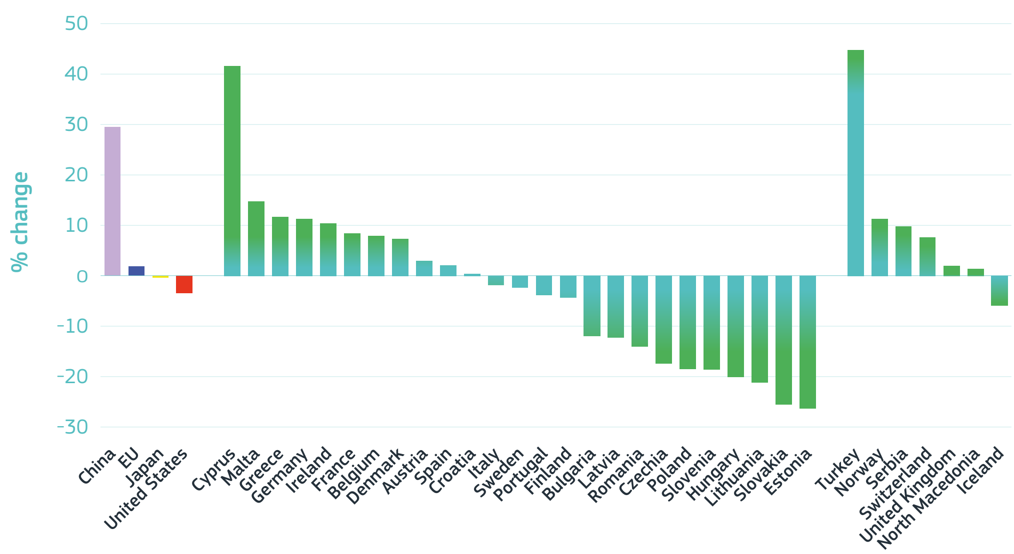
Science, research and innovation performance of the EU 2020

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

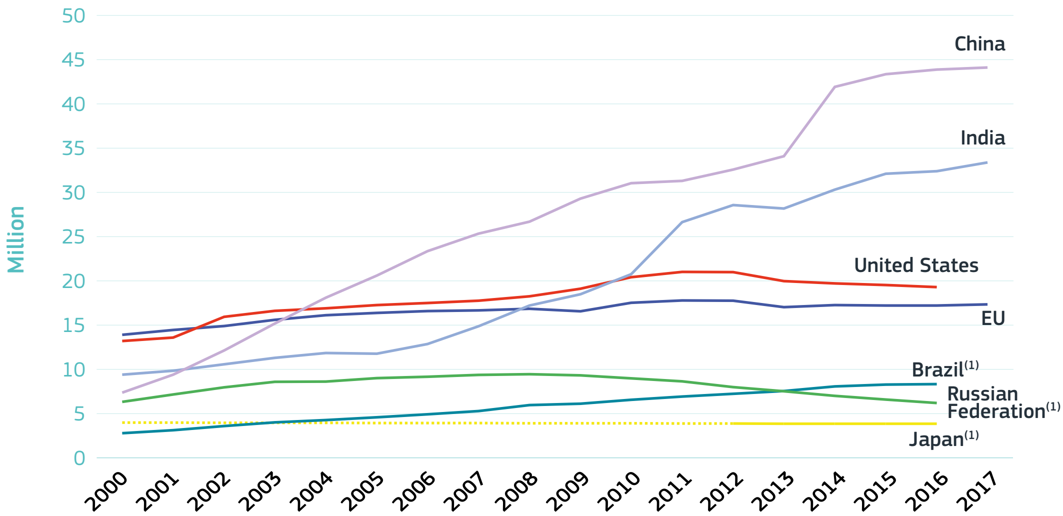
Note: (1)US, JP: 2013-2016; IE: 2014-2017.

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 992 000 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 (267 000) and Africa (180 000)[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 220 000 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.

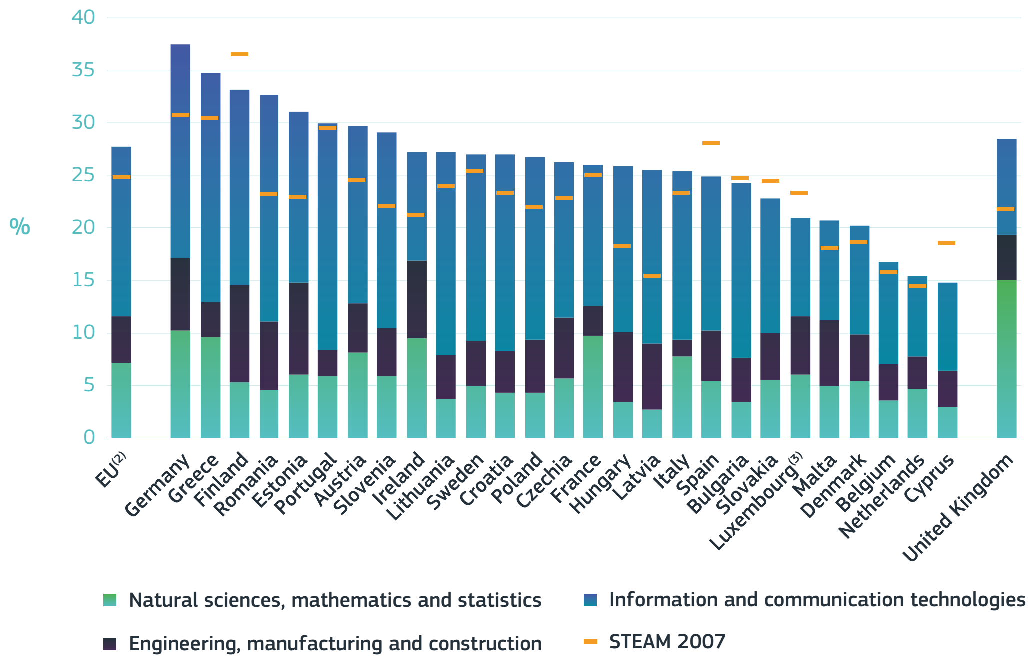
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter52/figure-52-14.xlsx

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

9 Furthermore, there were 220 000 Asian, 30 000 African and 23 000 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

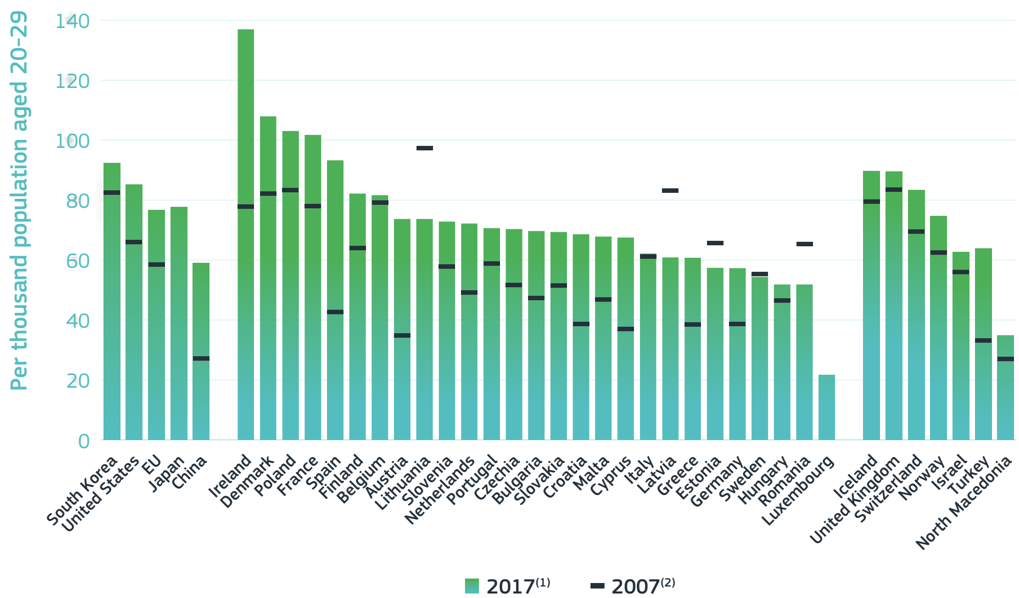
Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: educ_uoe_enrt03)

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



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.

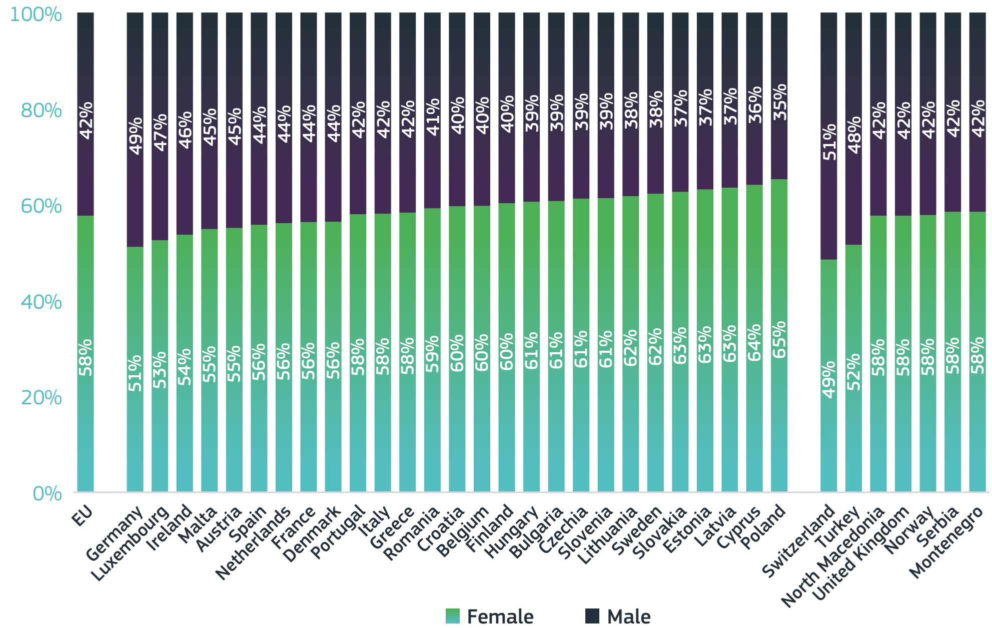
Gender imbalances among graduates are greater compared to the number of enrolled students as 54% of students in higher education were women. In 2017, the share of women reached 57.6% when considering tertiary graduates in the EU (Figure 5.2-17). Germany is the EU country with the most equal gender balance (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

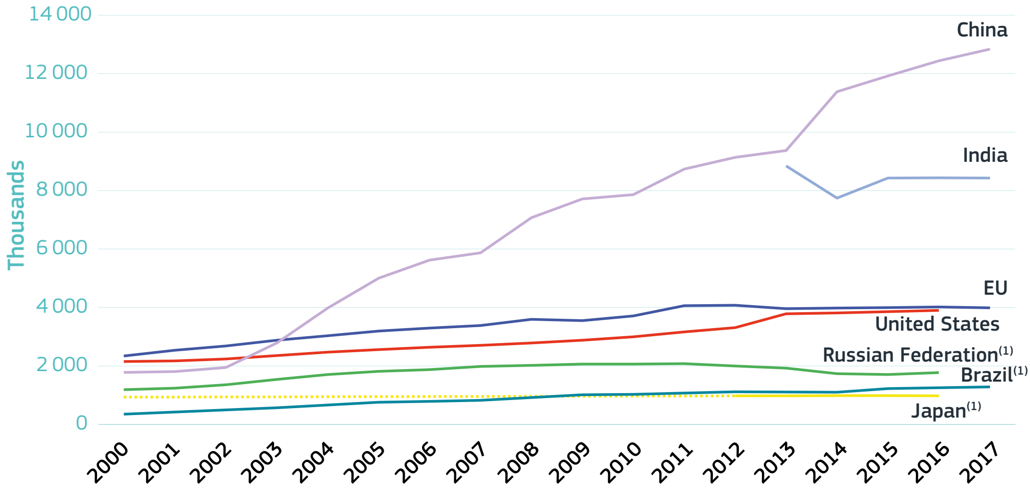
Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: educ_uoe_grad01)

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



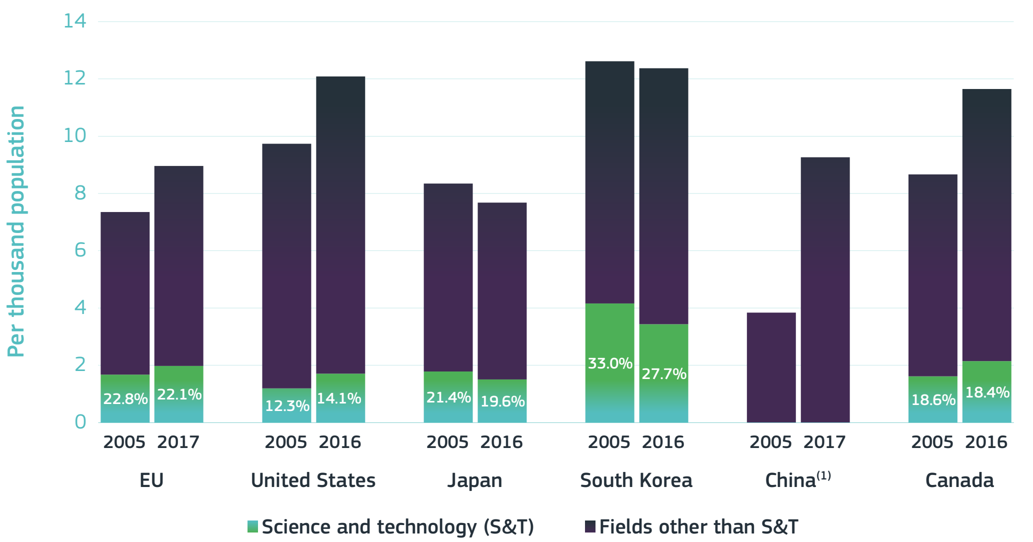
Science, research and innovation performance of the EU 2020

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

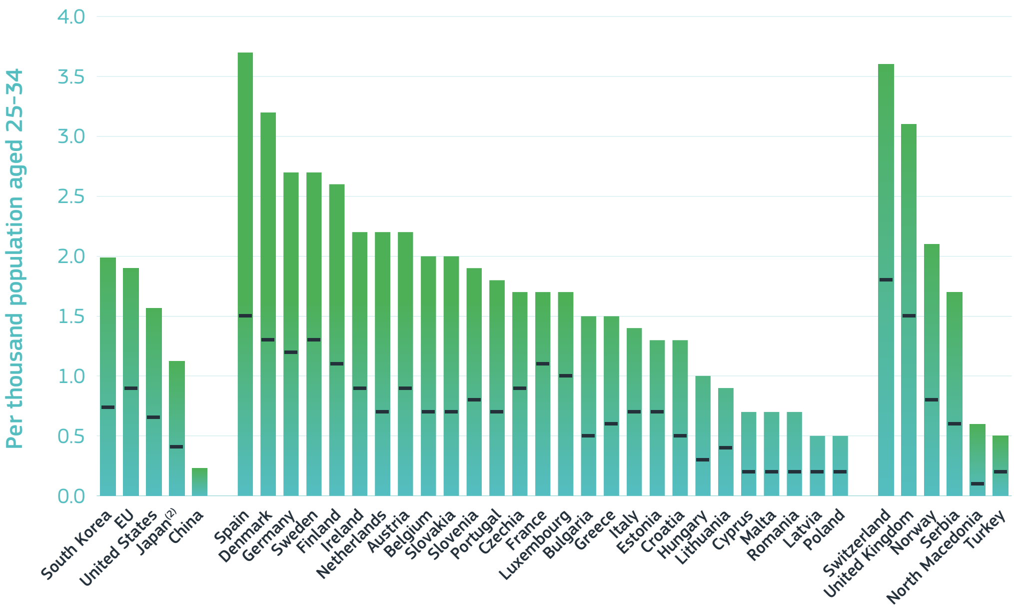
Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: educ_uoe_grad02), OECD (Graduates by field), UNESCO and World Bank data

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.

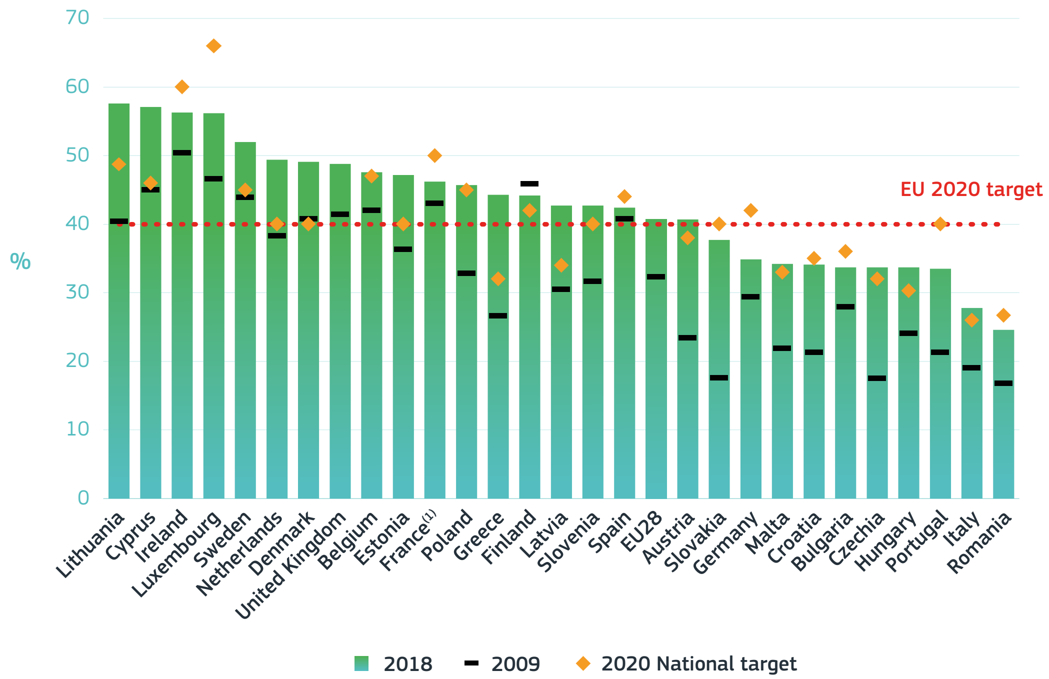
In 2018, the EU reached its target for the share of people with tertiary attainment, and also made progress in achieving the target for early leavers from education and training. Progress in the number of tertiary graduates (with some time lags) contributed to achieving the EU's headline target for tertiary 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)

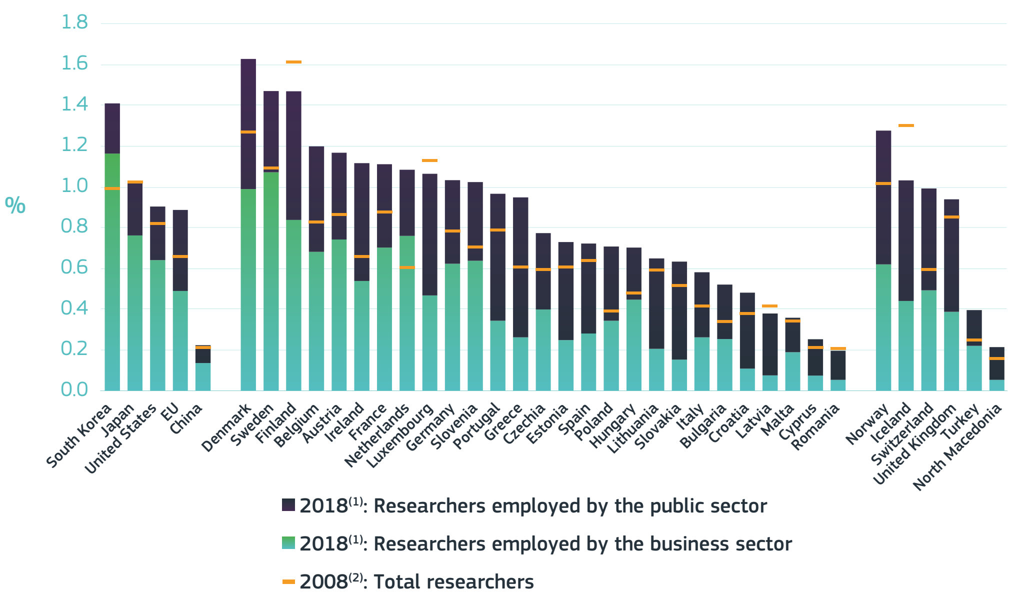
Note: [(1)]Breaks in series occur between 2014 and the previous years and between 2011 and the previous years for HRST data.

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

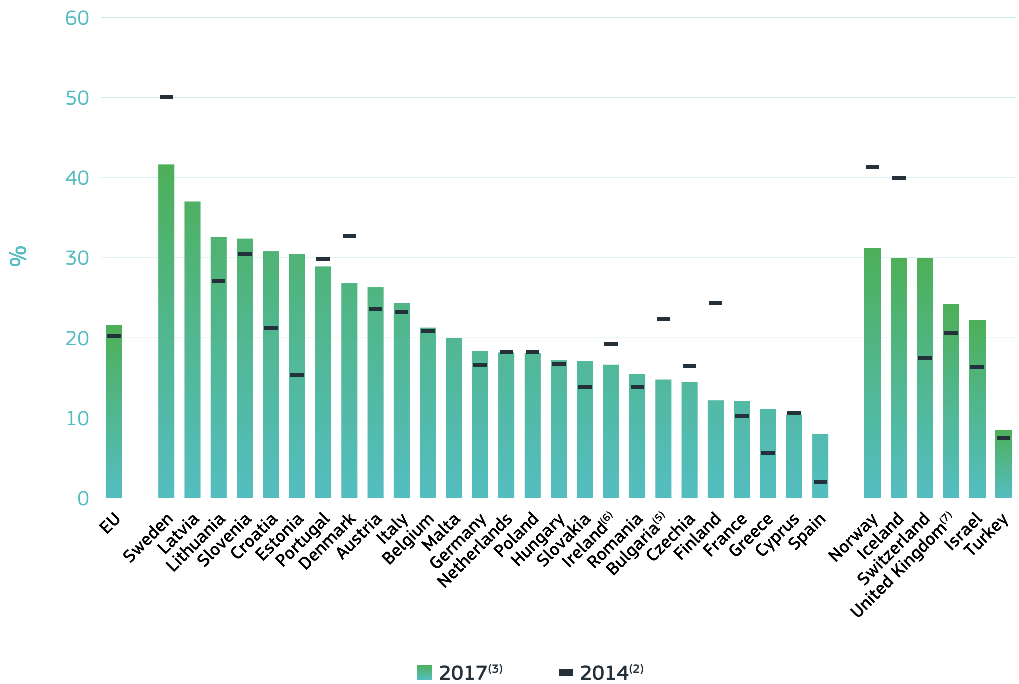
Notes: [1]US: 2016; JP, KR, CN, CH, TR: 2017. [2]US: 2007-2016; JP, CH: 2008-2017; KR, CN, TR: 2007-2017; PT, SI: 2008-2018; EL: 2011-2018. JP, CN, FR, IT, LU, NL, PT, RO, SI, FI, SE, IS: show break in series between 2007-2018. [3]CH: 2008; LU: 2009; FR: 2010 EL, NL: 2011. [4]EU aggregate estimated and 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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