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Digital Economy and Society Index (DESI) 2020

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Digital Economy and Society Index (DESI) 2020

Thematic chapters

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1 Human Capital

The current COVID-19 pandemic has shown how important digital assets have become to our economies and how basic and advanced digital skills sustain our economies and societies. Although already 85% of citizens used the internet in 2019, prior to the COVID-19 crisis, only 58% possesses at least basic digital skills. Therefore, having an internet connection is not sufficient; it must be paired with the appropriate skills to take advantage of the digital society. Digital skills range from basic usage skills that enable individuals to take part in the digital society and consume digital goods and services, to advanced skills that empower the workforce to develop new digital goods and services.

Table 1 Human capital indicators in DESI

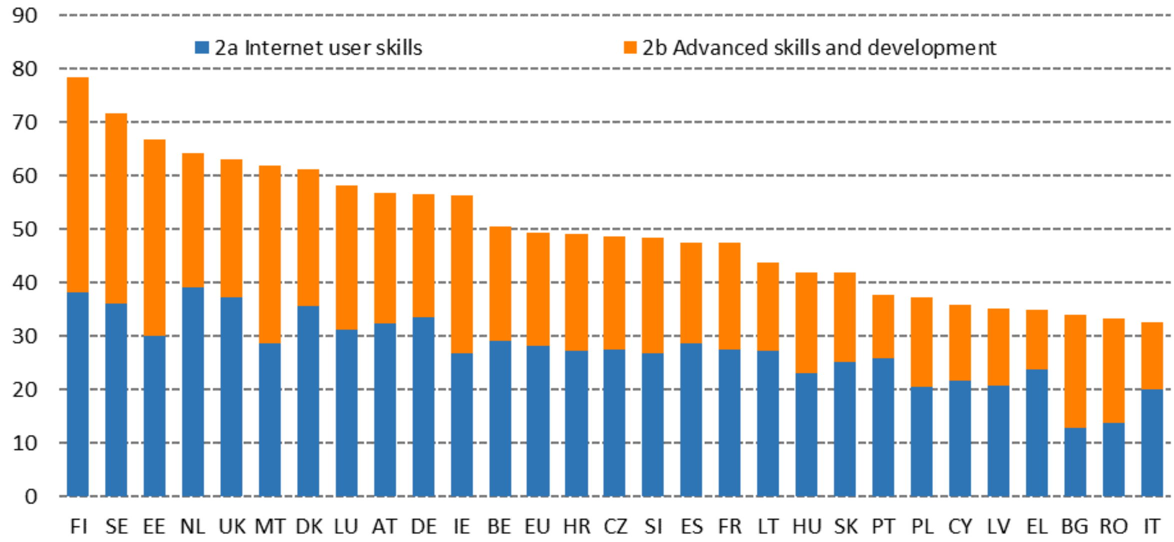
	EU	
	DESI 2018	**DESI 2020**
2a1 At least basic digital skills % individuals	**57%** 2017	**58%** 2019
2a2 Above basic digital skills % individuals	**31%** 2017	**33%** 2019
2a3 At least basic software skills % individuals	**60%** 2017	**61%** 2019
2b1 ICT specialists % total employment	**3.7%** 2016	**3.9%** 2018
2b2 Female ICT specialists % female employment	**1.3%** 2016	**1.4%** 2018
2b3 ICT graduates % graduates	**3.5%** 2015	**3.6%** 2017

Source: DESI 2020, European Commission.

1.1 Human capital in 2019

The human capital dimension of the DESI has two sub-dimensions covering 'internet user skills' and 'advanced skills and development'. The former draws on the European Commission's Digital Skills Indicator, calculated based on the number and complexity of activities involving the use of digital devices and the internet. The latter includes indicators on ICT specialists and ICT graduates. According to the latest data, Finland is leading in both sub-dimensions of human capital, followed by Sweden, Estonia and the Netherlands for overall performance. Italy, Romania and Bulgaria rank the lowest. In comparison to last year, the largest increases in human capital were observed in Malta (+7 percentage points), Bulgaria (+5 percentage points) and Estonia (+4 percentage points).

Figure 1 Human capital dimension (Score 0-100), 2019



Source: DESI 2020, European Commission.

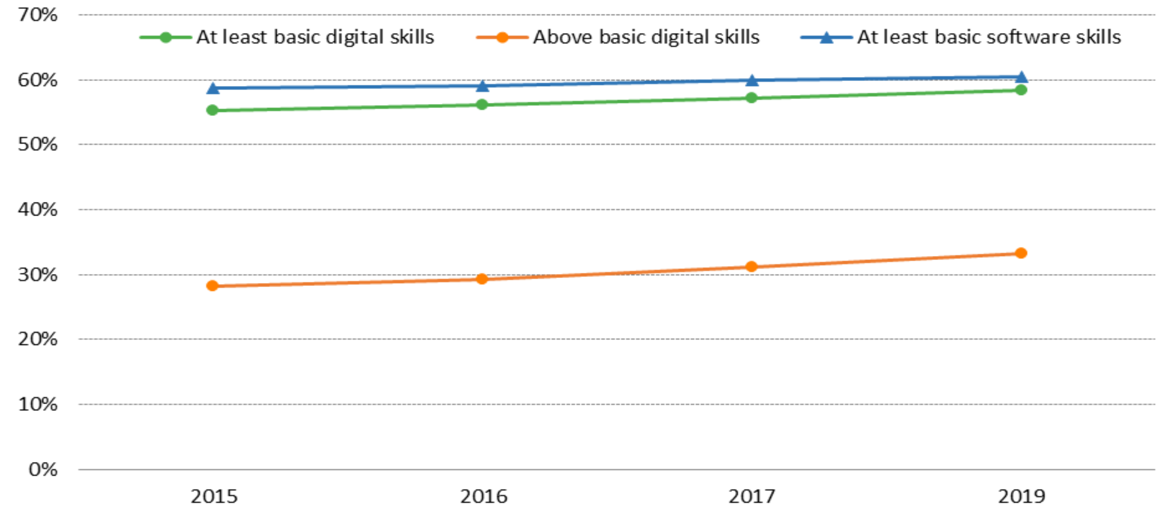
1.2 Access barriers

Although already 85% of citizens used the internet in 2019, some barriers still persist. The top reasons for not having internet access at home in 2019 remain the lack of need or interest (46% of households without internet access in 2019), insufficient skills (44%), equipment costs (26%) and high cost barriers (24%). The deterring effect of each of these factors varies significantly in strength across Member States. For example, only 5% of Estonian households without internet access mentioned costs as a barrier, but as many as 53% did so in Portugal. Lack of relevant skills remains by far the most important factor deterring households from having internet access at home. Moreover, given that this factor limits awareness of potential benefits from digitisation, it may also be among the reasons behind the large numbers of EU households that still claim not to have internet access at home because they do not need it.

1.3 Digital skills

Throughout the last 4 years, the level of digital skills has continued to grow slowly, reaching 58% of individuals having at least basic digital skills, 33% with above basic digital skills and 61% of individuals having at least basic software skills. The skills indicators are strongly influenced by socio-demographic aspects. For example, 82% of young individuals (16-24), 85% of those with high formal education, 68% of employed or self-employed people and 87% of students have at least basic digital skills. By contrast, only 35% of of those aged 55-74 and 30% of the retired and the inactive possess basic skills.

Figure 2 Digital skills (% of individuals), 2015–2019(1)

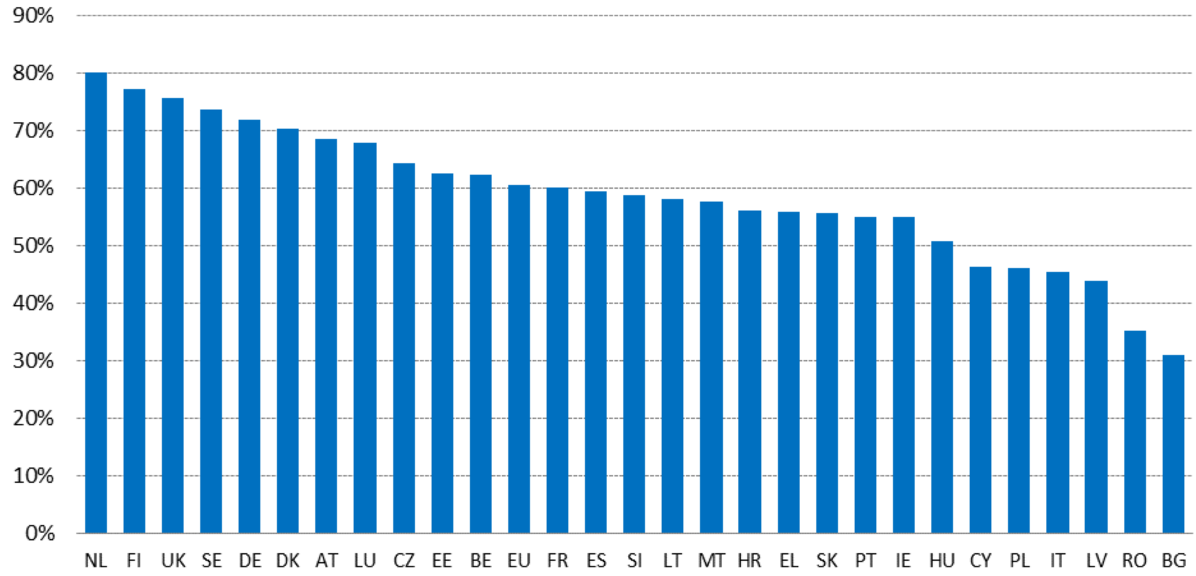


Source: Eurostat, Community survey on ICT usage in Households and by Individuals.

1.4 Software skills

Software skills are becoming a prerequisite for entry into many jobs. Looking at the *internet users skills* sub-dimension of DESI, the largest skills deficit, both among the active labour force and the population at large, is in the use of software for content manipulation. 61% of Europeans have at least basic software skills. In Member States like the Netherlands, Finland and the UK, three out of four individuals have at least basic software skills (80%, 77% and 75% respectively). In contrast, only 31% of Bulgarians and 35% of Romanians have at least basic software skills. This indicator is also strongly influenced by socio-demographic aspects. For example, 85% of young individuals (16-24), 87% of those with high formal education, 70% of employed or self-employed people and 91% of students possess at least basic software skills. Nevertheless, only 38% of those aged 55-74 and 32% of the retired and the inactive possess basic skills in this domain.

Figure 3 At least basic software skills (% of individuals), 2019



Source: Eurostat, Community survey on ICT usage in Households and by Individuals.

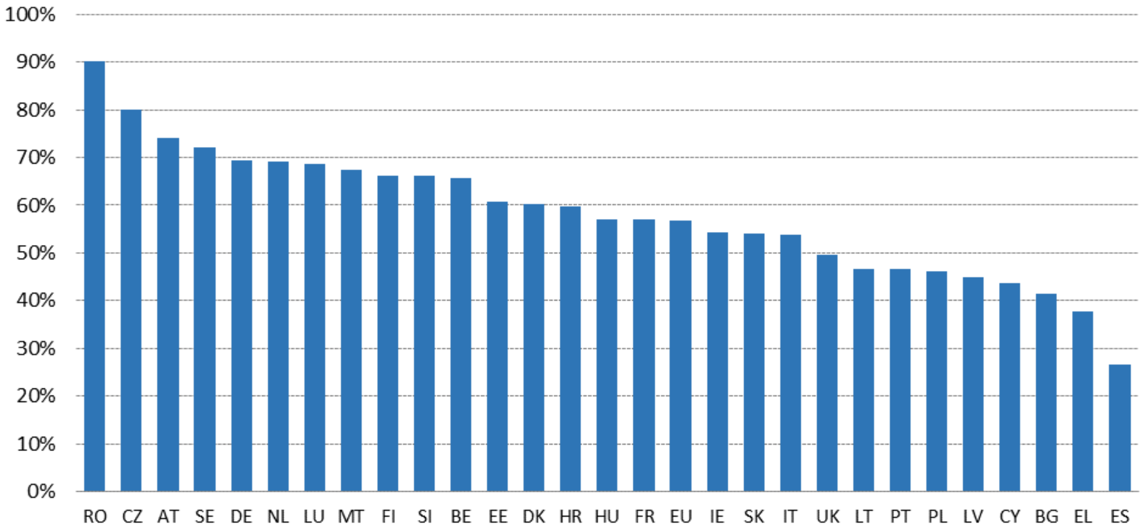
(1) From 2017 the digital skills indicators are collected biennially.

1.5 ICT specialists

The *advanced skills and development* sub-dimension looks at the workforce and its potential to work in and develop the digital economy. This takes into account the percentage of people in the workforce with ICT specialist skills and includes a separate indicator on female ICT specialists. At the same time, it looks at the share of ICT graduates.

In 2018, some 9.1 million people worked as ICT specialists across the EU. The highest number was reported in the UK and Germany (both 1.6 million), followed by France (1.1 million). In 2019, 20% of enterprises employed ICT specialists to develop, operate or maintain ICT systems or applications. This ratio is 75% for large enterprises as opposed to 19% of SMEs. At the same time during 2018, 57% of enterprises that recruited or tried to recruit ICT specialists reported difficulties in filling such vacancies; it was experienced by 64% of large enterprises and 56% of SMEs. The problem is even more widespread in Romania and Czechia, where at least 80% of enterprises that recruited or tried to recruit ICT specialists reported such difficulties.

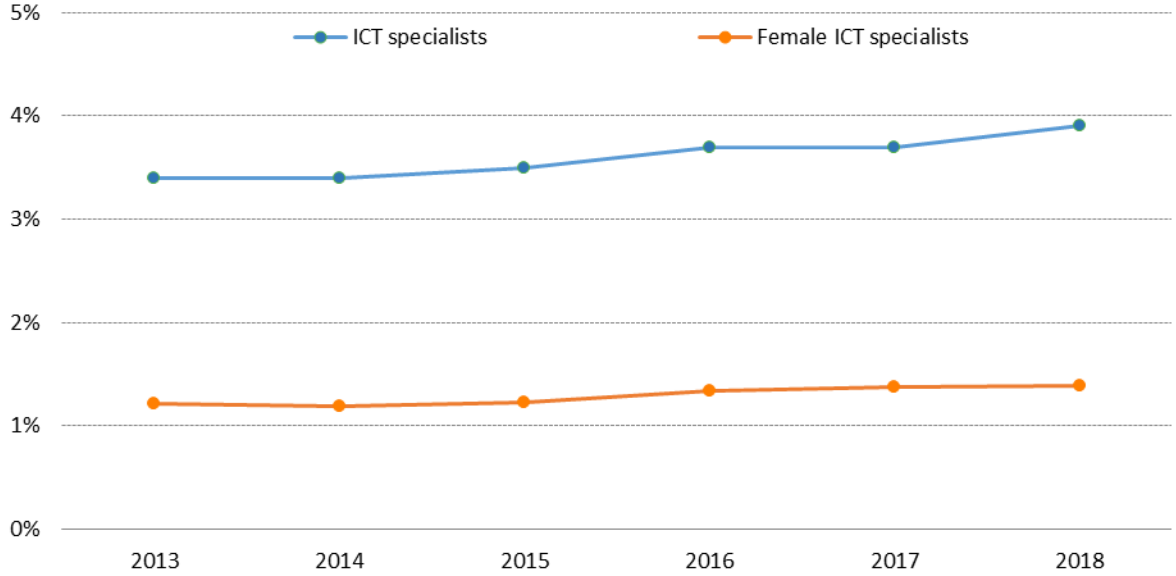
Figure 4 Hard to fill vacancies (% of enterprises that recruited or tried to recruit ICT specialists), 2019



Source: Eurostat, Community survey on ICT usage and e-commerce in enterprises.

The share of ICT specialists is slowly progressing and reached 3.9% of total employment in 2018. 83.5% of ICT specialists were male in 2018, 5.7 percentage points higher than in 2008. In Hungary and Czechia, 9 out of 10 ICT specialists were men, while in and Bulgaria and Lithuania one in four were female.

Figure 5 ICT specialists (% of total employment), 2018



Source: Eurostat, European Union Labour Force Survey.

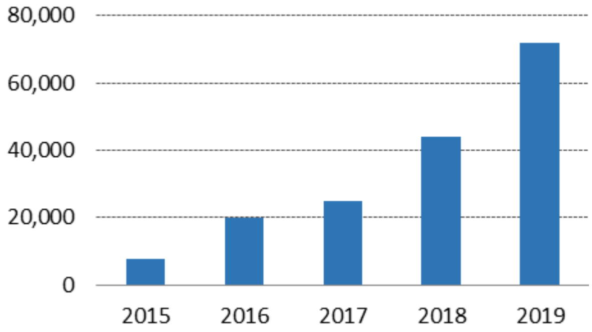
Enterprises are providing more and more training to their personnel to develop or upgrade their ICT skills. During 2018, overall 24% of enterprises provided ICT training for their personnel. The leaders in this domain are Finland (37%) and Belgium (36%). In countries like Poland (13%), Lithuania (11%), Bulgaria (10%) and Romania (6%), the provision of such a training was considerably lower. When looking at company size, 70% of large enterprises actively provided the training, while only 23% of SMEs did so.

1.6 EU Code Week

Europe and the world saw further increases in EU Code Week activities in 2019. EU Code Week is a grassroots movement run by volunteers, ambassadors, leading teachers and coding enthusiasts around the world. It is backed by the European Commission and education ministries in the EU and Western Balkan countries. The European Commission supports EU Code Week as part of its Digital Single Market strategy and through the Digital Education Action Plan.

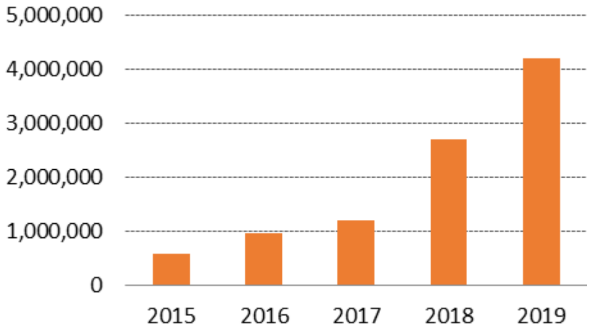
EU Code Week provides teachers with free resources, ready-made lesson plans, online introductory courses and other materials to help them bring coding and technology to all subjects and classrooms. In the 2019 edition, which proved to be the largest ever, a total of 4.2 million participants took part in more than 72,000 activities in over 80 countries around the world.

Figure 6 EU Code Week (number of activities worldwide) 2015-2019



Source: European Commission.

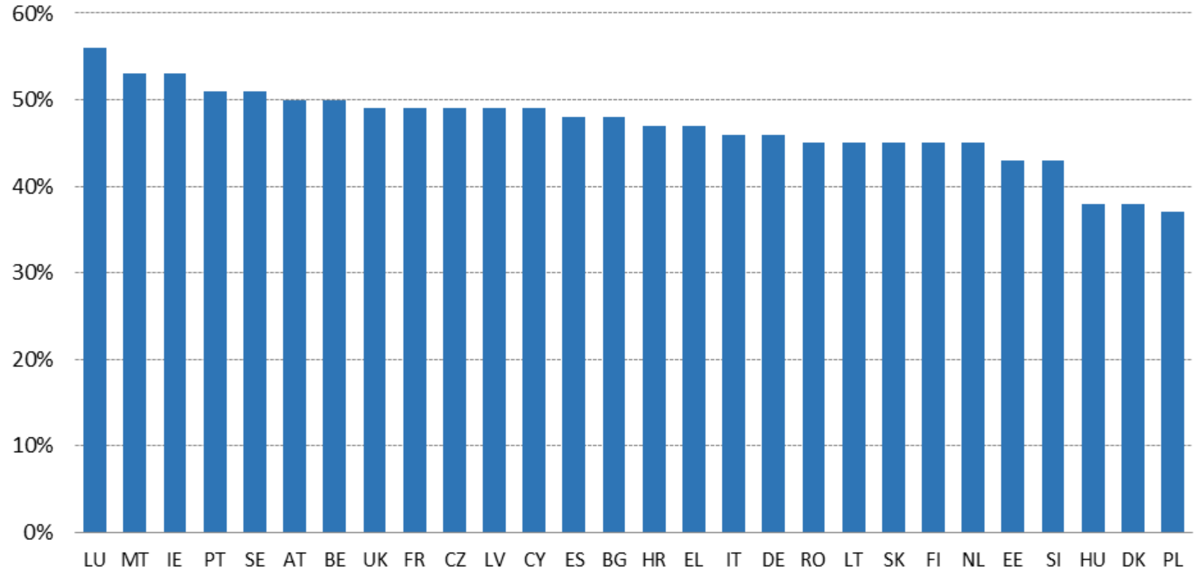
Figure 7 EU Code Week (number of participants worldwide) 2015-2019



Source: European Commission.

47% of participants in the EU in the 2019 edition of EU Code Week were female. Luxembourg was the European champion in women's participation at 56%. In countries like Poland, Denmark and Hungary, men constituted more than 60% of all participants in EU Code Week activities in 2019.

Figure 8 Female participation in EU Code Week (% of participants), 2019



Source: European Commission.

The next edition of Code Week will take place between 10 and 25 October 2020; organisers can already start registering their activities on the EU Code Week map.

Given the difficult and unpredictable situation around COVID-19, an important part of EU Code Week 2020 will move online. Teachers, students, parents, librarians and other tech enthusiasts will find even more resources, tips and best practices on the codeweek.eu website. They will also get the possibility to participate in more online networking events, workshops and remote coding challenges.

2 Use of internet services

Citizens with an internet connection and the necessary digital skills to take advantage of it can engage in a wide range of online activities. Although already 85% of citizens used the internet in 2019, prior to the COVID-19 pandemic, the current crisis may have the positive impact of increasing further the number of internet users and their interactions online. This dimension of the DESI measures how many people use the internet and what activities they do online. Activities include the consumption of online content (e.g. entertainment such as music, movies, TV or games, obtaining media-rich information or engaging in online social interaction), using modern communication activities (e.g. taking part in video calls), and transaction activities such as online shopping and banking.

Table 2 Use of internet services indicators in DESI

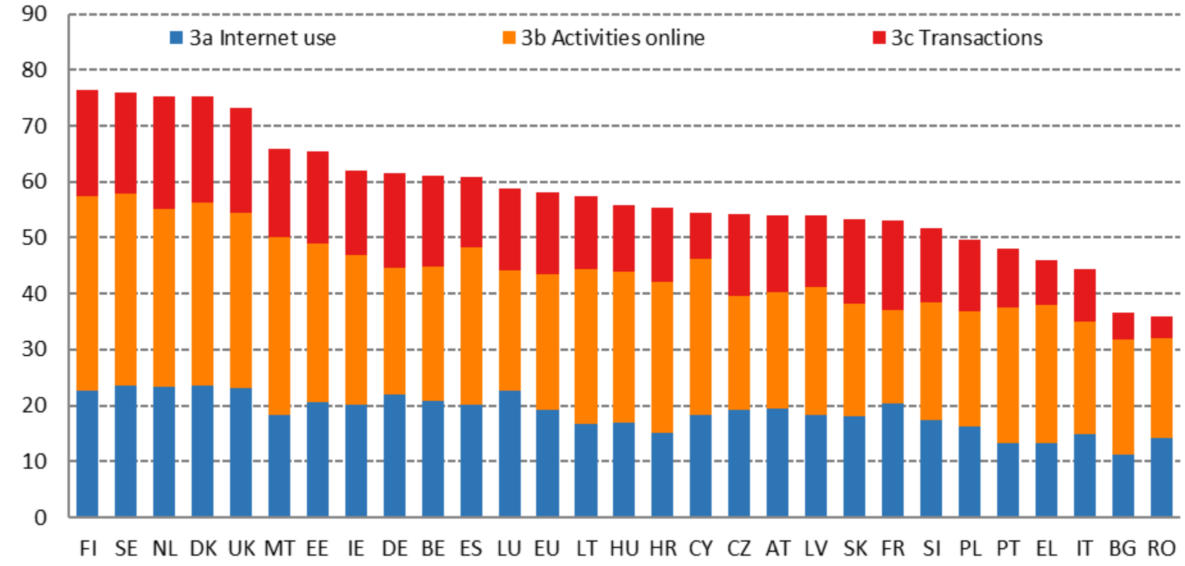
	EU	
	DESI 2018	**DESI 2020**
3a1 People who have never used the internet % individuals	**13%** 2017	**9%** 2019
3a2 Internet users % individuals	**81%** 2017	**85%** 2019
3b1 News % internet users	**72%** 2017	**72%** 2019
3b2 Music, videos and games % internet users	**78%** 2016	**81%** 2018
3b3 Video on demand % internet users	**21%** 2016	**31%** 2018
3b4 Video calls % internet users	**46%** 2017	**60%** 2019
3b5 Social networks % internet users	**65%** 2017	**65%** 2019
3b6 Doing an online course % internet users	**9%** 2017	**11%** 2019
3c1 Banking % internet users	**61%** 2017	**66%** 2019
3c2 Shopping % internet users	**68%** 2017	**71%** 2019
3c3 Selling online % internet users	**22%** 2017	**23%** 2019

Source: DESI 2020, European Commission.

2.1 Use of internet services in 2019

People in the EU engage in a wide range of online activities; however, there are still large disparities across EU Member States regarding the use of internet services. Finland, Sweden, the Netherlands and Denmark have the most active internet users, followed by the UK, Malta, Estonia and Ireland. Conversely, Romania, Bulgaria and Italy are the least active. Ireland and Spain were the Member States that registered the largest improvement in this dimension compared with the previous edition (up 7 and 6 percentage points respectively). They were closely followed by Belgium. Hungary and Finland, which also made significant progress in comparison to their results in the 2019 edition of DESI (+5 percentage points).

Figure 9 Use of internet services (Score 0-100), 2020



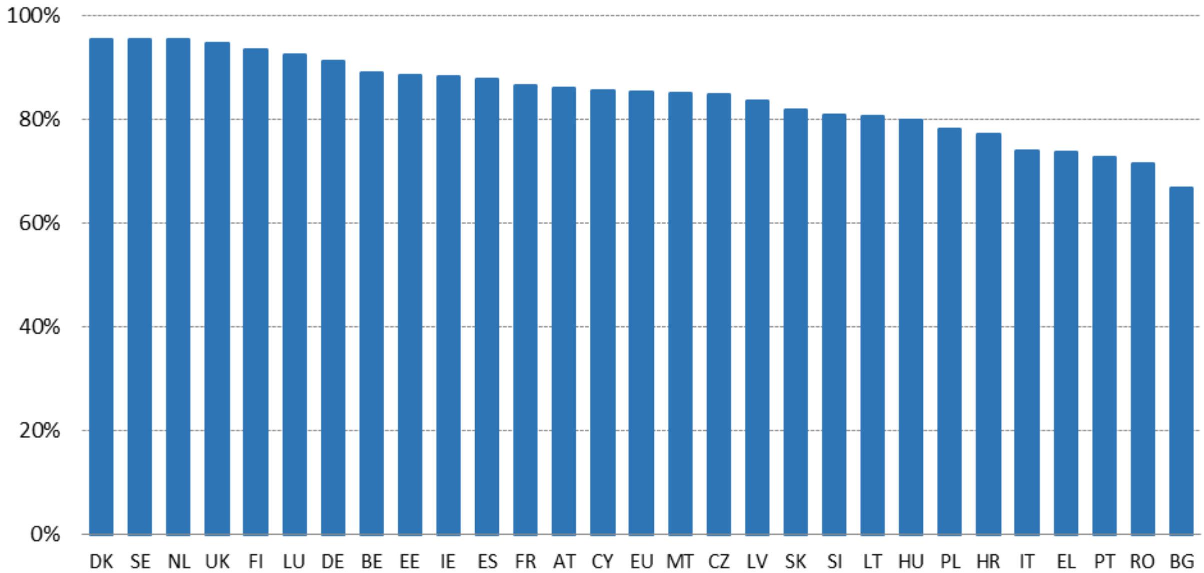
Source: DESI 2020, European Commission.

2.2 Regular internet users

In Member States such as Denmark, Sweden and the Netherlands, the vast majority of the population (95%) uses the internet at least once a week. Noteworthy increases in comparison to last year were recorded in Ireland (+8 percentage points) Spain and Hungary (+5 percentage points). However, in some Member States, over one quarter of the population still does not regularly go online (33% of Bulgarians and 28% of Romanians).

The most active internet users are young individuals (97% of those aged between 16 and 24 are regular internet users), those with a high level of formal education (97%) and students (98%).

Figure 10 Regular internet users – at least once a week (% of individuals), 2019



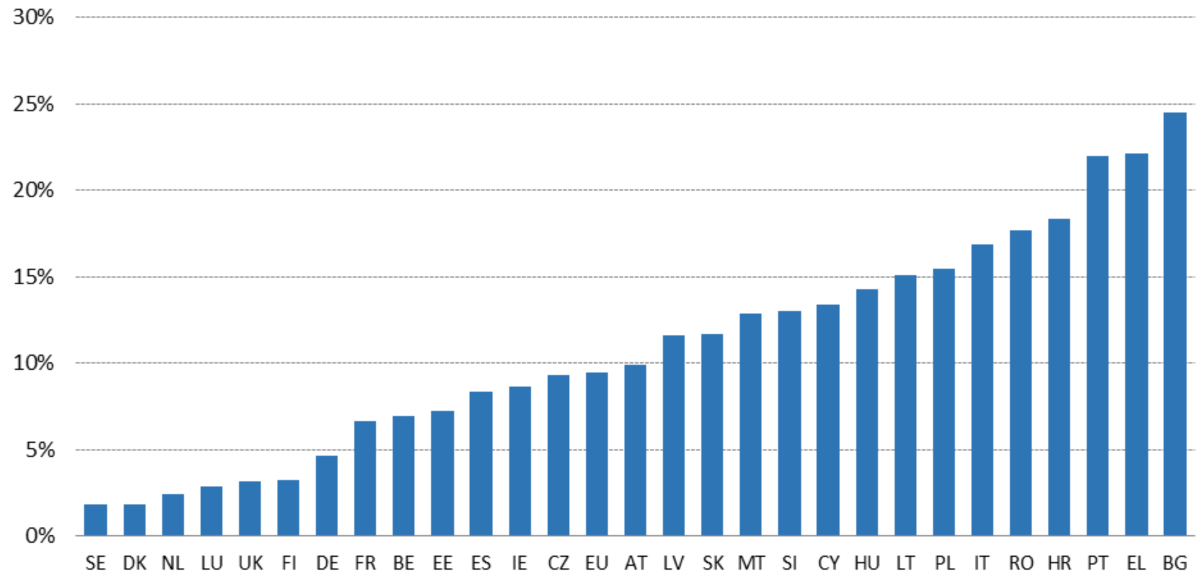
Source: Eurostat, Community survey on ICT usage in Households and by Individuals.

2.3 People who have never used the internet

The share of people in the EU who have never gone online decreased again in 2019, although the current share of 9.5% warrants further action. Despite convergent trends, large differences remain across Member States. The share of people in the EU not using the internet fell in nearly all Member States in 2019. Sweden, Denmark, the Netherlands and Luxembourg are the countries where the share is the lowest (below 3%). The ratio is still large in Bulgaria (24%), Greece (22%), Portugal (22%) and Croatia (18%). The Member States reporting the largest reductions were Ireland with a drop of 7 percentage points, and Spain and Malta with drops of 4 percentage points.

There is a high number of non-users among people with no or low education levels (24%), among those aged between 55 and 74 (23%), and the retired and the inactive (26%).

Figure 11 People who never used the internet (% of individuals), 2019



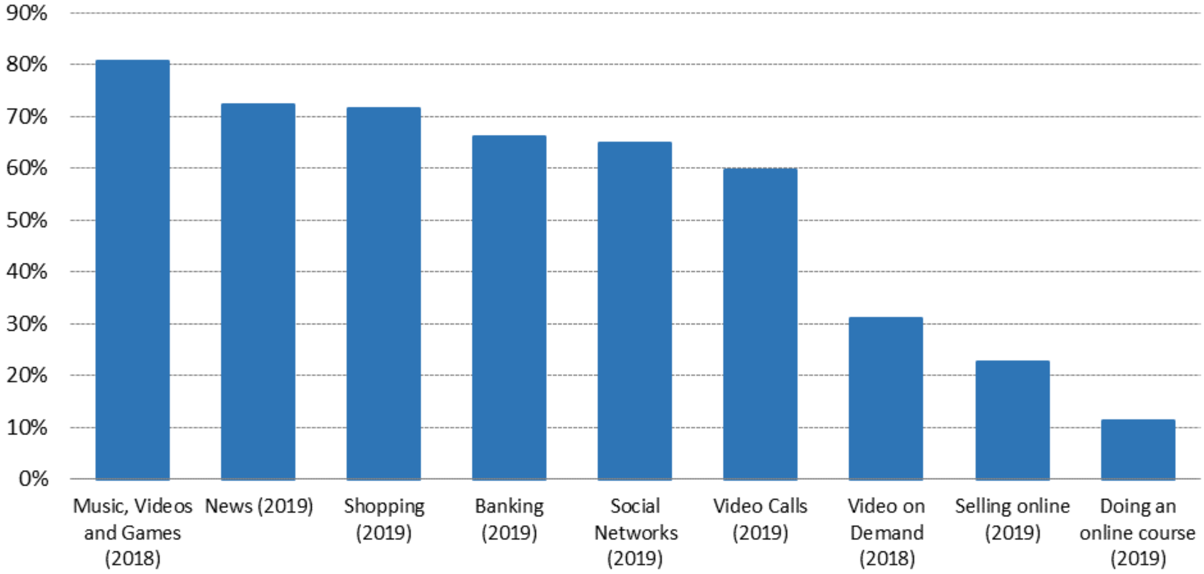
Source: Eurostat, Community survey on ICT usage in Households and by Individuals.

2.4 Online services

Using the internet for listening to music, playing games or watching videos is still the most common activity (81% of individuals who used internet in the last 3 months). Reading news online is the second most popular activity shown in the DESI (72%), while 2 in 3 internet users shop (71%) or bank online (66%). In contrast, doing an online course is among the least popular activities online (11%). It is relatively widespread in Finland (22%) and in the UK (20%) to participate in e-learning activities.

Growth in the use of online services continued in 2019. Annual variation in the different activities considered in the *use of internet services* dimension has been limited. The percentage of people using the internet for shopping, banking and doing an online course increased slightly (about 2.5 percentage points in each). The largest increase concerned video calls, where the share of users went from 49% in 2018 to 60% in 2019. The current crisis may further boost internet usage.

Figure 12 Online activities (% of internet users), 2018 or 2019



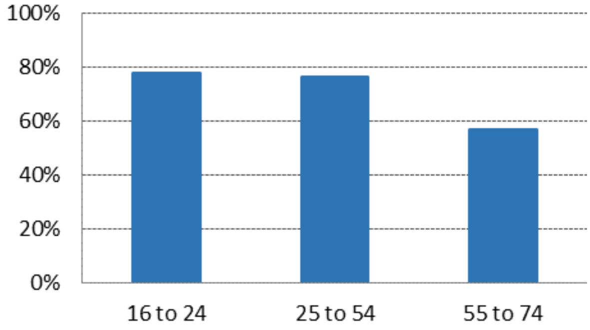
Source: Eurostat, Community survey on ICT usage in Households and by Individuals.

2.5 e-Commerce

The upward trend in e-commerce continued in 2019, with around 71% of EU internet users ordering goods and services online. e-Commerce varies considerably across EU Member States. In 2019, 91% of internet users in the UK and 86% in Denmark shopped online, compared to only 29% in Romania. The largest annual increases were in Croatia (10 percentage points) and in Hungary (8 percentage points).

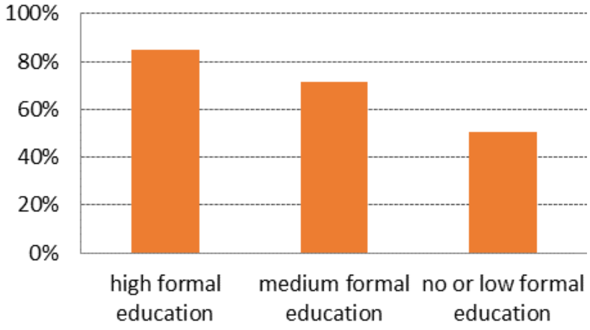
e-Commerce is influenced by age, level of education and employment situation. Young people make up the most active age group of online shoppers (78% of 16-24-year olds), while the proportion of internet users with a higher level of education shopping online (85%) is 35 percentage points higher than those with a lower level of formal education. There is no significant difference by gender as, 72% of male and 71% of female internet users shop online.

Figure 13 Online shopping (% of internet users) by age groups, 2019



Source: Eurostat, Community survey on ICT usage in Households and by Individuals.

Figure 14 Online shopping (% of internet users) by education level, 2019



Source: Eurostat, Community survey on ICT usage in Households and by Individuals.

Cross-border online shopping is advancing more slowly. Among online shoppers, 35% made online purchases from sellers in other EU countries, while 87% made online purchases in their home countries. An increase could be observed for purchases from sellers in other EU countries (from 29% in 2014 to 35% in 2019) and from sellers outside the EU (from 17% in 2014 to 27% in 2019).

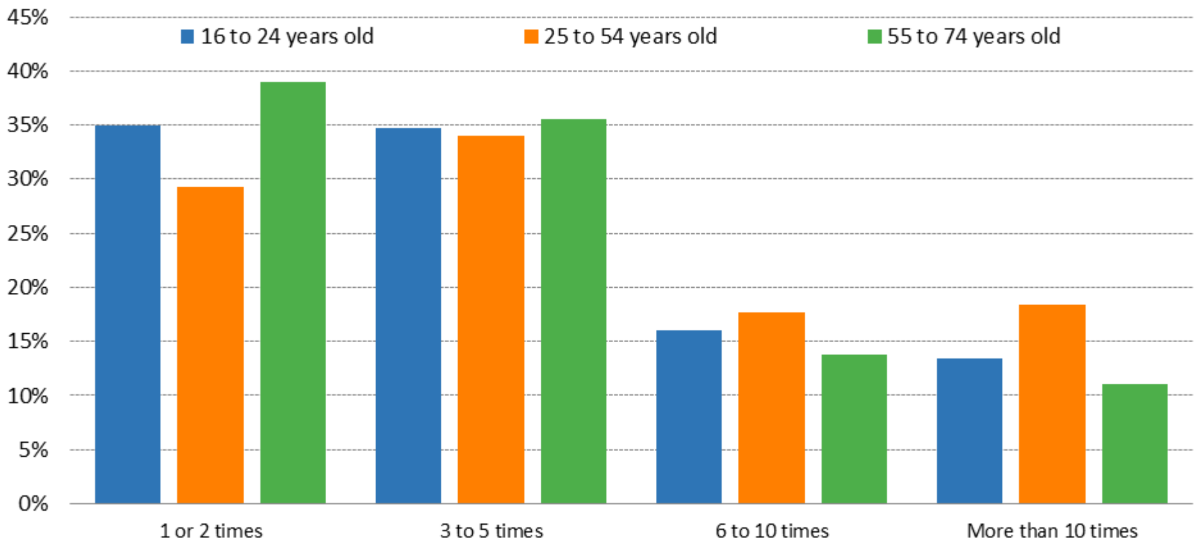
2.6 e-Commerce – categories of goods and services

In 2019, the most popular categories of goods and services purchased online in the EU were clothes and sports goods. These were ordered online by 65% of online shoppers. Clothes and sports goods were followed by travel and holiday accommodation (54%), household goods (46%), tickets for events (41%), and finally books, magazines and newspapers, which were chosen by every third European (33%). Only 17% bought computer hardware, while 16% purchased medicines.

Online shoppers aged 16-24 favoured clothes and sports goods in their online purchases (73% of individuals), while people aged 25-54 were the most frequent buyers of travel and holiday accommodation (57%), household goods (52%), and tickets for events (43%). People aged 16-24 were purchasing also video games software, other software and upgrades (34%), or films and music (34%). People aged 55-74 took the lead in buying medicines (20%).

About 34% of online buyers bought goods or services for private use between three and five times, while 32% had done so once or twice. 16% made online purchases over 10 times in the previous 3 months. Over 4 in 10 online shoppers claimed to have spent between €100 and €499 on online purchases over the previous three-month period.

Figure 15 Frequency of online shopping by age groups (% of individuals who purchased online in the last 3 months), 2019



Source: Eurostat, Community survey on ICT usage in Households and by Individuals.

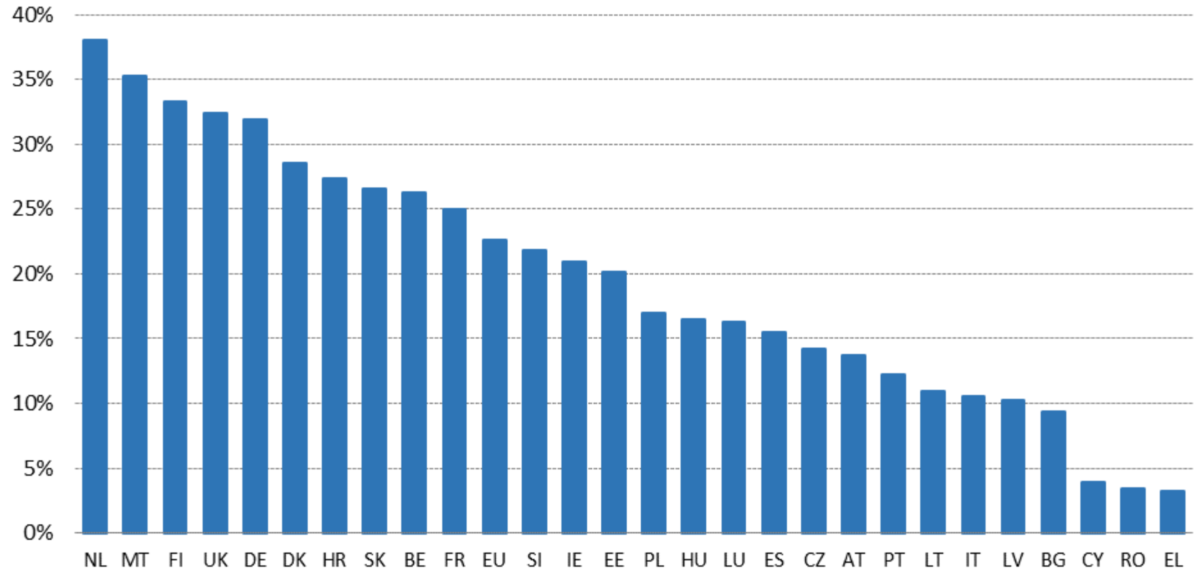
65% of e-buyers reported having no problem when buying or ordering goods or services in the previous 12 months. Problems encountered most often by EU online shoppers related to slower deliveries than indicated at the time of making the purchase (19%).

Among internet users who have purchased more than one year ago, or did not purchased at all, the main reason given for not making purchases online was a preference for shopping in person to see the products before the purchase (73%). Other, much less reported factors, were payment security concerns (24%) and lack of skills or knowledge (21%).

2.7 People selling online

In 2019, 23% of internet users sold goods or services over the internet in the last three months. The highest shares among EU Member States were recorded in the Netherlands (38%), Malta (35%) and Finland (33%). Belgium and Finland recorded the highest increase in comparison to last year (both were up 5 percentage points). Cyprus, Romania and Greece are the countries with the weakest performance (below 5%) among other EU Member States.

Figure 16 Selling online in the last three months (% of internet users), 2019



Source: Eurostat, Community survey on ICT usage in Households and by Individuals.

3 Integration of digital technology

Digital technologies enable businesses to gain competitive advantage, improve their services and products and expand their markets. Digital transformation of businesses opens up new opportunities and boosts the development of new and trustworthy technologies. This dimension measures the digitisation of businesses and e-commerce.

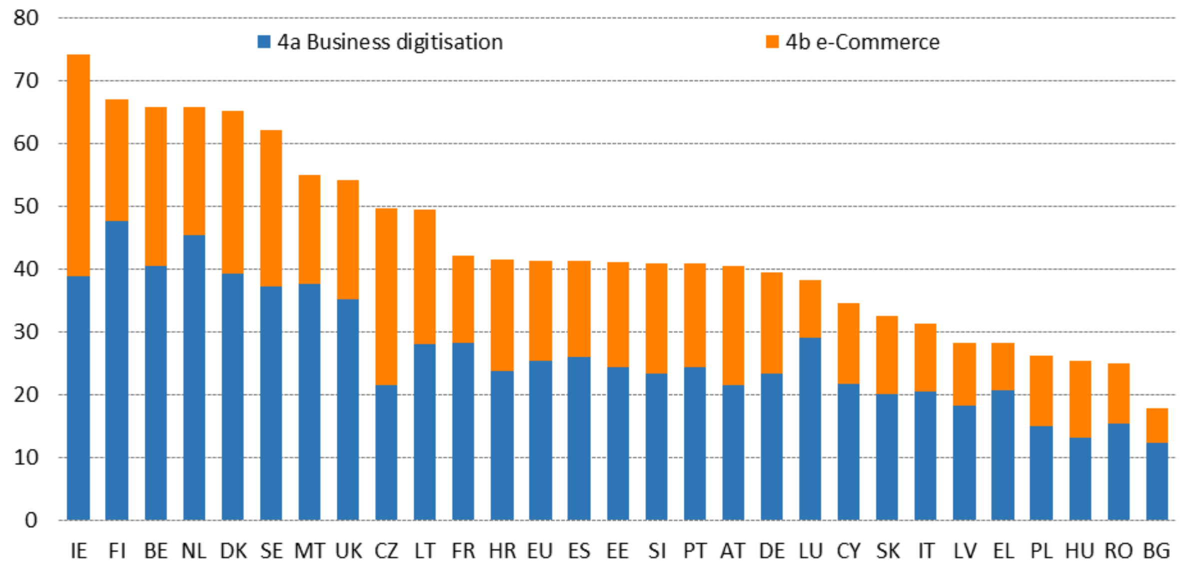
Table 3 Integration of digital technologies indicators in DESI

	EU	
	DESI 2018	**DESI 2020**
4a1 Electronic information sharing % enterprises	**34%** 2017	**34%** 2019
4a2 Social media % enterprises	**21%** 2017	**25%** 2019
4a3 Big data % enterprises	**10%** 2016	**12%** 2018
4a4 Cloud % enterprises	**NA**	**18%** 2018
4b1 SMEs selling online % SMEs	**17%** 2017	**18%** 2019
4b2 e-Commerce turnover % SME turnover	**10%** 2017	**11%** 2019
4b3 Selling online cross-border % SMEs	**8%** 2017	**8%** 2019

Source: DESI 2020, European Commission.

The top performers are Ireland, Finland, Belgium, the Netherlands, Denmark and Sweden with scores greater than 55 points (out of 100). At the other end of the scale, Bulgaria, Romania, Hungary Poland, Greece and Latvia lag behind with scores less than 35 points, significantly below the EU average of 43 points.

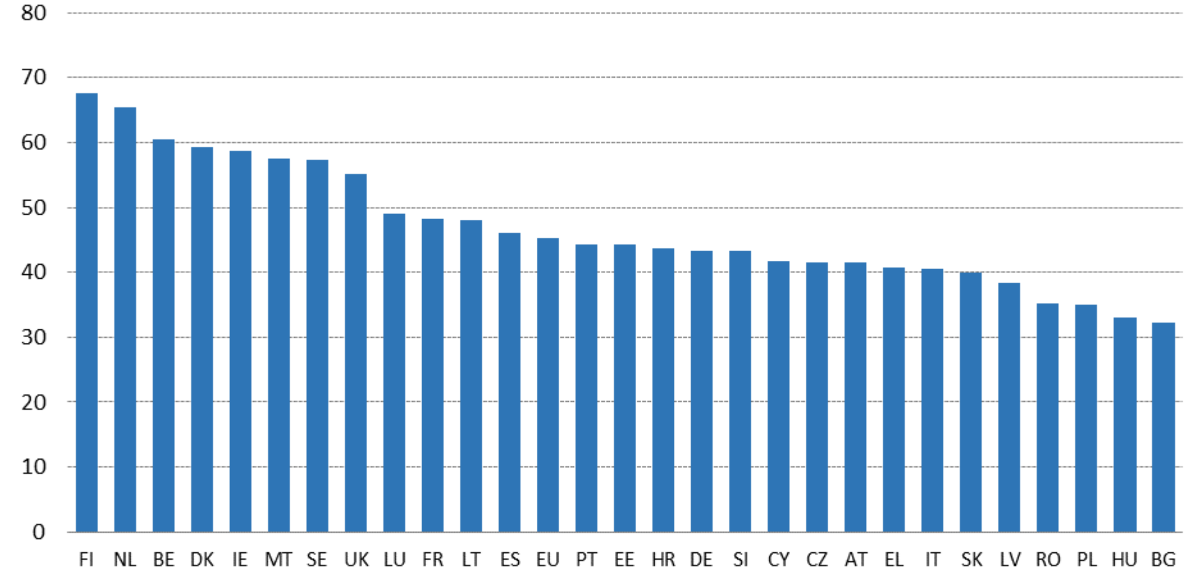
Figure 17 Digital Economy and Society Index (DESI) 2020, integration of digital technologies



Source: DESI 2020, European Commission.

The leading countries on '4a business digitisation' are Finland, the Netherlands and Belgium, with scores above 60 points. Bulgaria, Hungary, Poland, Romania, Latvia and Slovakia lag behind in the adoption of e-business technologies, scoring below 40 points.

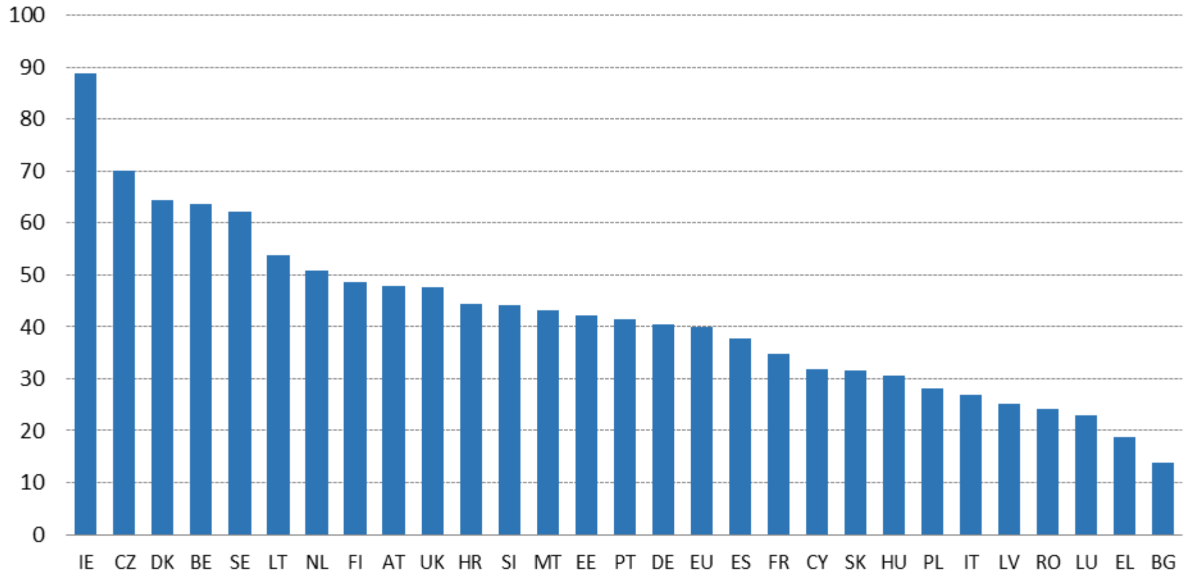
Figure 18 Integration of digital technologies, business digitisation index, 2020



Source: DESI 2020, European Commission.

Ireland, Czechia, Denmark, Belgium and Sweden are the top five countries in '4b e-commerce', with scores above 60 points. Ireland leads in all the three indicators under e-commerce (i.e. SMEs selling online, e-commerce turnover and selling online cross-border). Bulgaria, Greece, Luxembourg and Romania perform the worst with scores below 25 points.

Figure 19 Integration of digital technologies, e-commerce index, 2020



Source: DESI 2020, European Commission.

3.1 Digital intensity index

The Digital Intensity Index (DII) measures the use of different digital technologies at enterprise level. The DII score (0-12) of an enterprise is determined by how many of the selected digital technologies it uses. Figure 20 presents the composition of the DII in 2019. It also shows the degree of penetration and speed of adoption of the different technologies monitored by the DII. Large companies are more digitised than SMEs. While some aspects seem to be reaching saturation, at least for large companies, for most aspects there is still room for improvement.

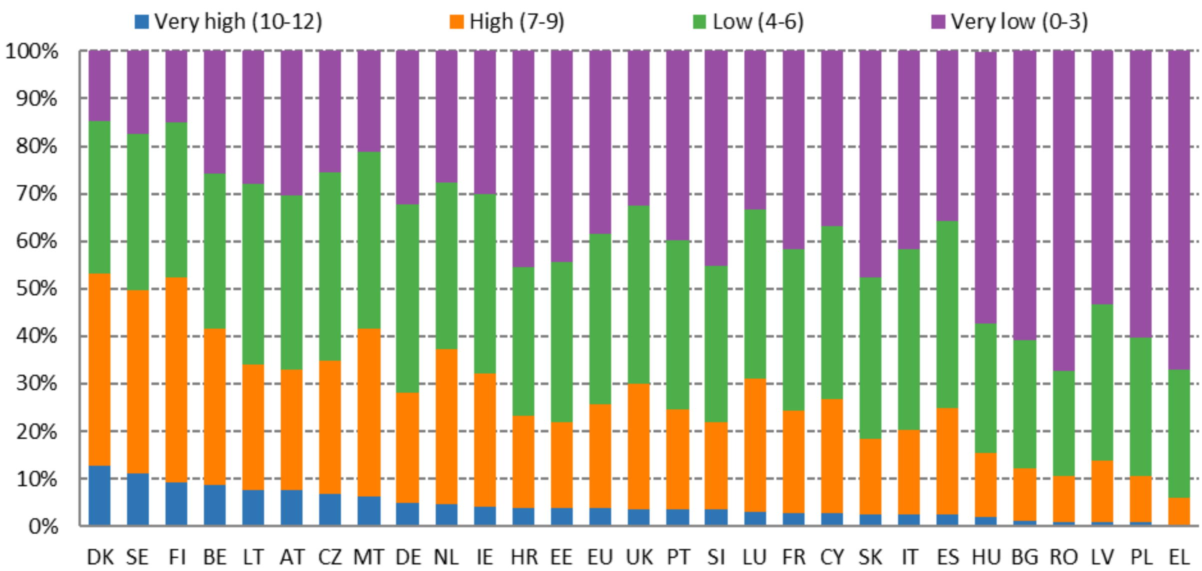
Figure 20 Digital Intensity Index indicators tracking digitisation processes (% enterprises), 2019

	Large	SMEs
Use anyICT security measures	99%	92%
Make persons employed aware of their obligations in ICT 'security related issues'	91%	61%
Maximum contracted download speed of the fastest internet connection is at least 30 Mb/s	80%	49%
Use ERP software package to share information	78%	33%
Use any social media	78%	52%
Use social media for any purpose	76%	50%
Use customer relationship management (CRM) software	62%	32%
>50% of employed people use computers and the internet	55%	44%
>20% of workers with portable devices for business use	46%	36%
Sell online (at least 1% of turnover)	39%	18%
Receive electronic orders (web or EDI) from customers from other EU countries	23%	8%
> 1% of the total turnover web sales and B2C web sales> 10% of the web sales	10%	8%

Source: Eurostat, Community survey on ICT usage and e-commerce in enterprises.

Denmark and Sweden are the only countries in the EU where the percentage of enterprises with a very high DII (i.e. possessing at least 10 out of the 12 monitored digital technologies) is above 10%, followed by Finland and Belgium with 9%. By contrast, in countries such as Romania, Greece, Bulgaria, Poland and Hungary the majority of businesses (over 55%) have made only a small investment in digital technologies (i.e. have a very low DII).

Figure 21 Digital Intensity Index by level (% of enterprises), 2019

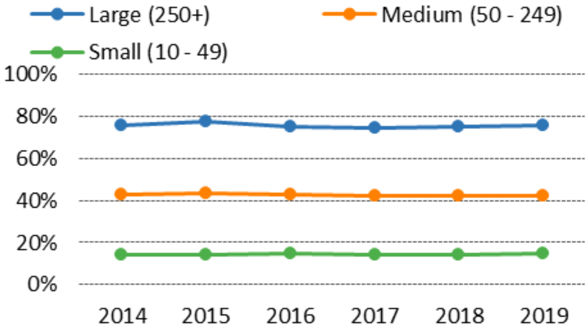


Source: Eurostat, Community survey on ICT usage and e-commerce in enterprises.

3.2 ICT specialists in enterprises

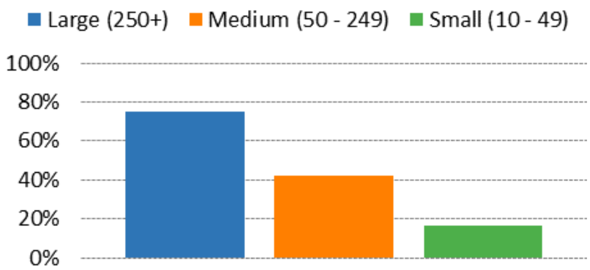
Large enterprises have a scale advantage, and as a result 75% of them employ internal ICT specialists. The share of small enterprises employing ICT specialists increased from 14% in 2018 to 15% in 2019. For medium-sized enterprises the increase was limited (42.5% in 2019, compared to 42.1% in 2018).

Figure 22 Enterprises employing ICT specialists (% of enterprises), 2014-2019



Source: Eurostat, Community survey on ICT usage and e-commerce in enterprises.

Figure 23 Enterprises employing ICT specialists (% of enterprises), 2019

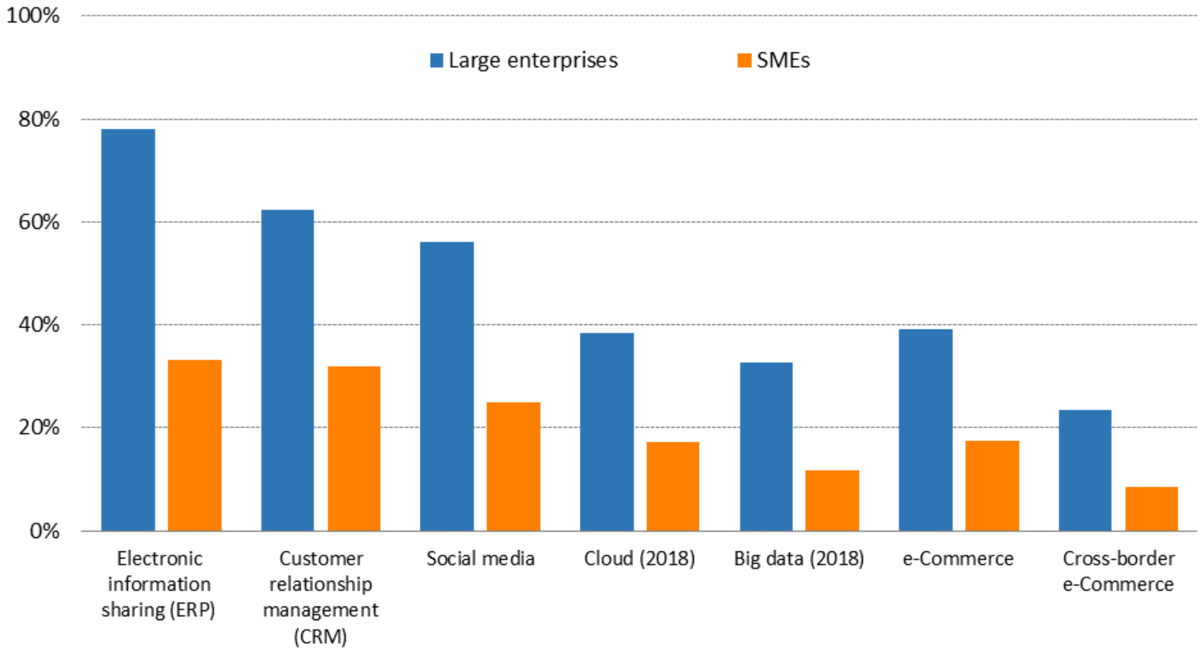


Source: Eurostat, Community survey on ICT usage and e-commerce in enterprises.

3.3 Adoption of digital technologies by enterprises

It is evident that large enterprises adopt new technologies more often. Electronic information sharing through enterprise resource planning (ERP) software is much more common in large enterprises (78%) than in SMEs (33%). SMEs (32%) use customer relationship management (CRM) systems to analyse information about clients for marketing purposes less than large enterprises (62%). In contrast, large enterprises (78%) and SMEs (52%) are active on social media. SMEs exploit e-commerce opportunities to a limited extent, as only 18% sell online (versus 39% of large enterprises) and only 8% sell cross-border online (23% for large enterprises). There are many other technological opportunities yet to be exploited by SMEs such as cloud services and big data.

Figure 24 Adoption of digital technologies (% entreprises), 2019

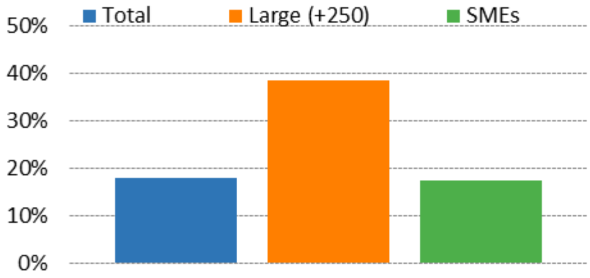


Source: Eurostat, Community survey on ICT usage and e-commerce in enterprises.

3.4 Cloud computing

In 2018, 26% of European enterprises purchased cloud computing services and incorporated cloud technologies to improve their operations while reducing costs; this was an increase of 25% on 2016. The cloud uptake of larger companies (56%) was higher than for SMEs (25%) in 2018.

Figure 25 Cloud computing services of medium-high sophistication (% of enterprises), 2018

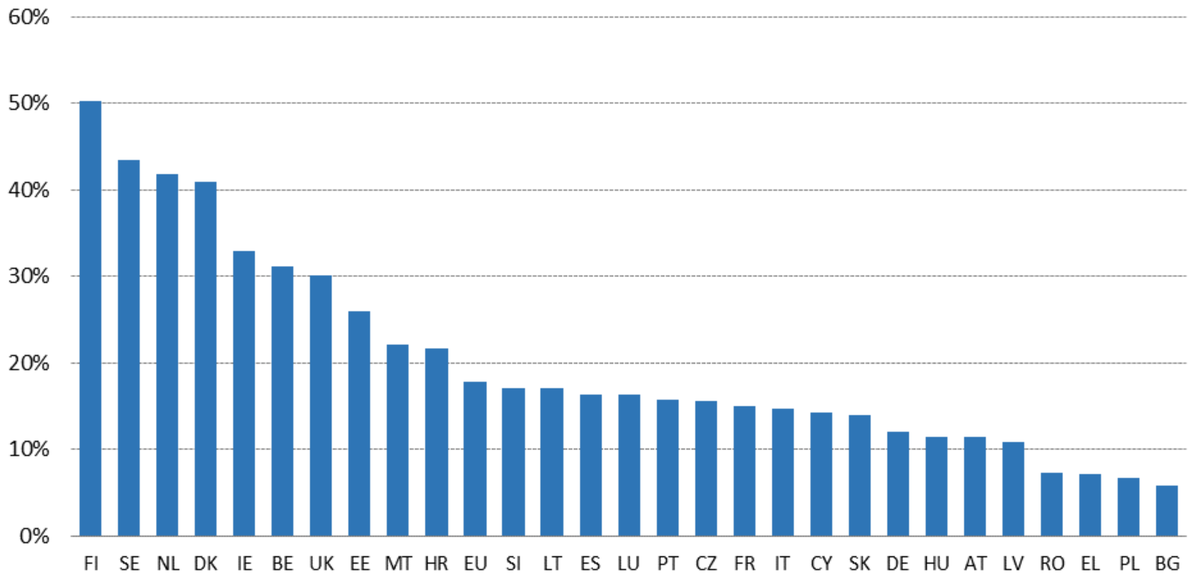


Source: Eurostat, Community survey on ICT usage and e-commerce in enterprises.

18% of companies use medium-highly sophisticated services (i.e. hosting of the enterprise's database, accounting software applications, CRM software and computing power). The ratio for large enterprises is 39%, well above that of SMEs (17%).

Finnish enterprises are leaders in incorporating cloud services of medium-high sophistication. 50% of Finnish enterprises buy such services, an increase of 50% between 2014 and 2018. Sweden, the Netherlands and Denmark follow at more than 40%. However, the gap between top and low performers remains large, with Bulgaria, Poland, Greece and Romania scoring below 10%.

Figure 26 Cloud computing services of medium-high sophistication per country (% of enterprises), 2018

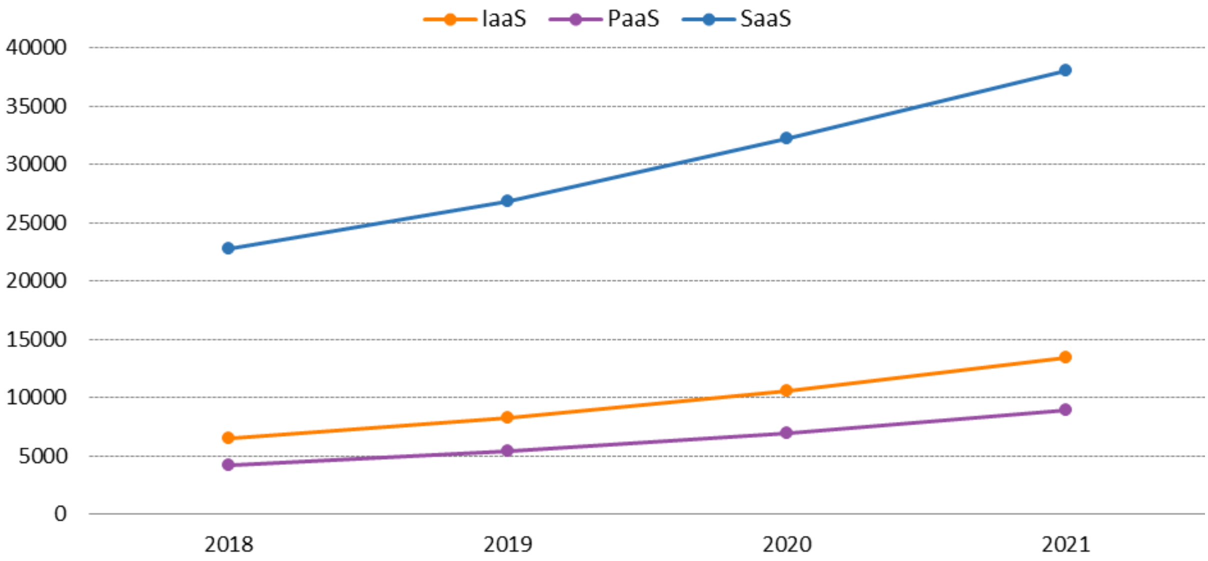


Source: Eurostat, Community survey on ICT usage and e-commerce in enterprises.

Across the EU market, total revenues generated by public cloud services, i.e. Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) increased by 21% between 2018 and 2019. Total revenues are expected to continue to grow by 50% between 2019 and 2021.

SaaS represents almost two thirds of total public cloud revenues generated on the EU market and is forecasted to continue until at least 2021. IaaS and PaaS represent 20% and 13% respectively of total public cloud revenues generated on the EU market. Between 2019 and 2021, it is forecasted that IaaS and PaaS will grow at 63% and 67% respectively both at a higher rate than SaaS over the same period (42%).

Figure 27 EU public cloud service revenues per category (forecast revenues for 2020 and 2021) (€ million), 2018 – 2021

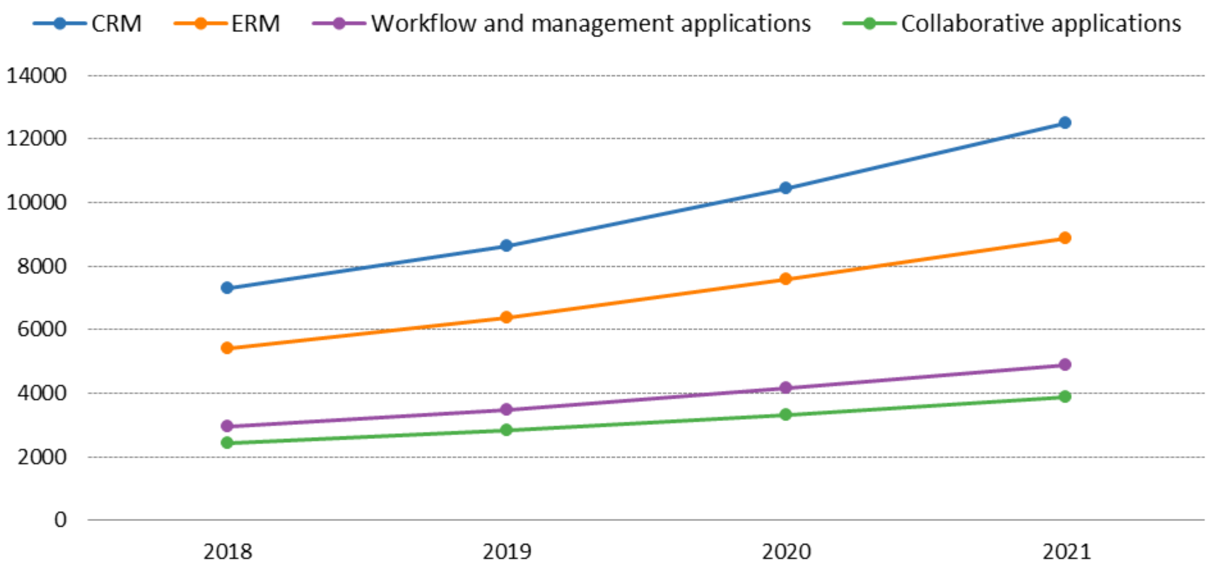


Source: European Commission based on IDC.

Between 2018 and 2019, among the four applications contributing the most to SaaS revenues across the EU market, the revenue growth rates for each increased by the following percentages: 18% for content workflow and management applications, 18% for CRM, 17% for enterprise risk management (ERM) and 16% for collaborative applications. These are also expected to remain the most prominent applications contributing to total SaaS revenues until at least 2021, with expected respective revenue growth rates of 40%, 45%, 40% and 37% between 2019 and 2021.

Software security, as a SaaS application, contributed €115.5 million to total SaaS revenues on the EU market. Its revenue growth rate is expected to increase by 48% between 2019 and 2021, making it the fastest growing SaaS application over that period.

Figure 28 Revenue of the top 4 SaaS Applications as share of total SaaS EU (forecast revenues for 2020 and 2021) (€ million), 2018 – 2021



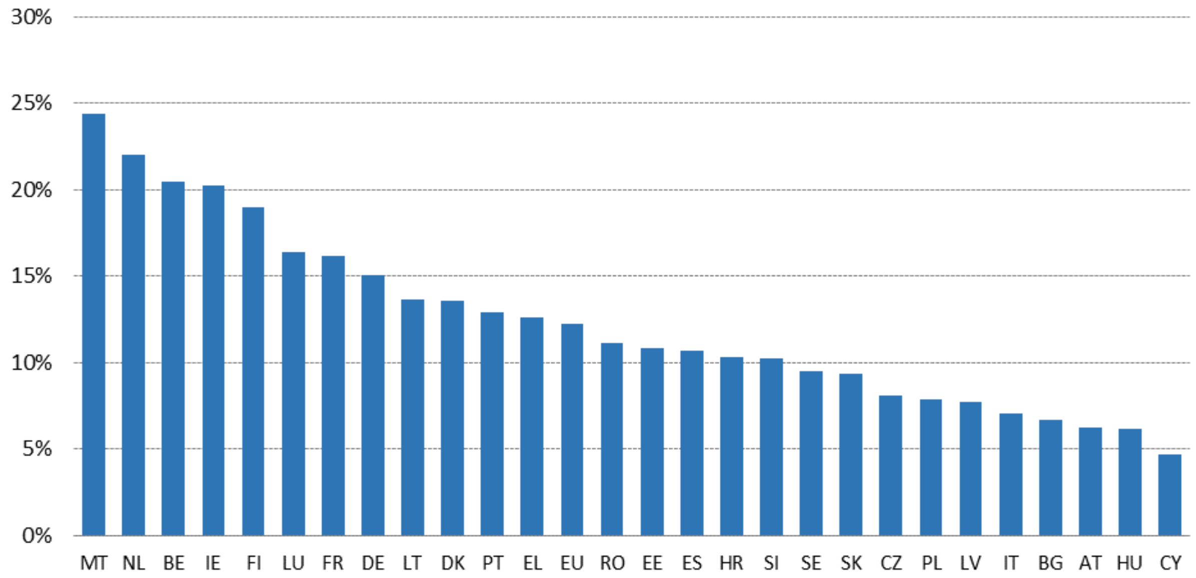
Source: European Commission based on IDC.

3.5 Big data

Enterprises all over the EU are constantly adapting to new technologies for collecting, storing and analysing data. In 2018, 12% of companies used big data for analysing large volumes of data. This helped them to produce near time or real time results from data that come in different format types. Large companies have the lion's share in big data processing (with 33% of them using big data), while SMEs have still room for improvement to take advantage of all the benefits of big data (12% use big data).

In Malta, almost a quarter of enterprises use big data. The Netherlands, Belgium and Ireland follow closely, with at least 20%. On the other hand, enterprises in Cyprus, Hungary, Austria and Bulgaria barely use big data at all.

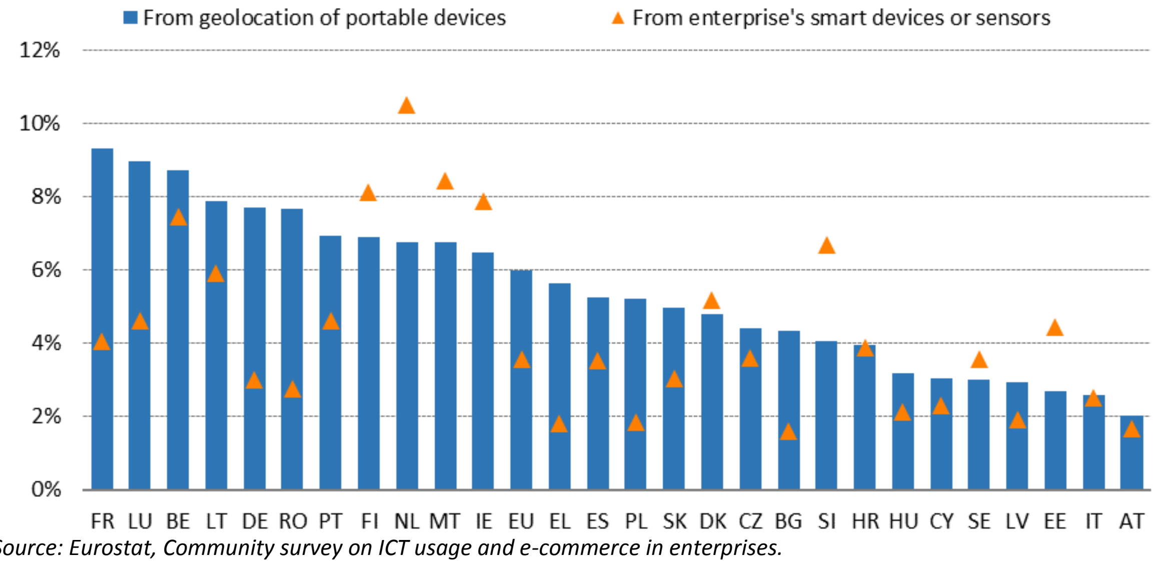
Figure 29 Enterprises analysing big data from any data source (% of enterprises), 2018



Source: Eurostat, Community survey on ICT usage and e-commerce in enterprises.

Nearly 6% of enterprises analyse big data from geolocation of portable devices, while 4% analyse data from their smart devices or sensors.

Figure 30 Sources used by enterprises to analyse big data (% of enterprises), 2018

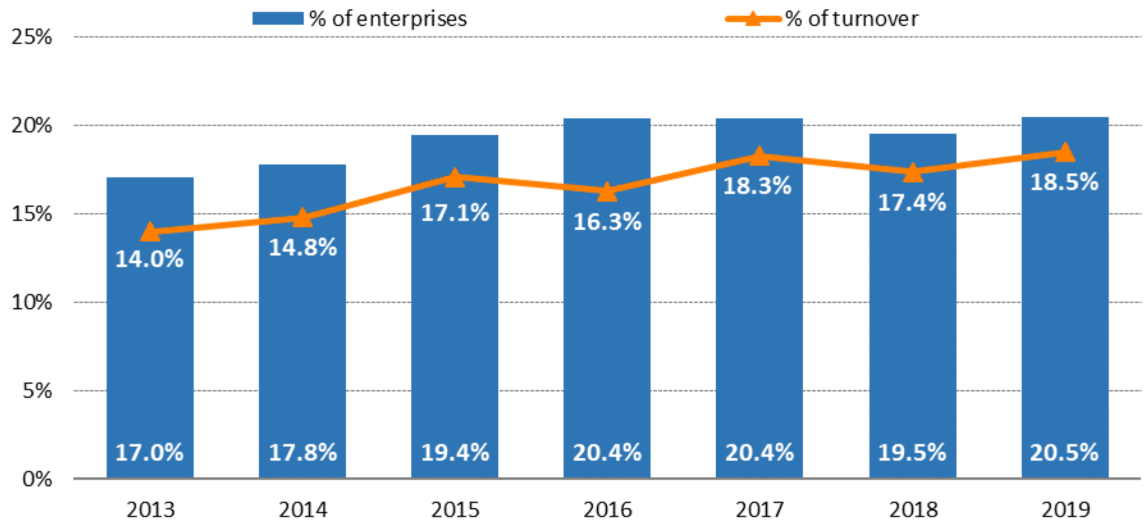


Source: Eurostat, Community survey on ICT usage and e-commerce in enterprises.

3.6 e-Commerce

Already before the COVID-19 outbreak, one in five EU enterprises made online sales. For 2019, online sales amounts to 18% of total turnover of companies that employ 10 or more people. Between 2013 and 2019, the percentage of companies selling online increased by 3.5 percentage points and the turnover of these companies realised from online sales increased by 4.5 percentage points.

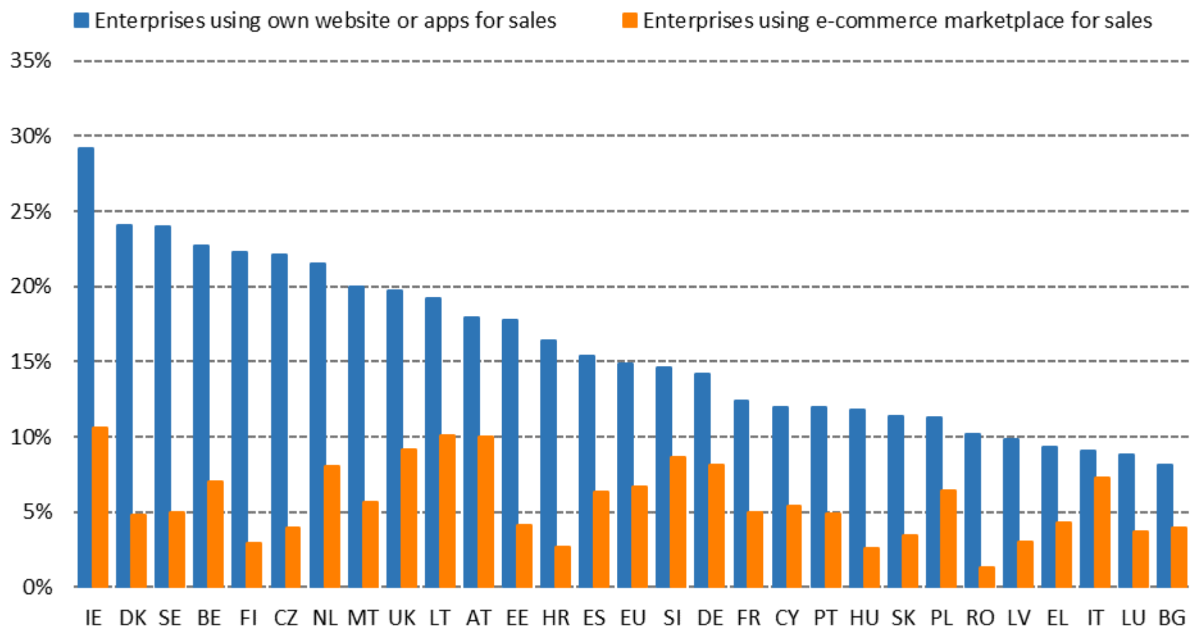
Figure 31 Trends in e-commerce (% of enterprises, % of turnover), 2013-2019



Source: Eurostat, Community survey on ICT usage and e-commerce in enterprises.

Prior to the pandemic, almost 15% of enterprises were active on online marketplaces in Europe using their own website or apps for selling online. Ireland is the leader with 29% of its enterprises active on online marketplaces, followed by Denmark and Sweden (each with 24%). Almost 7% of all enterprises in the EU sold through e-commerce marketplaces used by several enterprises for trading products. Online platforms may facilitate economic growth by enabling sellers to access new markets and reach new customers at lower costs.

Figure 32 Online sales broken down by own website or apps and marketplace (% enterprises), 2019

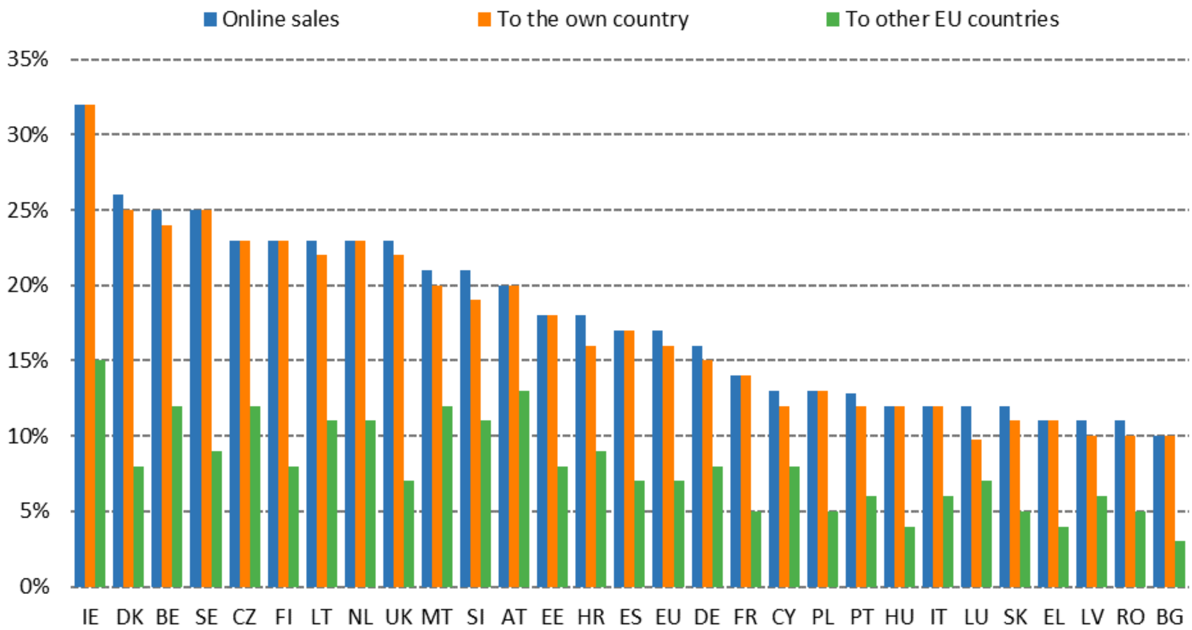


Source: Eurostat, Community survey on ICT usage and e-commerce in enterprises.

3.7 Cross-border e-commerce

Enterprises benefit from cross-border e-commerce by exploiting economies of scale. This helps to reduce costs, increase efficiency, promote competitiveness and improve productivity. Cross-border e-commerce is even more important for enterprises and especially SMEs that are confined to a small home market. Only 7% of enterprises have web sales to customers in other EU countries, while almost all enterprises with web sales report that they sell to customers in their own country (16%). Enterprises in Ireland, Denmark, Belgium and Sweden have the largest proportion of online sales, with 25% or more of their sales occuring online. Ireland is also the country, where companies are most likely to make cross-border web sales to other EU countries (15% of Irish enterprises have web sales across borders), followed by Austria (13%) Belgium (12%), Czechia (12%) and Malta (12%).

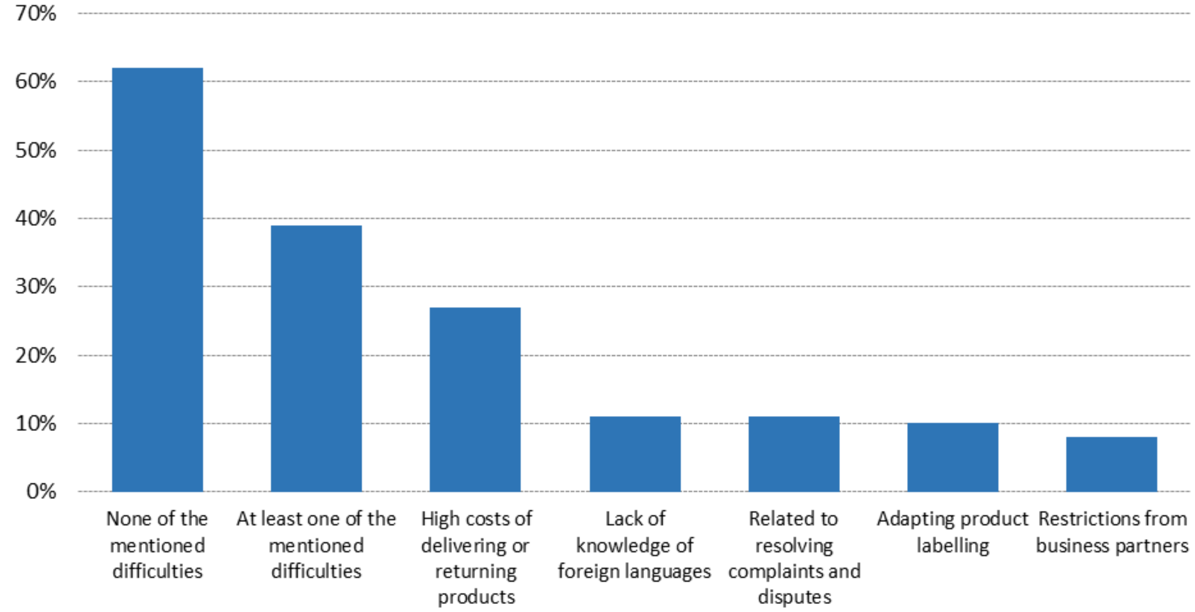
Figure 33 Web sales to own country and other EU countries (% of enterprises), 2019



Source: Eurostat, Community survey on ICT usage and e-commerce in enterprises.

Most of enterprises (62%) with web sales to other EU countries have no difficulties when selling to customers in other EU countries. On the other hand, almost 40% report at least one obstacle that is mainly related to economic factors (e.g. high costs of delivering or returning products, a problem reported by 27% of enterprises). Other factors such as linguistic and legal problems are also significant. The lack of knowledge of foreign languages and problems related to resolving complaints and disputes are also highlighted as difficulties by 11% of the enterprises selling online to other EU countries.

Figure 34 Difficulties when selling to other EU countries (% of enterprises with web sales to other EU countries), 2019

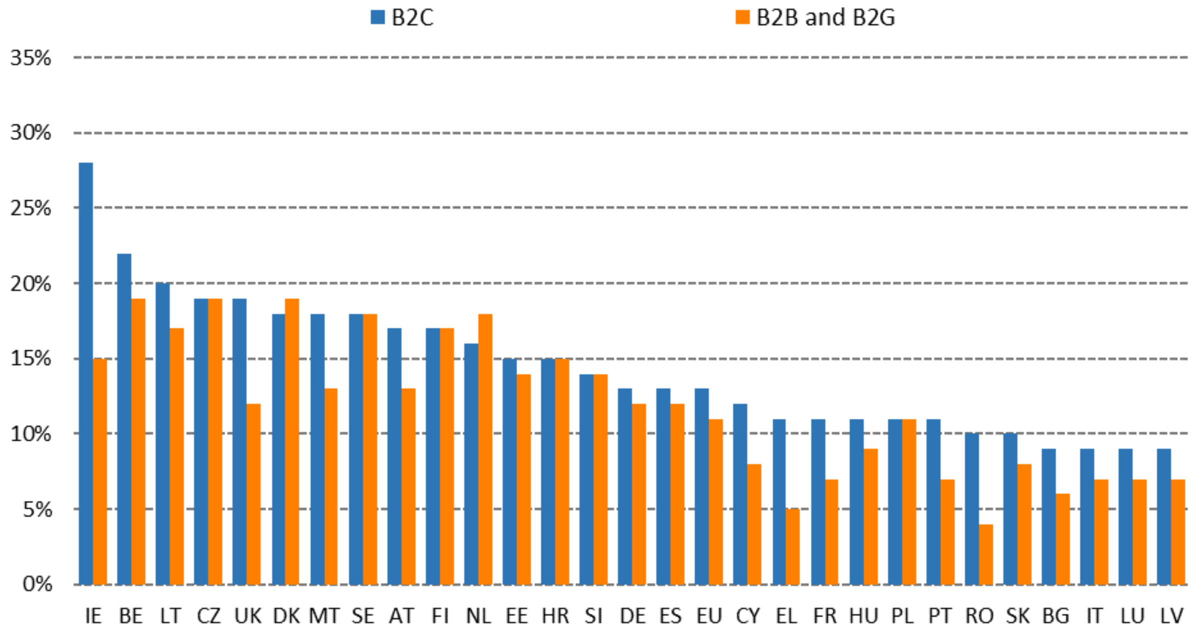


Source: Eurostat, Community survey on ICT usage and e-commerce in enterprises.

3.8 Business to business (B2B), business to government (B2G) and business to consumers (B2C) web sales

11% of EU enterprises report web sales to businesses and governments. 13% have web sales to consumers, ranging from 9% of enterprises in Latvia, Luxembourg, Italy and Bulgaria to 28% in Ireland.

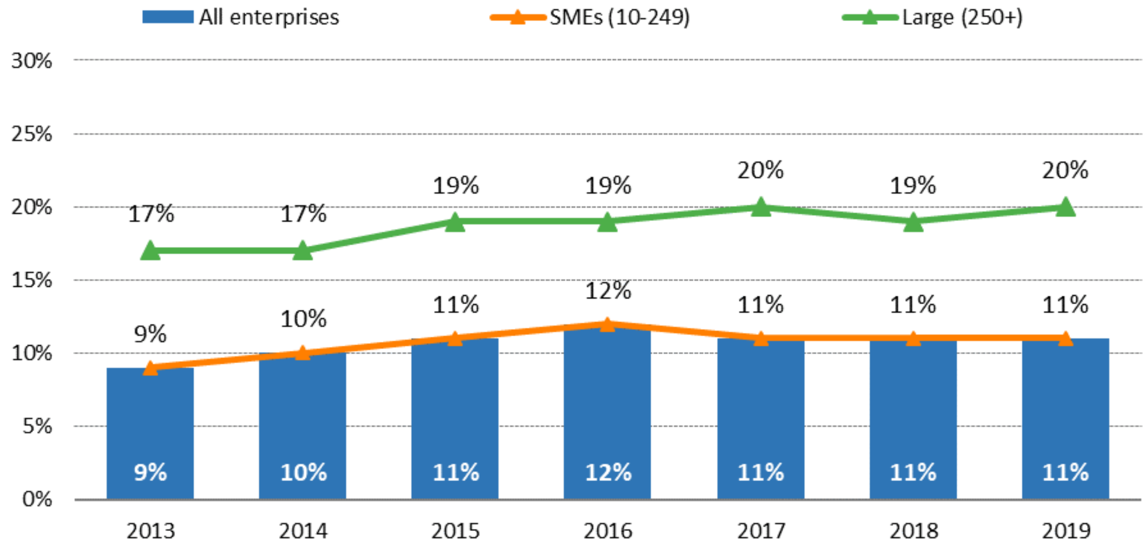
Figure 35 Enterprises exploiting B2C, B2B and B2G opportunities (% of enterprises), 2019



Source: Eurostat, Community survey on ICT usage and e-commerce in enterprises.

11% of enterprises sell through a website or an app to other enterprises or governments, slightly more than in 2013 (9%). Large enterprises are more active in this segment with 20% of large companies selling B2B or B2G online, up from 17% in 2013. However, only 11% of SMEs are active in B2B or B2G online sales.

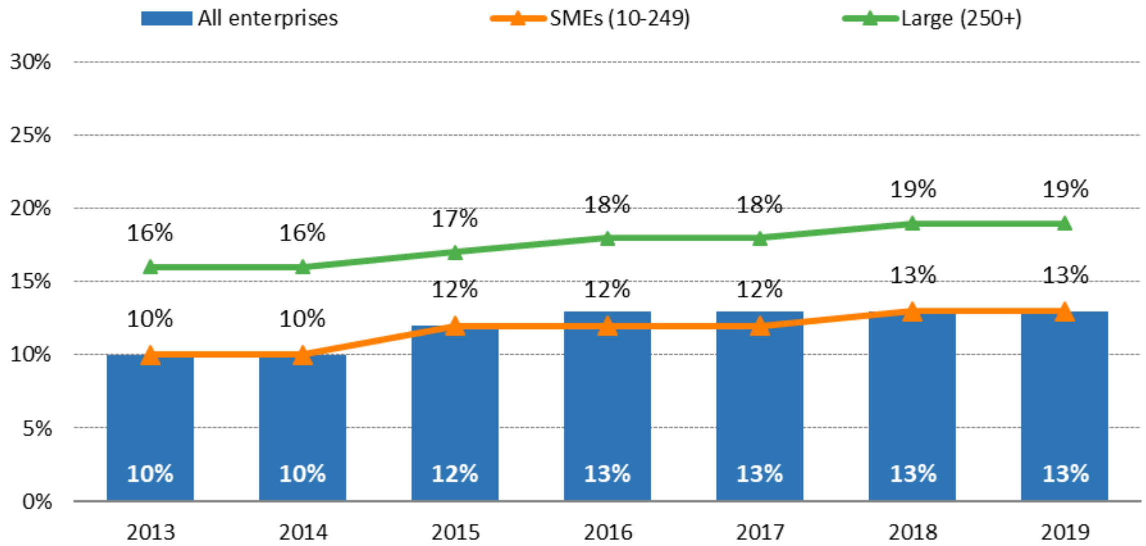
Figure 36 Enterprises exploiting B2B and B2G opportunities (% of enterprises), 2013-2019



Source: Eurostat, Community survey on ICT usage and e-commerce in enterprises.

Web sales to consumers follow the same trend as B2B and B2G sales. 13% of enterprises perform web sales to consumers. The increase since 2013 is 3 percentage points for large and SMEs.

Figure 37 Enterprises exploiting B2C opportunities of online sales (% of enterprises with B2C online sales more than 10% of the web sales), between 2013 and 2019



Source: Eurostat, Community survey on ICT usage and e-commerce in enterprises.

4 Digital public services

Digital technologies increasingly place new demands and expectations on the public sector. Realising the full potential of these technologies is a key challenge for governmental organisations. Effective e-government can provide a wide variety of benefits including more efficiency and savings for both governments and businesses. It can also increase transparency and openness. This dimension measures both the demand and supply sides of digital public services as well as open data.

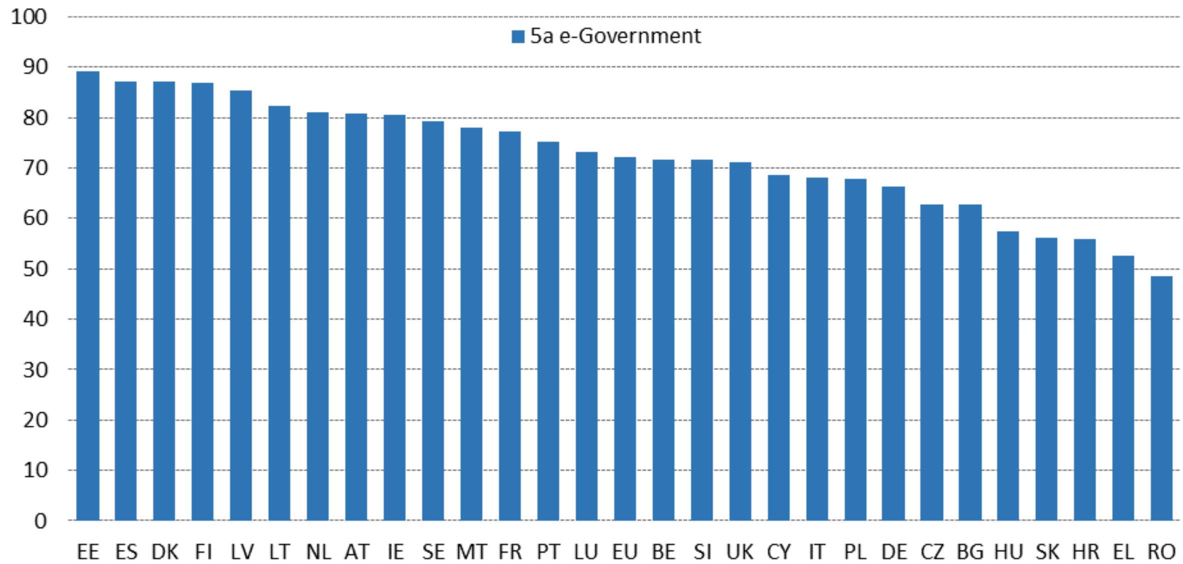
Table 4 Digital public services indicators in DESI

	EU	
	DESI 2018	**DESI 2020**
5a1 e-Government users % internet users needing to submit forms	**58%** 2017	**67%** 2019
5a2 Pre-filled forms Score (0 to 100)	**53** 2017	**59** 2019
5a3 Online service completion Score (0 to 100)	**85** 2017	**90** 2019
5a4 Digital public services for businesses Score (0 to 100) - including domestic and cross-border	**83** 2017	**89** 2019
5a5 Open data % of maximum score	**NA**	**66%** 2019

Source: DESI 2020, European Commission.

The top performers are Estonia, Spain, Denmark, Finland and Latvia, all of which have scores greater than 85. On the other hand, Romania, Greece, Croatia, Slovakia and Hungary all score less than 60 and significantly below the EU average of 72.2.

Figure 38 Digital Economy and Society Index (DESI) 2020, digital public services



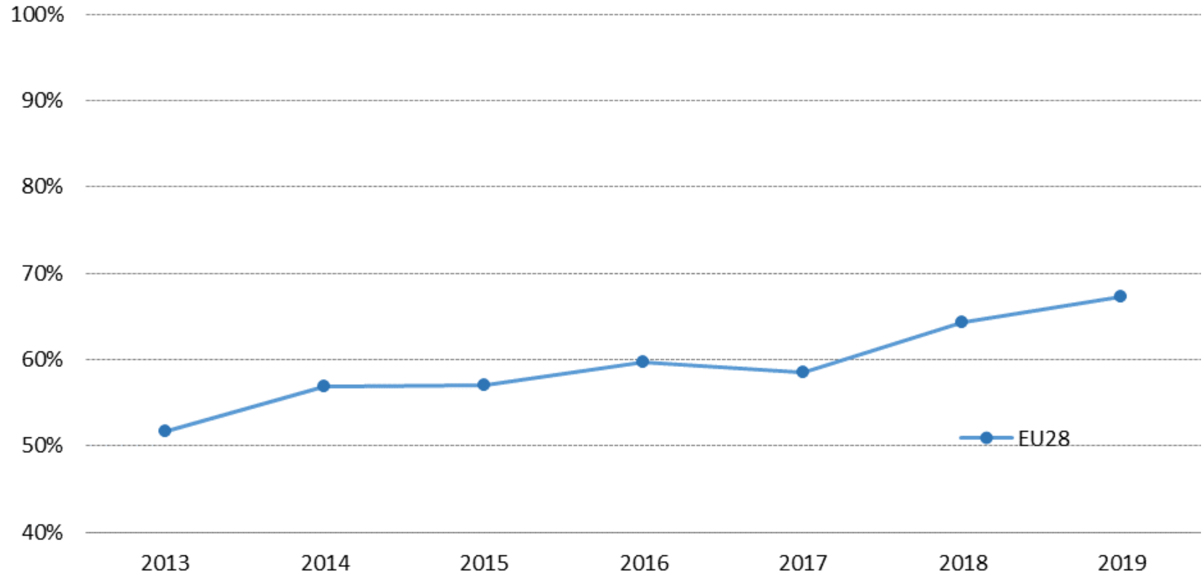
Source: DESI 2020, European Commission.

4.1 e-Government users

This indicator considers out of all internet users who needed to submit forms to the public administration - the percentage who submitted the forms through online means.

Demand for digital public services is growing: 67% of EU citizens who needed to submit forms to public authorities did so online in 2019. This is an increase from 64% 2018. It is noteworthy that since 2013, the number of e-government users has increased by 26 percentage points, from 41% to 67%.

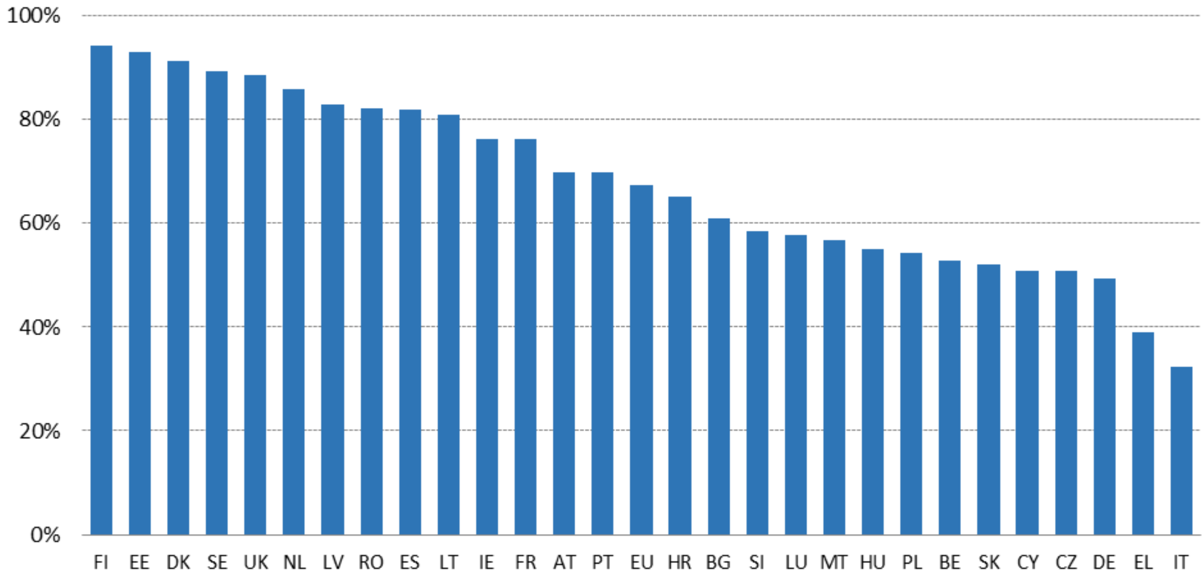
Figure 39 e-Government users submitting filled-in forms to public authorities in the last 12 months (% of all internet users needing to submit filled forms to public authorities), 2013-2019



Source: Eurostat, Community survey on ICT usage in Households and by Individuals.

Finland, Estonia and Denmark performed very well on this measure, with more than 90% of internet users (aged 16-74) who needed to submit filled forms to the public administration choosing governmental portals, Italy and Greece were less strong in this measure, and were the only two countries where less than 40% of internet users submitted forms to public authorities online. 20 countries performed better in 2019 than in 2018, with Malta making the largest improvement - an increase of 7 percentage points. Malta was followed by Germany and Spain which both improved by 6 percentage points.

Figure 40 e-Government users submitting filled forms to public authorities over the Internet in the last 12 months (% of all internet users needing to submit forms to public authorities), 2019



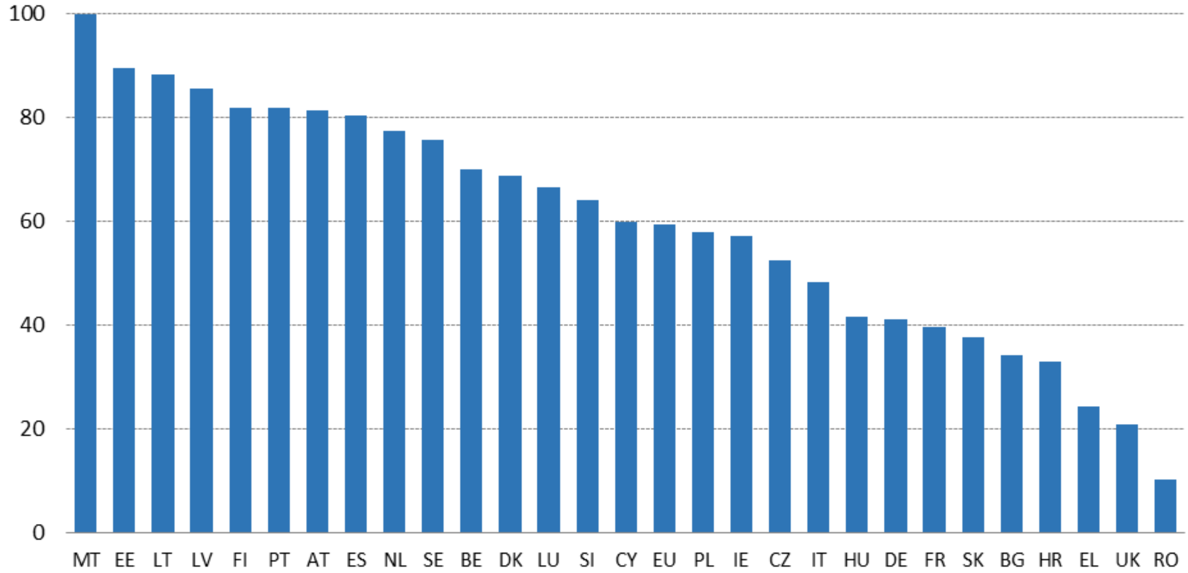
Source: Eurostat, Community survey on ICT usage in Households and by Individuals.

4.2 Pre-filled forms

This indicator measures the extent to which data that is already known to the public administration is pre-filled in forms presented to the user, awarding a maximum overall score of 100. The use of inter-connected registers is key to ensuring that users do not have to resubmit the same data to the public administration.

In 2019, most of the countries improved on this measure, when compared to 2018. Only three countries (Ireland, the Netherlands and Belgium) recorded lower scores than in 2018. Luxembourg (+11 points), Hungary (+11 points), Bulgaria (+8 points) and Spain (+7 points) progressed most in 2019. The best performing countries in 2019 were Malta, Estonia, Lithuania and Latvia, all of which had scores above 85 points. However, there is a substantial gap between the best and worst performing countries, with Romania, the UK and Greece, all scoring below 30 points.

Figure 41 Pre-filled forms (Score 0 to 100), 2019



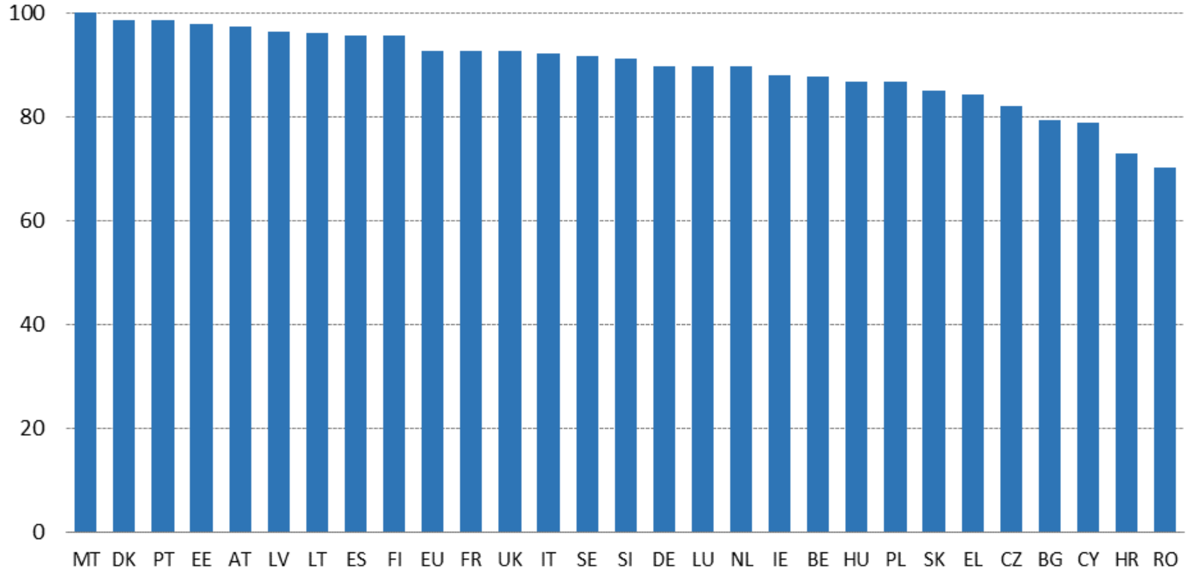
Source: eGovernment Benchmark, Capgemini.

4.3 Online service completion

Online service completion refers to the extent to which the various steps needed for dealing with the public administration can be done completely online.

Malta, Denmark, Portugal, Estonia and Austria performed the best on this measure. Altogether 14 countries (Malta, Denmark, Portugal, Estonia, Austria, Latvia, Lithuania, Spain, Finland, France, the UK, Italy, Sweden and Slovenia) scored above 90 points. Romania, Croatia, Cyprus and Bulgaria scored less than 80. The Netherlands fell by 2.6 points, while Lithuania and Czechia both fell by less than 1 point compared to 2018. Croatia is the country with the greatest increase (+9.1 points) compared to 2018, followed by the UK (+6.5 points), Slovakia (+5.6 points), Slovenia (+5.1 points) and Hungary (+5.1 points).

Figure 42 Online service completion (score 0 to 100), 2019



Source: eGovernment Benchmark, Capgemini.

4.4 Digital public services for businesses (including the cross-border dimension)

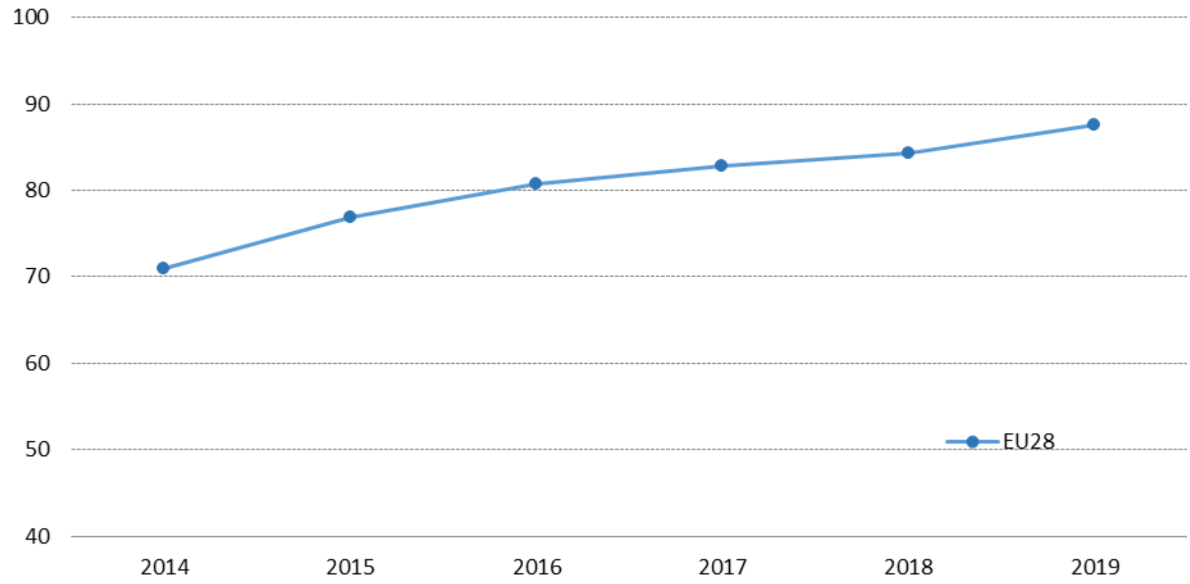
The indicator measures the degree to which public services for businesses are interoperable and work cross-border. It is calculated as the average of the national and cross-border online availability for basic services[(2)].

The indicator assesses to what extent basic public services for businesses, when starting a business and conducting regular business operations, are available online and across borders in other EU Member States. Services provided through a portal receive a higher score, while services that only provide information online but which require operations to be carried out offline receive a lower score.

The score for e-government services for businesses is growing steadily. Compared to 2018, there was an increase of 3.3 points in 2019. Since 2014, the increase is more than 16.5 points.

[(2)] Basic services: services and procedures needed to fulfil the essential requirements of a Life Event, i.e. core registration and other transactional services. More information: https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=55174

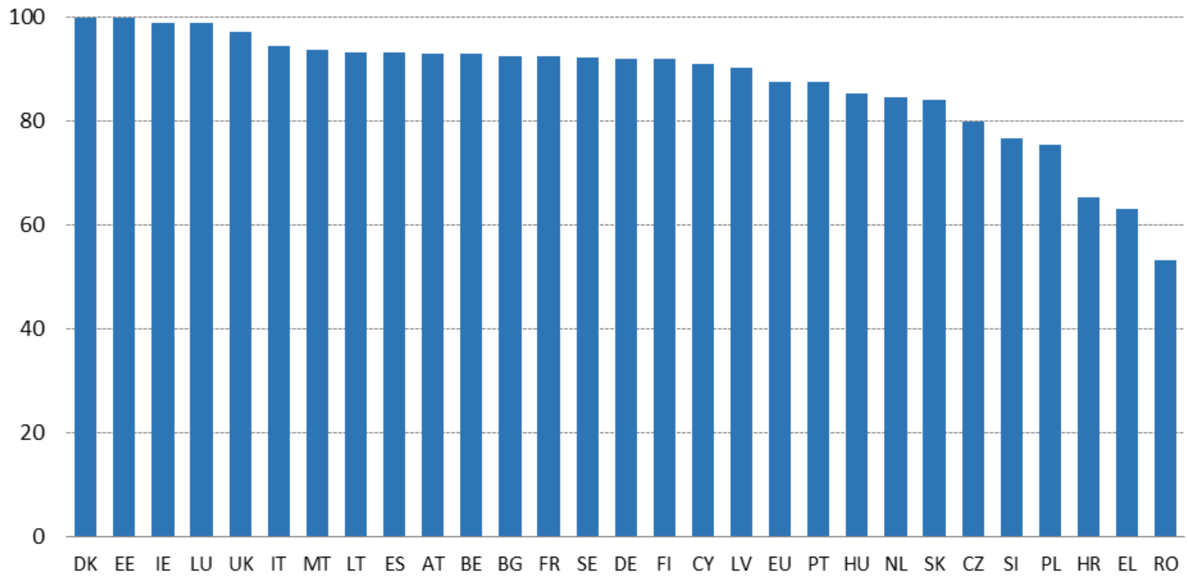
Figure 43 e-Government services for businesses (Score 0 to 100), 2013-2019



Source: eGovernment Benchmark, Capgemini.

Altogether, 18 countries (Denmark, Estonia, Ireland, Luxembourg, the UK, Italy, Malta, Lithuania, Spain, Austria, Belgium, Bulgaria, France, Sweden, Germany, Finland, Cyprus and Latvia) scored more than 90 points (out of 100). On the other hand, Romania, Greece and Croatia scored below 70. Germany, Belgium and Italy recorded the greatest improvement compared to 2018, each improving by 12.5 points. None of the Member States recorded a fall. However, 13 Member States saw no change in their score compared to 2018.

Figure 44 e-Government services for businesses (Score 0 to 100), 2019



Source: eGovernment Benchmark, Capgemini.

4.5 Open data

This indicator measures the government's commitment to open data[3].

Since 2018, the level of maturity of open data has been based on the four following indicators.

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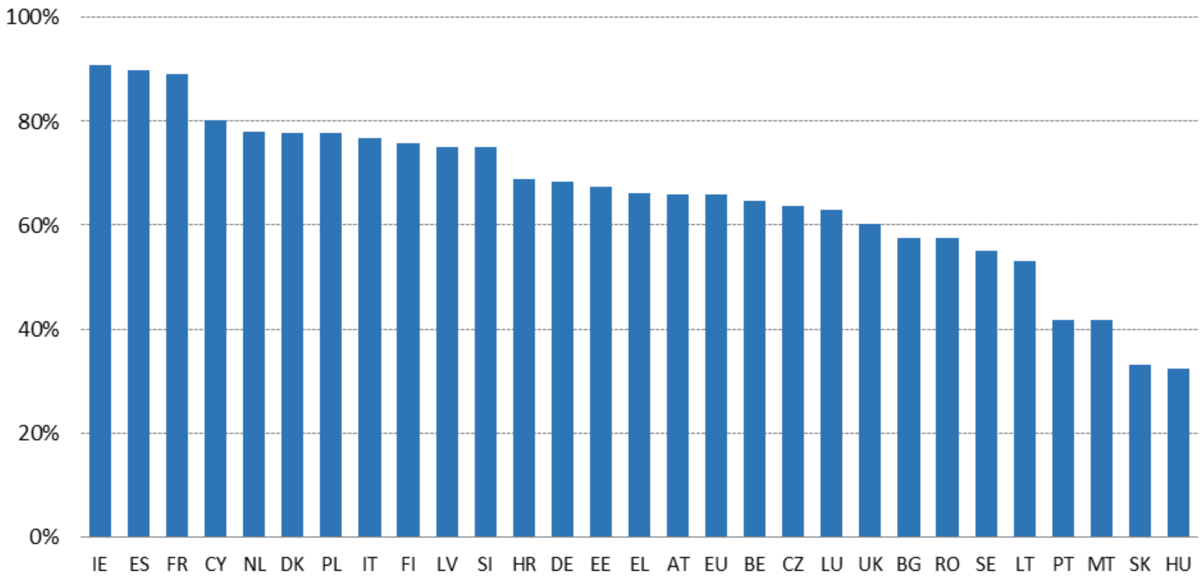
[3] Open Data in Europe 2019: https://www.europeandataportal.eu/en/dashboard/2019

1. Open data policy:
   (i) the presence at national level of specific policies on open data and licensing norms; and
   (ii) the extent of coordination at national level to: (a) provide guidelines to national, local and regional administrations; and (b) set up coordinated approaches towards data publication.
2. Open data portals: the development of national portals and their level of sophistication in featuring available open data.
3. Open data impact: the impact of open data at country level on four dimensions: political, social, environmental and economic.
4. Open data quality:
   (i) the extent to which national portals have a systematic and automated approach to harvesting metadata from sources across the country; and
   (ii) the extent to which national portals comply with the metadata standard DCAT-AP (specification for metadata records).

The overall results across the EU show broad diversity in the speed of transformation and in the priorities that countries have set. The countries that are less advanced in open data typically choose to take what they deem to be the natural first steps. This means investment in modernising their national portals so the portals become the main gateways to open data available throughout the country. The more 'mature' open-data countries take a slightly different approach, focusing instead on improving the quality of their data publication. The middle-performing countries have a different approach to both the less advanced and the more 'mature' countries: they are now focusing on: (i) understanding the impact derived from open data; and (ii) activities to monitor and capture this impact.

Ireland, Spain and France performed well on this measure, scoring more than 80%. On the other hand, Hungary, Slovakia, Malta and Portugal underperformed, with scores below 50%.

Figure 45 Open data (% of the maximum open data score), 2019



Source: European Data Portal.

4.6 User centricity

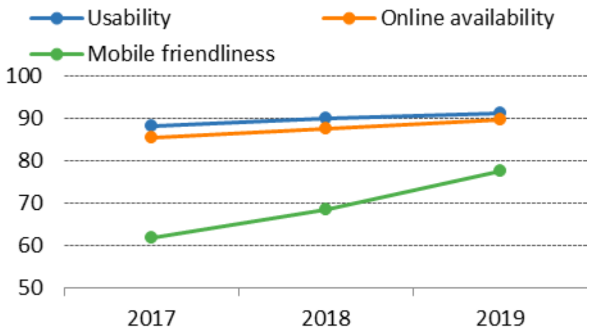
This indicator includes the following three key elements of online service provision.

1. Online availability: this illustrates how services are made available (there are four possibilities: the service is automated; the service is available online through a portal or

directly; information on the service is available either through a portal or online; the service or any information about the service is not online available).

2. Usability: this measures the availability of support channels and feedback mechanisms, such as online chats.
3. Mobile friendliness: this captures the extent to which government services are available through mobile devices, providing a seamless and convenient mobile experience to the public and businesses.

Figure 46 User centricity breakdown (Score 0 to 100), 2017-2019

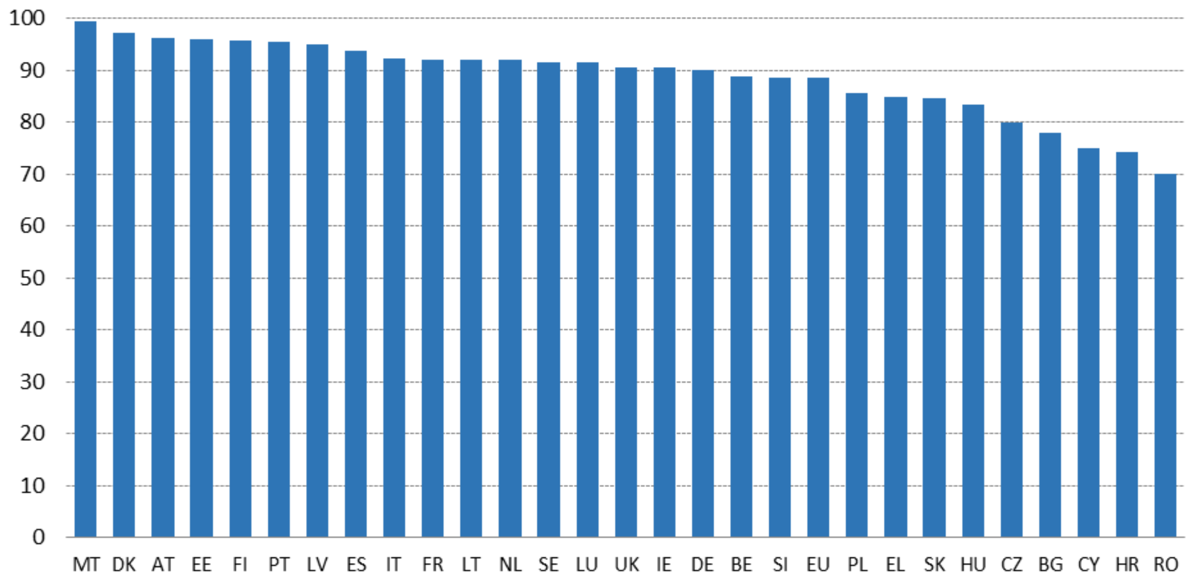


Source: eGovernment Benchmark, Capgemini.

Over the last three years, online availability has improved by 4.2 points to 88.5, broadening the online scope of public services. Moreover, usability has increased by 3 points to 91.4. Encouragingly, public sector services are becoming more mobile-friendly, allowing users to find information and obtain services anytime and anywhere. Since 2017, there has been a significant progress in mobile friendliness, with an improvement of more than 15.5 points.

Malta, Denmark, Austria, Estonia, Finland, Portugal and Latvia are in the lead, all scoring more than 95 points. Romania, Croatia and Cyprus are lagging behind, all scoring less than 75 points.

Figure 47 User centricity (Score 0 to 100), 2019



Source: eGovernment Benchmark, Capgemini.

4.7 Key enablers

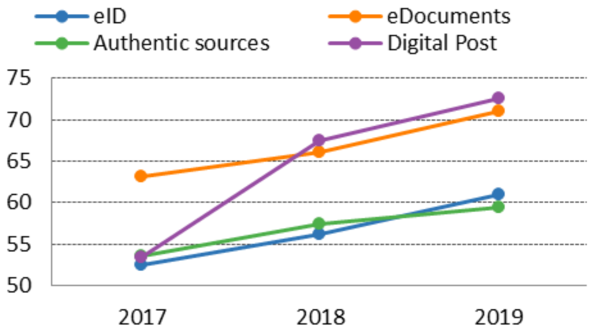
The key enabler indicator includes the following four elements of online service provision and availability.

1. Electronic Identification (eID) a government-issued document for online identification and authentication.

2. eDocuments: a document that has been authenticated by its issuer using any means recognised under applicable national law, specifically through the use of electronic signatures, i.e. not a regular PDF or Word document.
3. Authentic sources (named as pre-filled forms in DESI): base registries used by governments to automatically validate or retrieve data related to individuals or businesses.
4. Digital post: assesses whether public authorities allow people to receive communications digitally only, hence reducing paper mailings. Digital post refers to the possibility for governments to communicate with people or entrepreneurs by electronic means only, such as through personal electronic mailboxes.

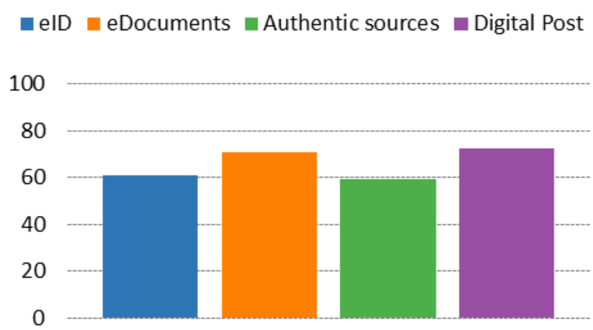
Member States have ample room to improve the implementation of key enablers in their service provision. For 2019, the eID indicator stands at 61 (out of 100); eDocuments at 71; authentic sources at 59.4; and digital post at 72.6. However, there has been notable progress, especially in the take-up of digital post. Since 2017, the use of key enablers has increased by 10.4 points in total. In that time, eID recorded an increase of 8.5 points, eDocuments increased by 7.9 points, and authentic sources by 5.9 points. Digital post recorded the greatest increase (19.3 points) since 2017.

Figure 48 Key enablers progress (Score 0 to 100), 2017-2019



Source: eGovernment Benchmark, Capgemini.

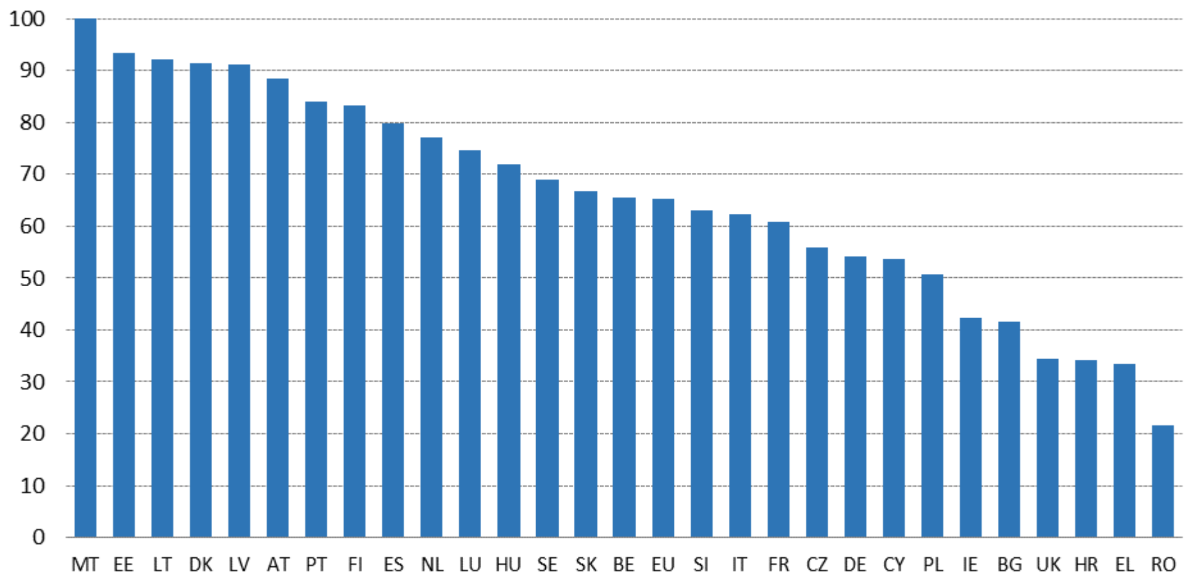
Figure 49 Key enablers (Score 0 to 100), 2019



Source: eGovernment Benchmark, Capgemini.

Malta, Estonia, Lithuania, Denmark and Latvia are in the lead on key enablers, scoring more than 90 points in 2019. Romania, Greece, Croatia and the UK are lagging behind, scoring less than 40 points.

Figure 50 Key enablers progress in Member States (Score 0 to 100), 2019



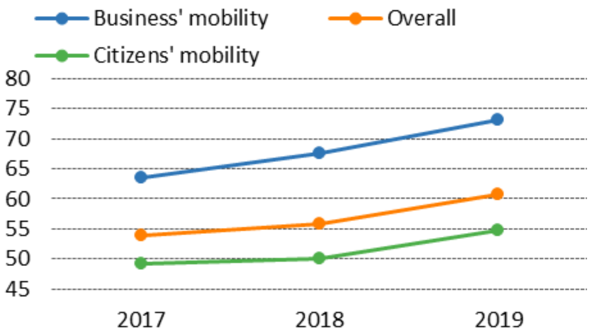
Source: eGovernment Benchmark, Capgemini.

4.8 Cross-border mobility

Cross-border mobility indicates the extent to which users of public services from another EU country can use the online services of the EU country being assessed.

Cross-border mobility includes four indicators, assessed in a cross-border scenario: online availability, usability, eID and eDocuments. These indicators measure whether services are available online, whether they are usable and whether key enablers like eID and eDocuments work for people from abroad.

Figure 51 Cross-border mobility (Score 0-100), 2017-2019

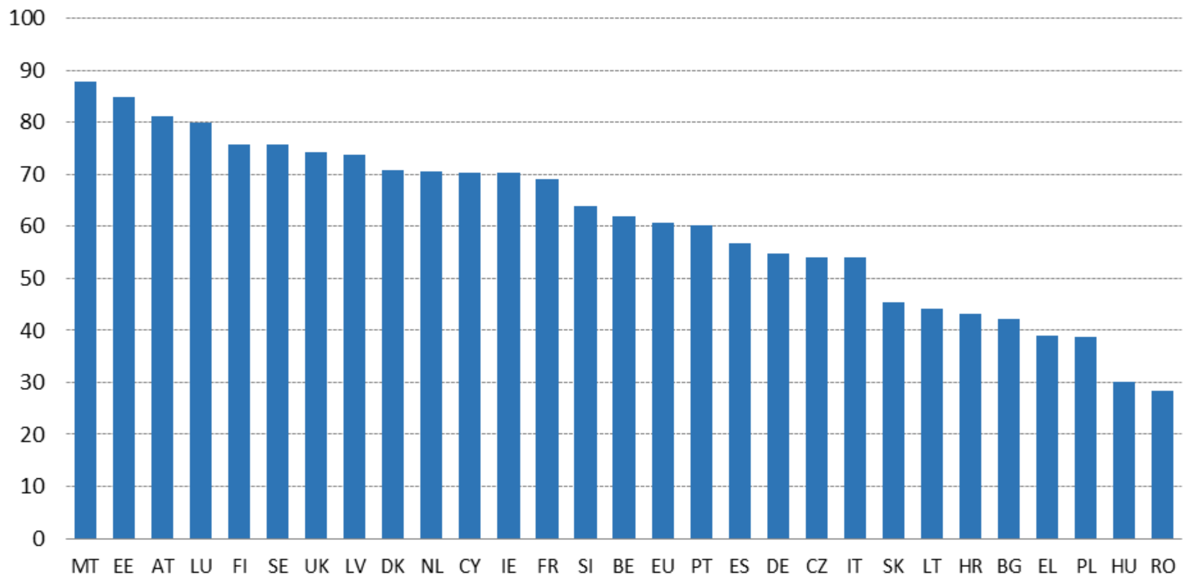


Source: eGovernment Benchmark, Capgemini.

The cross-border availability and usability of services for businesses is much more advanced when compared to cross-border services directed at the public. However, there has also been significant progress in services offered to the public. Over the last 3 years, business mobility has risen by 9.5 points to 73 and citizens' mobility by 6.8 points to 60.8.

Malta, Estonia, Austria and Luxembourg lead the EU in this measure, all scoring more than 80 points. The countries with less cross-border flexibility and advancement are Romania, Hungary, Poland and Greece, all of which have scores below 40. The countries that have made the most progress since 2018 are Luxembourg (+16.8 points), Cyprus (+13.5 points), Austria (+12.7 points), Italy (+11.7 points) and Estonia (+10.9 points).

Figure 52 Cross-border mobility (Score 0-100), 2019



Source: eGovernment Benchmark, Capgemini.

5 Emerging technologies

This chapter presents the current state of play of four emerging technologies: blockchain, High Performance Computing (HPC), quantum technology, and data and edge computing. On artificial intelligence, the Commission will soon publish an analytical report based on a large scale survey of enterprises. Consequently no assessment is included in this report.

The objective of this chapter is to provide an overview of: (i) the current and future size of the global market; (ii) public and private investment; (iii) jobs and education; and (iv) research and innovation activity. All the dimensions are only available for some technologies. In addition, given the lack of data, the trend analysis at Member State level is not available for most of the indicators.

5.1 Blockchain

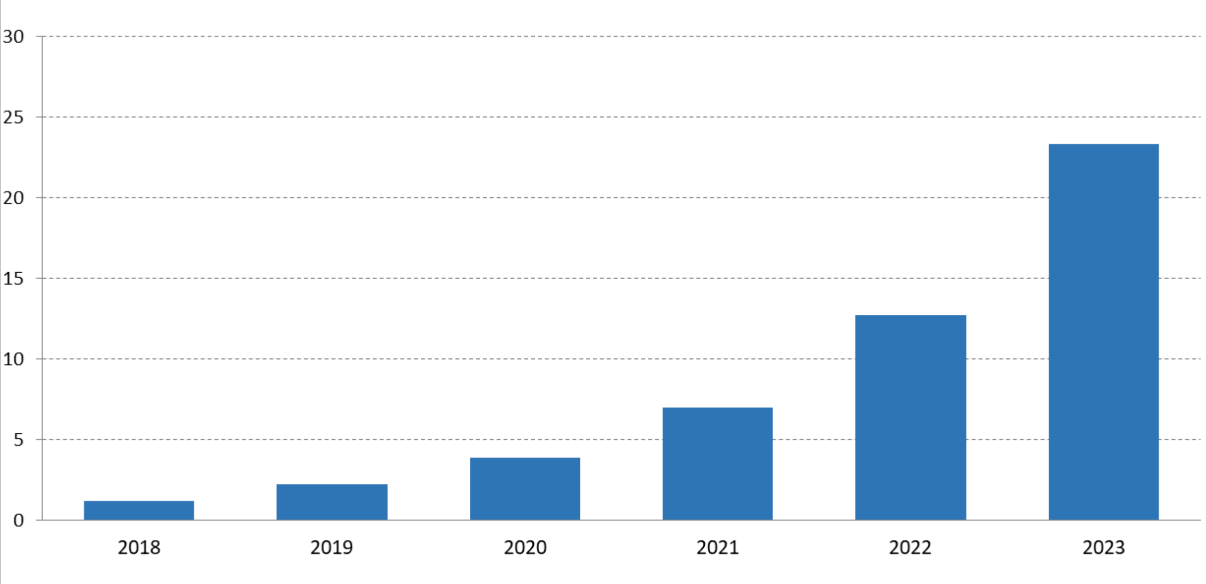
Blockchain is a decentralised technology (a type of Distributed Ledger Technology) employing cryptographic techniques to record and synchronise data in 'chains of blocks'. It allows people and organisations to reach agreement and permanently record transactions and information in a transparent way without a central authority. Therefore, it facilitates the creation of decentralised, trusted, transparent and user-centric digital services. The combination of blockchain with other cutting-edge technologies, like the Internet of Things (IoT) or artificial intelligence can improve the security, performance, and management of the new systems[(4)]. Blockchain technologies will play an important role as a trust protocol and its development alongside quantum computing is fundamental to define quantum-resistant solutions for blockchain[(5)].

Blockchain is one of the major technological breakthroughs of the past decade. It has evolved from the technology enabling Bitcoin to include a myriad of possible applications in other areas such as industry, trade and the public sector. Although blockchain is expected to transform the way the world uses the internet and digital services over the next 10-to-15 years, it is still in its infancy. Blockchain systems still face many challenges, including performance; scalability; energy consumption; integration with legacy infrastructures; interoperability; potential collusion between participants; management of public-private keys; and the protection of personal, sensitive or confidential data[(6)].

The market revenues for blockchain-based technologies are expected to grow significantly in the coming years from around $2.2 billion in 2019 to over $23.3 billion by 2030.

[(4)] Weingärtner, Tim, *Tokenization of Physical Assets and the Impact of IoT and AI*, EU Blockchain Observatory and Forum, Brussels, 2019.
[(5)] The European Union Blockchain Observatory & Forum, *Blockchain innovation in Europe*, 2018.
[(6)] European Commission, JRC, *Blockchain Now and Tomorrow,* June 2019.

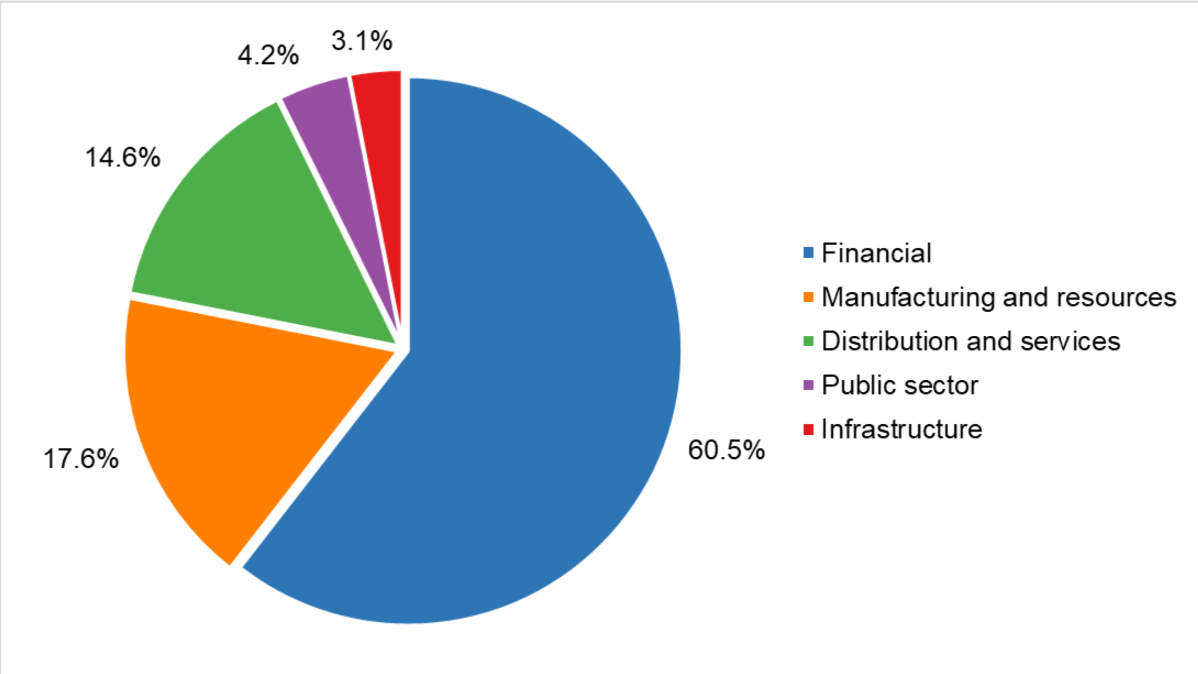
Figure 53 Size of the blockchain market worldwide, 2018-2023, in $ billion



Source: Statista.

The financial sector was one of the first sectors to invest in blockchain technologies. In 2018, the financial sector accounted for around 60% of the market value, followed by the manufacturing and resources sector (17.6%) and the distribution and services sector (14.6%). The public sector and the infrastructure sector accounted for lower shares of 4.2% and 3.1% respectively[7].

Figure 54 Blockchain market value worldwide in 2018, by sector



Source: Statista.

Blockchain start-ups began to emerge in 2009. In 2018, the largest number of blockchain start-ups were established in the USA and China, and only 15% in the EU. The UK hosts almost half of the EU's blockchain start-ups, followed by Germany, France and Estonia, with shares of 8%, 7% and 6%, respectively[6].

[7] Statista, IDC (based on survey H1 2017)

The vast majority of investment in blockchain technologies is concentrated in early fundraising rounds, being venture capital and Initial Coin Offerings (ICOs) the two largest funding sources. ICOs are a new type of funding. They allow start-ups to raise money by selling 'tokens' directly to investors, bypassing the venture capitalists and investment bankers who have traditionally been the conduits for start-up or corporate financing[(5)]. The first significant investment in blockchain start-ups came in 2014 from venture capital funds (around €450 million). The surge in ICOs and venture capital investments meant that investment then rapidly increased to €3.9 billion in 2017 and more than €7.4 billion in 2018[(6)].

In 2009-2018, the global level of blockchain funding of all types, including venture capital, grants and ICOs exceeded €13.1 billion. US firms received 33% of the funding, followed by the EU with 22% (€2.9 billion) and China with 21%. Of the investment attracted by EU firms, the UK received almost 70% of the total funding (€2.02 billion), followed by the Netherlands with 12% (€352 million). Companies in France received 6% (€167 million), followed by Estonia and Germany (€110 million and €97 million, respectively) (see *Figure 55)*. European start-ups obtained 60% of their total funding through ICOs, while the equivalent figure for US blockchain start-ups did not exceed 18%[(8)].

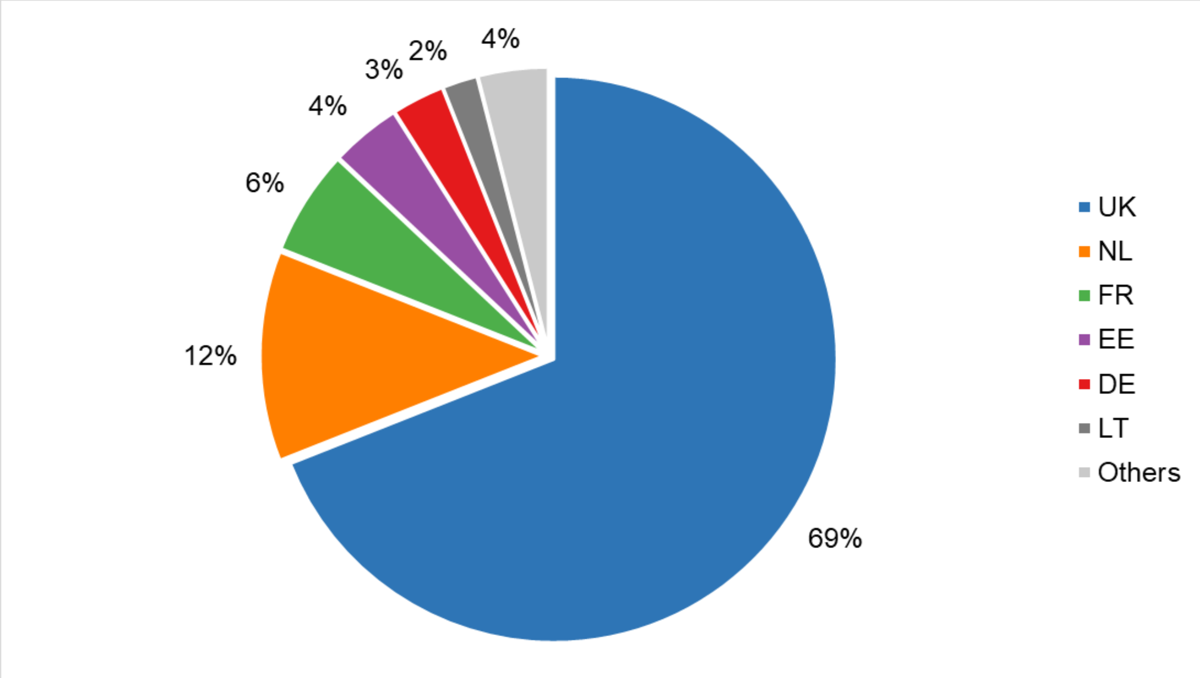
Empirical evidence points to a significant overall investment gap in AI and blockchain technologies in Europe in comparison with the US and China. One of the underlying differences between the US and Europe is that, between 2009 and 2018, European blockchain start-ups made far greater use of alternative forms of finance than their US counterparts. For example, European start-ups obtained a large amount of funding through ICOs. Innovative European companies managed to raise almost 60% of their total financing in this way during this period, while the equivalent figure for US blockchain start-ups did not exceed 18%.

Despite this rapid increase in investment and accompanying investor interest, investors still lack the knowledge about emerging technologies like blockchain and quantum computing. This knowledge gap is preventing investors from adequately assessing the technical and financial viability of deep-tech solutions. Investors often lack the necessary knowledge and tools to recognise truly disruptive technologies that are likely to lead to the next wave of innovations. Information asymmetries are therefore a major bottleneck preventing European blockchain start-ups from accessing funding. This has led to significant underinvestment in such businesses in Europe[(9)].

[(8)] https://ec.europa.eu/digital-single-market/en/blogposts/forging-new-frontiers-finance-digital-innovations

[(9)] Bjorn-Soren Gigler, *Financing the Deep Tech Revolution. How investors assess risks in Key Enabling Technologies (KETs)*, European Investment Bank, 2018.

Figure 55 Share of blockchain funding in the EU, 2009-2018



Source: European Commission, JRC, Blockchain Now and Tomorrow, June 2019.

In Europe, the European Blockchain Partnership (EBP) was created in 2018 through a ministerial declaration signed by Member States. The EBP established a European Blockchain Services Infrastructure (EBSI) to support the delivery of cross-border digital public services with the highest standards of security and privacy. In 2020, EBSI will deploy a network of distributed blockchain nodes across Europe, supporting applications focused on selected use cases(10). In parallel, the European strategy on blockchain is currently being drawn up and is expected to be adopted by mid-2020(11).

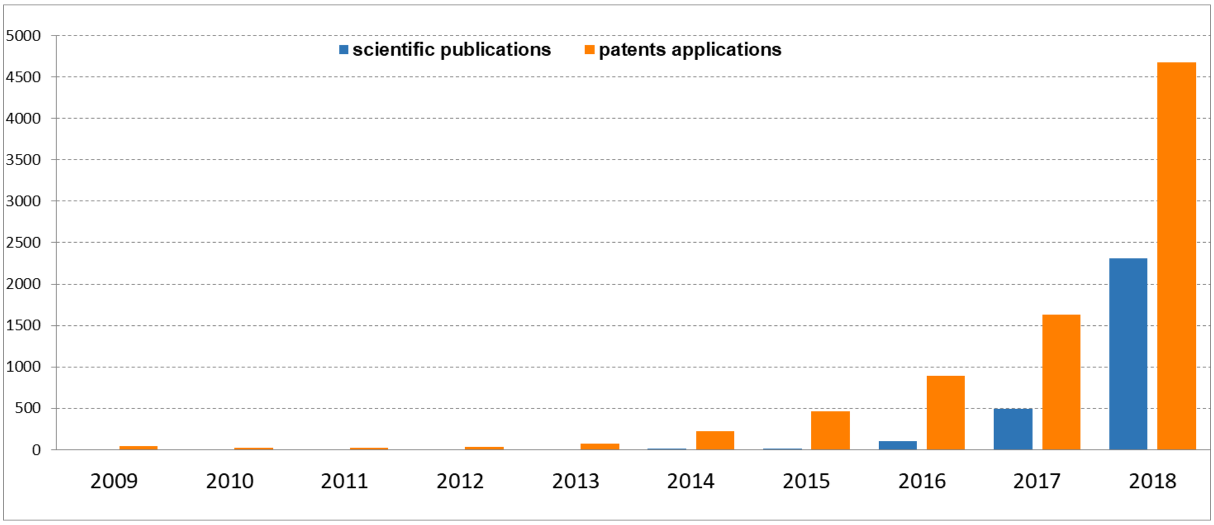
Research programmes are supporting the development and market update of blockchain and distributed ledger technologies. In 2020, the European Commission launched a new artificial intelligence and blockchain investment fund of €100 million. This equity investment instrument will support innovative companies and start-ups through the Horizon 2020 programme. Thanks to the leveraging of the European Fund for Strategic Investments (EFSI) and the European Investment Fund (EIF), the AI and blockchain investment fund will 'crowd-in' private investment. It is estimated that the total investment volume in the first phase 2020-2021 will be around €300-400 million. The plan is to scale up the AI and blockchain investment fund under the InvestEU programme starting in 2021, to eventually reach an investment volume of approximately €1-2 billion(8).

On research and innovation, the number of scientific publications about blockchain technologies has increased significantly since 2014, and particularly since 2018. More than half of the publications are conference papers, and around 30% are scientific articles(12). A similar trend can be seen in the number of blockchain patent applications worldwide, which rose from 72 in 2013 to more than 4,600 in 2018(13). China and the US are global leaders in scientific publications and patent

(10) https://ec.europa.eu/digital-single-market/en/blockchain-technologies
(11) European Commission, *Shaping Europe's digital future*, COM(2020)67 final, 19.2.2020.
(12) Scopus analyzer, keyword (blockchain).
(13) Statista.

applications. The EU is third in blockchain patent applications. In Europe, the UK and Germany are among the top 10 countries in both areas[12], [13].

Figure 56 Total number of blockchain scientific publications vs. patent applications worldwide, 2009-2018



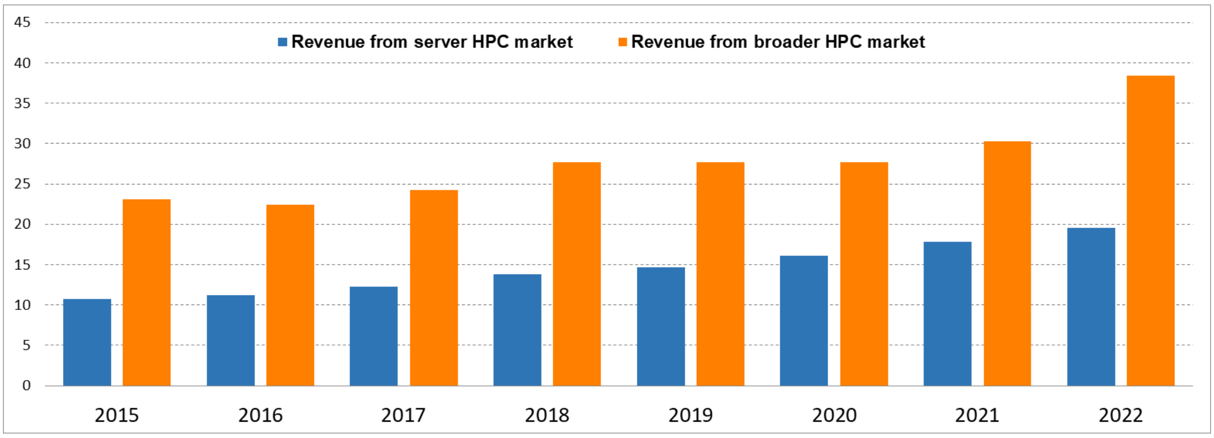
Source: Scopus (scientific publications), Statista (patent applications worldwide).

5.2 High Performance Computing (HPC)

High Performance Computing (HPC), also known as supercomputers, is used by public and private sector users to solve highly complex computational or data intensive problems. HPC helps people to better understand and better respond to a variety of socioeconomic challenges in areas such as aerospace, automotive, manufacturing, health, and climate change. The demand for HPC will increase considerably in the coming years. The combination of HPC with artificial intelligence, big data and cloud computing will foster the rapid development of new applications and services across multiple sectors, including more traditional parts of the economy.

Revenues from the broader HPC market worldwide is expected to grow from around $27 billion in 2018 to almost $40 billion in 2022. The broader HPC market includes servers, storage, middleware, applications and services. Within the broader HPC market, revenues for the server market alone are expected to increase worldwide from around $13 billion in 2018 to almost $20 billion in 2022.

Figure 57 HPC server market vs. HPC broader market revenue worldwide, 2015-2022, in $ billion

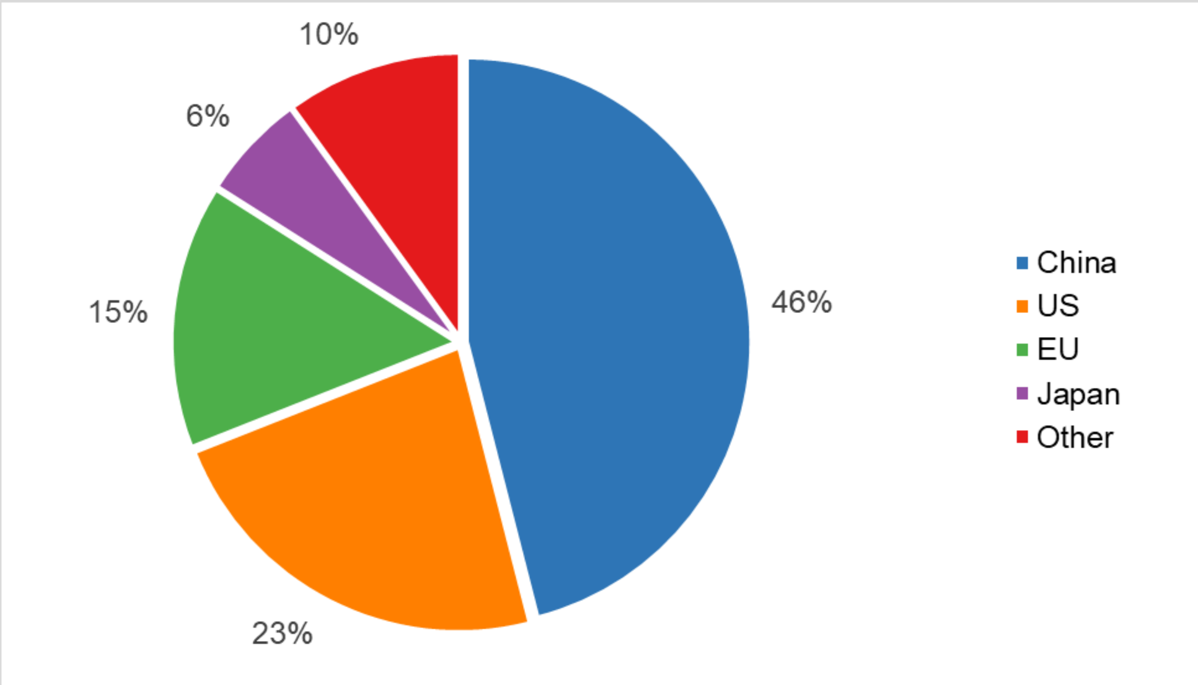


Source: Statista, insideHPC.

Europe is a leader in HPC applications, but its supercomputing infrastructure is falling behind in world rankings. An accepted headline indicator of competitiveness in HPC is the number of systems in the top-10 and top-500 lists of supercomputers in each of the world regions. This number reveals a country's or region's access to the most powerful supercomputers. As of September 2019, only 1 of the world's top-10 supercomputers was installed in the EU, ranking number 9. This is a decline since 2012, when the EU had 4 such systems. The current supercomputing power available in the EU is less than half of that available in the US or China, according to the list of the world's top-500 supercomputers (see *Figure 58*). Of the top-500 systems, 76 are installed in EU Member States, compared with 117 in the US and 228 in China.

Europe consumes one third of supercomputer resources worldwide, but provides only around 5% of those[14]. In addition, HPC use in Europe is currently concentrated in the public sector. Most HPC capacity and usage (over 90% of operating time) is installed at universities or research centres, and the remaining 10% serves commercial purposes and/or HPC end users. The main commercial users are large corporations in industrial sectors (e.g. automotive, aerospace, defence or energy) who use HPC systems, in particular to reduce research and development costs or to reduce time-to-market for their products. Although SMEs have recently started to use HPC, they still face many barriers limiting their use.

Figure 58 World Top 500 supercomputers, regional share 2019



Source: Top500.org list.

The combination of HPC services with cloud computing can make HPC capabilities much more accessible to a broader user base, particularly SMEs. The EU is funding R&D projects like the *Fortissimo Marketplace*[15], which offers HPC resources, software applications, expertise and tools. These are offered on a self-service basis and are mainly cloud-based, and are delivered by major HPC technology providers in Europe. In addition, national HPC competence centres will be created in each participating state of the Euro HPC Joint Undertaking (JU) to provide HPC services to industry (including SMEs), academia and public administrations. The aim of these competence centres will be to foster the transition towards wider uptake of HPC in Europe.

The US and China are investing intensively in HPC technologies, and the funding gap in Europe is expected to amount to €500 million per year. To address this issue in the period 2014-2018,

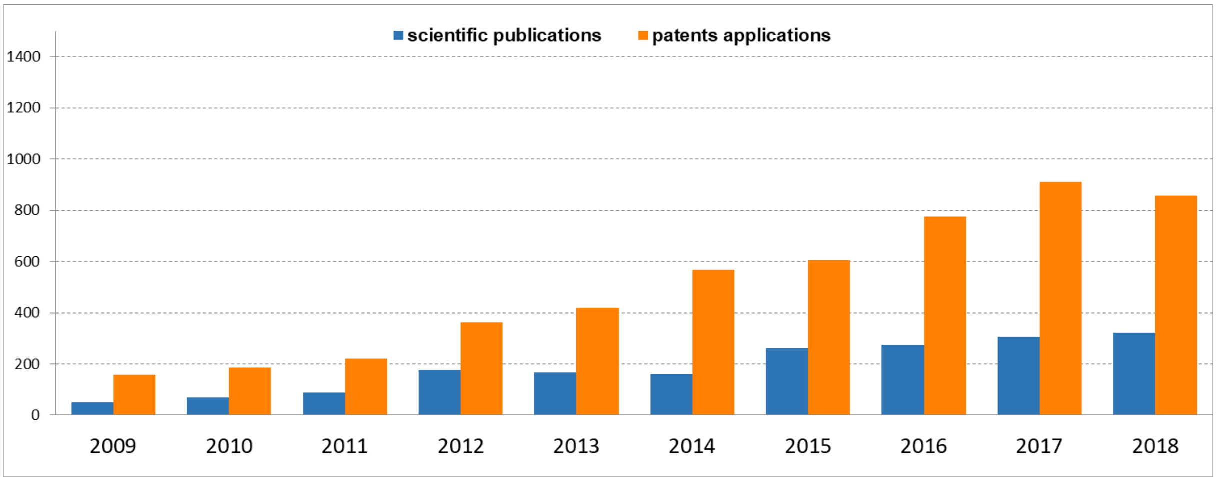
[14] European Commission, HPC factsheet https://ec.europa.eu/digital-single-market/en/news/high-performance-computing-factsheet
[15] https://www.fortissimo-project.eu/

different R&I investments supported the development of HPC technology in Europe to a total of €700 million[16]. In September 2018, the Euro HPC JU was established. Its main objective is to coordinate the efforts in Europe to: (i) deploy a world-class supercomputing infrastructure; (ii) build a competitive innovation ecosystem for HPC; (iii) promote HPC applications; and (iv) develop skills in HPC. The JU currently has 32 participating states: all EU Member States (with the exception of Malta), Montenegro, North Macedonia, Norway, Switzerland, Iceland and Turkey[17]. The initial co-investment with Member States is of €1 billion. An additional around €400 million will be contributed by private or industrial players in the form of in-kind contributions to the JU's activities. This initiative is expected to generate around €10 billion in investments in HPC applications[16]. By the end of 2020, the EuroHPC JU will acquire and install 8 supercomputers: 3 high-range (pre-exascale) supercomputers in Finland, Spain, and Italy that will place Europe back in the world's top-10; and 5 mid-to-high range (petascale) supercomputers in Luxembourg, Portugal, Czechia, Slovenia, and Bulgaria.

For 2021-2027, under the new Multiannual Financial Framework, the EU plans to invest more than €1 billion for R&I to create a leading European innovation ecosystem. It also plans to invest more than €5 billion for large-scale deployments and capability building, including: (i) the acquisition of exascale supercomputers and quantum computers; and (ii) the coordination of national HPC competence centres, large-scale training and skills upgrades.

As regards global activity on HPC research and innovation, the number of scientific publications has increased steadily since 2009, and particularly since 2014. Almost 70% of the publications are conference papers, and around 25% are scientific articles. Between 2009 and 2018, the number of patent applications worldwide grew at an annual average of about 20%[18], but it remains low compared to other emerging technologies.

Figure 59 Total number of HPC scientific publications vs. patent applications worldwide, 2009-2018



Source: Scopus (scientific publications and patent applications).

The US is by far the global leader in HPC scientific publications and patent applications, with around 50% of total publications and 80% of total patent applications. Germany and China follow close behind for HPC scientific publications, and the Japan Patent Office is the second most active in HPC patent applications[18].

Through the Horizon 2020 programme, the EU is fostering an HPC ecosystem capable of developing new European technology such as high performance energy efficient HPC chips. For example, the

(16) European Commission, HPC brochure.
(17) https://eurohpc-ju.europa.eu/
(18) Scopus analyzer, keyword (hpc AND high performance computing).

European R&D project European Processor Initiative[19] is, among other activities, conducting research to design and implement a roadmap for a new family of low-power European processors for extreme scale computing and high performance big data.

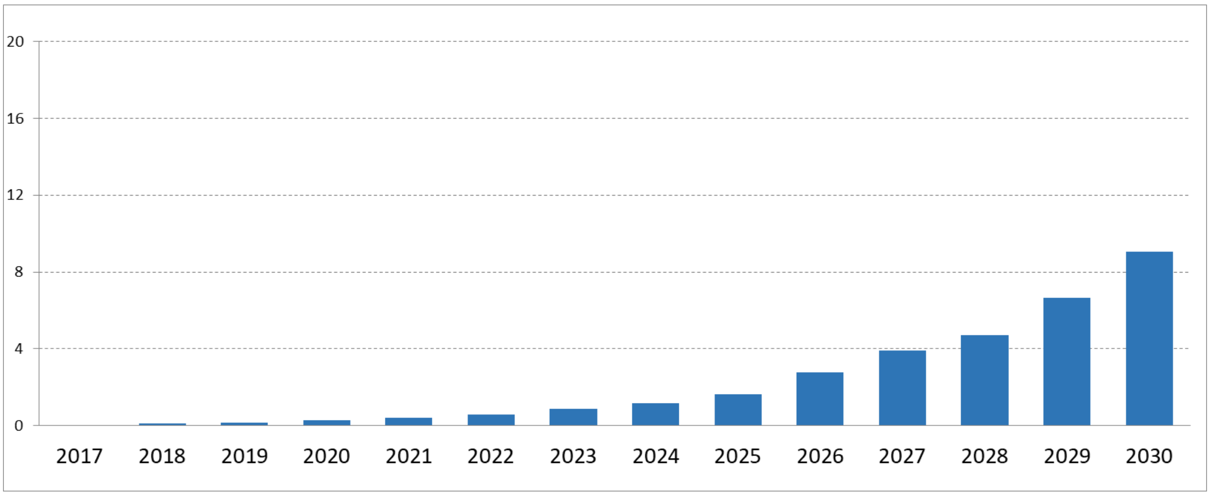
In Europe, there is an acute skills mismatch in emerging technologies between academic offer and the demand for skills profiles by industry. This problem is growing as the offer lags significantly behind market needs. Most Member States are facing shortages of ICT professionals and technicians, while the current educational offering of specialised, higher education programmes is limited. The academic offer of HPC courses/curricula in Europe is generally taught at masters level (two thirds of the total academic offer are at masters level). There are fewer specialised programmes in HPC than other technologies such as artificial intelligence: specialised programmes represent 20% of all HPC masters and 15% of all HPC bachelor programmes[20].

5.3 Quantum technology

Quantum technologies exploit the properties of quantum mechanics and physics to solve complex problems much faster or much better than traditional methods. They make possible the development of radically new technologies in computing, communication, security, and sensing. Quantum computing can be applied in many sectors (e.g. aerospace, agriculture, health, manufacturing, automotive or energy) and in combination with other digital technologies. For example, advanced cryptography techniques can help develop secure communications and improve detection of network intrusions.

Revenues from quantum computing market worldwide are expected to reach $260 million in 2020, of which $96 million will come from Europe. A significant increase in these revenues is estimated over the next 10 years to around $9 billion by 2030. North America is projected to be in the lead by 2030 with $2.7 billion, followed closely by Europe with $2.6 billion, and the Asia Pacific region with $2.1 billion[21].

Figure 60 Size of the enterprise quantum computing market worldwide 2017-2030, in $ billion



Source: Statista, Quantum Computing for Enterprise Markets report of Tractica.

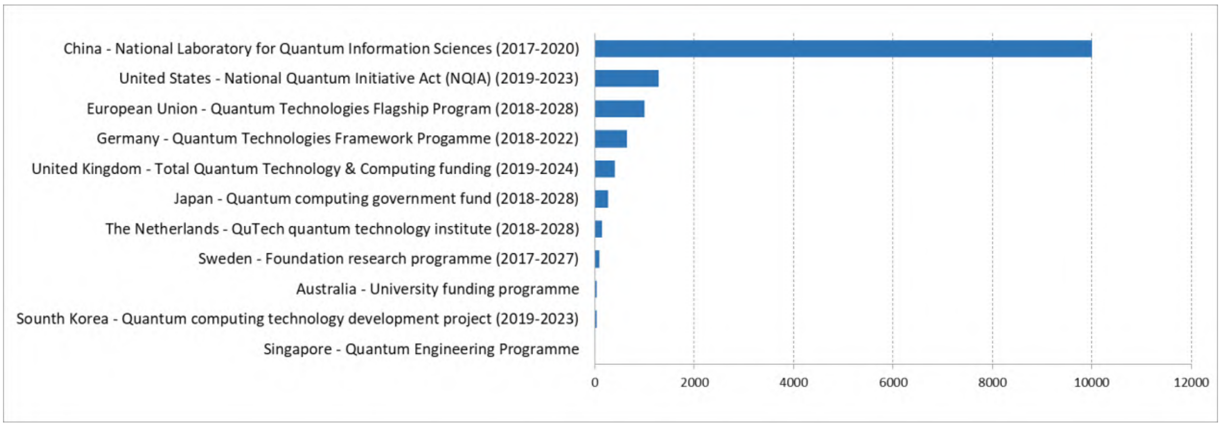
A great deal of investment and expertise will be needed to help quantum technologies transition from the research and development phase to deployment. The US, Japan, China, Korea, Canada and

[19] https://www.european-processor-initiative.eu/project/epi/
[20] European Commission, JRC, *Academic offer and demand for advanced profiles in the EU*, 2019.
[21] Quantum Computing, a dossier-plus on the state and outlook of the 5th generation of computing, Statista, October 2019.

Europe are investing strongly in quantum technologies. However, they still rely largely on public funds, and most of fundamental research is done in universities and research facilities. In 2017, China launched a $10 billion programme to build a national laboratory for quantum information sciences by 2020 (see *Figure 61*). Given its current technology readiness level, equity funding is still low for quantum computing compared to other emerging technologies.

In 2018, the EU launched the first phase of a ten-year, strategic Quantum Flagship research initiative with a budget of €1 billion. It covers five fields: quantum communication; quantum computing; quantum simulation; quantum metrology and sensing; and the basic science behind quantum technologies. In the period 2021-2027, quantum technologies will be supported by the Digital Europe programme (strategic digital capacities in Europe), the Horizon Europe programme (research and space applications) and the InvestEU programme (mobilising public and private investment using an EU budget guarantee).

Figure 61 Government funding/investment in quantum technology



Source: Statista, March 2019.

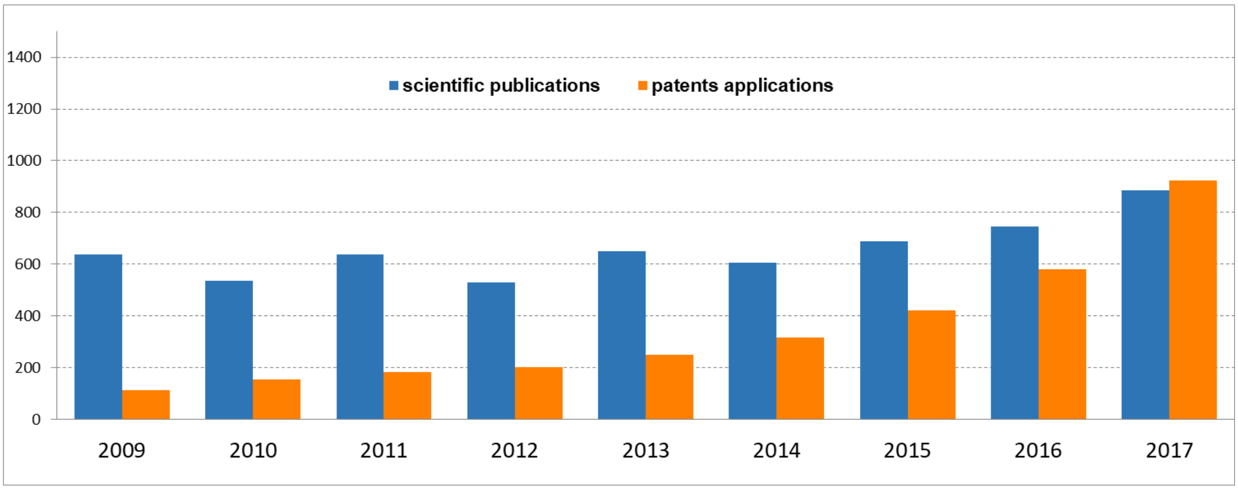
In June 2019, the European Commission and several Member States signed a ministerial declaration agreeing to explore together, over a period of 12 months, how to develop and deploy a quantum communication infrastructure (QCI) across the EU within the next 10 years(22). In addition, the European strategy on quantum is under preparation and is expected to be adopted by mid-2020(11).

In relation to research and innovation activities for quantum technologies, the number of annual scientific publication remained roughly unchanged until 2016, with a slight increase in 2017. Half of the publications are conference papers, and around 40% are scientific articles(23). The US is the most active in this field, followed by China and Germany.

(22) https://ec.europa.eu/digital-single-market/en/news/future-quantum-eu-countries-plan-ultra-secure-communication-network

(23) Scopus analyzer, keyword (quantum tecnolog*).

Figure 62 Total number of Quantum scientific publications vs. patent applications worldwide, 2009-2017



Source: Scopus (scientific publications), Statista (patent applications worldwide).

Patenting activity in the field of quantum computing started to accelerate in 2012. Quantum computing and quantum key distribution are the applications for which by far the most patent applications have been filed to date. The US leads in quantum computing and China leads in quantum key distribution[(24)]. Likewise, quantum metrology and sensing saw an increase in patent applications starting in 2009, but the number of patent applications is still low in absolute terms, and mainly driven by research institutes (patent applications in the field rose from 8 applications in 2009 to 83 in 2017). The leading patent authorities in this sub-sector are China, the US and the European Patent Office[(25)]. Even though commercial products based on quantum-computing are starting to emerge (for example in quantum sensing), the market for quantum technologies still appears to be limited. This might be explained by insufficient technological maturity and a lack of clear business cases: most of the patents do not target specific applications, and are instead directed at improving technologies[(24)].

5.4 Data and edge computing

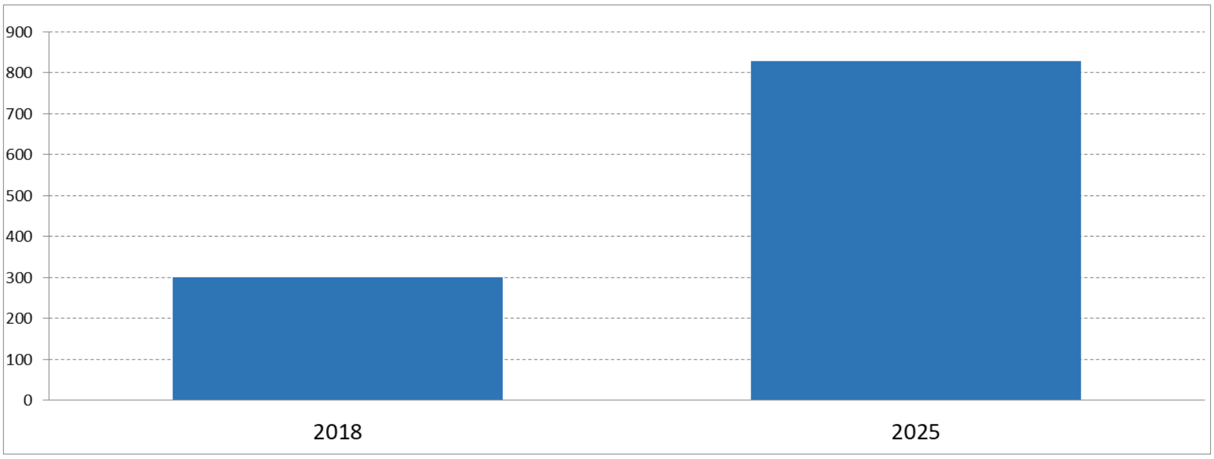
Data is an enabler of digital transformation and an accelerator of innovation for technologies such as the Internet of Things, artificial intelligence, cybersecurity or robotics. Large volumes of data are fuelling data-driven innovations. For example, they can help artificial intelligence to make breakthroughs in machine learning, as massive amounts of data are needed to train neural networks[(26)]. Likewise, using HPC and cloud computing together can make it possible to access and develop advanced analyses of large amounts of data in a very short time.

The volume of data produced in the world is growing rapidly, from 33 zettabytes in 2018 to an expected 175 zettabytes in 2025[(27)]. It is estimated that the EU27's data economy (the overall impacts of the data market on the economy as a whole) exceeded the threshold of €300 billion in 2018, up nearly 12% over the previous year. In addition, it is expected to reach €829 billion by 2025,

[(24)] Martino Travagnin, *Patent analysis of selected quantum technologies*, 2019.
[(25)] European Patent Office, *Landscape study on patent filling, quantum metrology and sensing,* 2019.
[(26)] European Commission, The European Data Market Monitoring Tool, *Data as the engine of Europe's digital future*, IDC report, 2019.
[(27)] European Commission, *A European strategy for data*, COM(2020)66 final, 19.2.2020.

accounting for 5.8% of EU GDP[28]. There were 5.7 million data professionals in the EU27 in 2018, and this figure is soon expected to double, reaching 10.9 million people by 2025[27].

Figure 63 Size of data economy in EU27, 2018 vs. 2025, in € billion



Source: The European data strategy, Shaping Europe's Digital Future, factsheet, February 2020.

This trend is also confirmed by the data market, which has increased significantly from €47 billion in 2014 to €72 billion in 2018 (EU28). This increase was registered in all EU Member States. The UK, France, Germany, Italy, Spain and the Netherlands accounted for approximately three quarters of the EU28 data market in 2018[26].

Open data (making data accessible for use and re-use by researchers and the general public) has a tremendous potential to create new products and services in many areas such as healthcare, transport, or energy. Open data is considered an enabler for the economy and is therefore similar to infrastructure. The size of the open data market in the EU27+[29] is expected to increase from about €184 billion in 2019 to about €199 billion in 2025 under a baseline scenario, or to about €334 billion in 2025 under an optimistic scenario[30]. The baseline scenario assumes that the impact of open data only grows at the same pace as EU GDP, while the optimistic scenario assumes higher growth rates based on several studies and forecasts by experts. The potential for job creation through publishing and re-using open data in both the public and private sector is significant. The number of employees working on open data in the EU27+[29] might increase from 1.09 million in 2019 to 1.12 million in 2025 under a baseline scenario, or to about 1.97 million in 2025 under an optimistic scenario[30].

In the next 5 years, the computing technologies enabling data storage and analytics will adapt by shifting from data centres and centralised cloud computing facilities (currently accounting for 80% of data storage) to decentralised systems (currently accounting for 20% of data storage) also known as 'edge computing' (e.g. smart connected objects)[27]. Edge computing is one of the emerging solutions to cope with the expected increase in data traffic due to the adoption of Internet of Things technologies. These technologies could lead to the existence of up to 80 billion connected devices worldwide by 2025. Edge computing will perform data processing close to the source where data is generated. It will also allow for smart workload balancing and energy efficient optimisation of data

[28] European Commission, *The European data strategy, Shaping Europe's Digital Future, factsheet, February 2020.*

[29] EU27 and EFTA countries (Iceland, Liechtenstein, Norway and Switzerland).

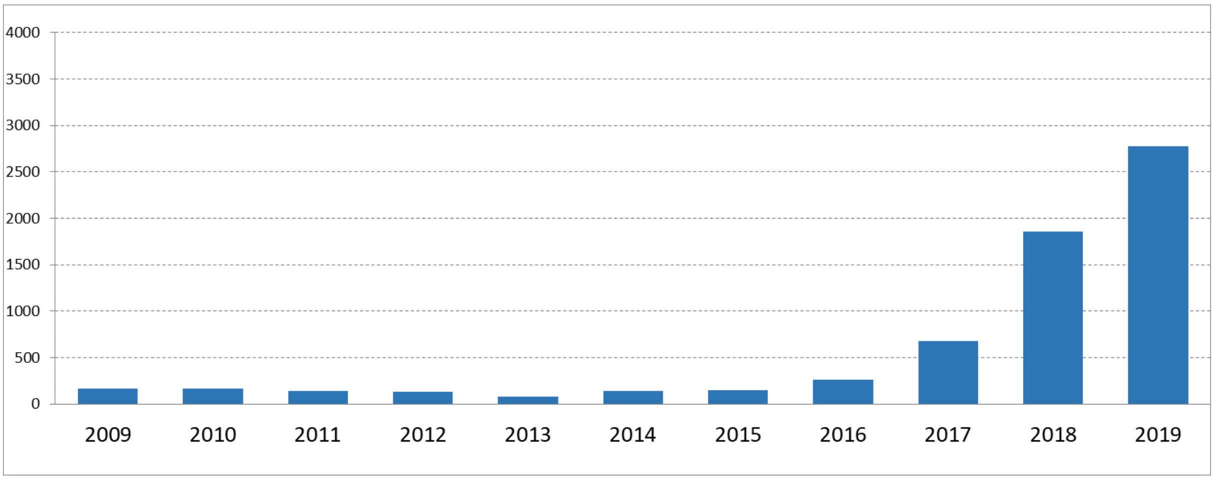
[30] European Commission, European Data Portal, *The economic impact of open data, Opportunities for value creation in Europe,* 2020.

flows between central servers and edge clouds. This approach can also make good use of resources that are not continuously connected to a network, such as smart phones or sensors[31].

Edge computing is expected to benefit market segments such as video surveillance, mobile video distribution, smart cities, transport, artificial intelligence in manufacturing, augmented reality, etc. The market value worldwide of the addressable markets for edge computing is expected to be €108 billion by 2024. This would represent a compound annual growth rate of about 30% for the period 2019-2024. In addition, about half of the market for edge computing is expected to be captured by cloud providers by 2024, while the other half will be shared between industrial, software and telecommunication companies[32].

Scientific activity around edge computing has also increased significantly in recent years, up from 260 scientific publications in 2016 to more than 2,700 in 2019. About 60% of the publications are conference papers, and about 35% are scientific articles[33]. China leads in the number of scientific publications, with almost 50% of total publications in 2019, followed by the US with about 25%.

Figure 64 Total number of Edge Computing scientific publications, 2009-2019



Source: Scopus (scientific publications).

(31) European Commission, JRC, *Artificial Intelligence: A European Perspective*, 2018.
(32) Idate.org, *Edge computing, key figures,* Emerging Tech, 2019.
(33) Scopus analyzer, keyword (edge computing).

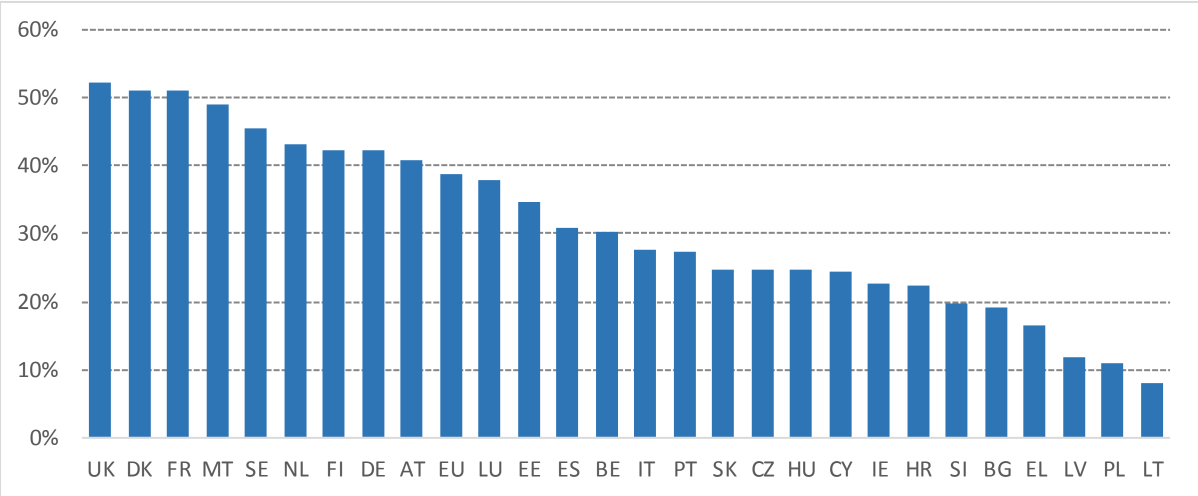
6 Cybersecurity

6.1 Internet security: incidents and concerns among EU citizens

Following the outbreak of the COVID-19 pandemic and the extensive use of digital tools, ensuring internet security and preventing cybercrime, data misuse or fraud are of paramount importance.

In 2029, 39% of EU citizens who used the internet in the last year[34] experienced security-related problems. This percentage varies greatly across Member States: from more than 50% in the UK to less than 10% in Lithuania.

Figure 65: Individuals who experienced a security-related problem (% of internet users) 2019

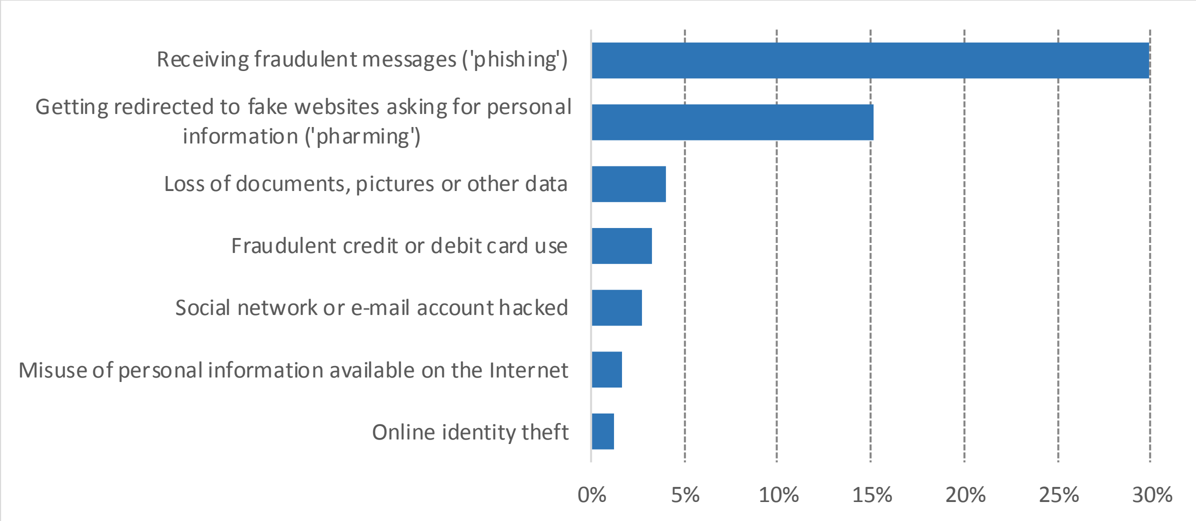


Data not available for Romania
Source: Eurostat, Community survey on ICT usage in Households and by Individuals.

Phishing and pharming are the most common security-related problems experienced. The receipt of fraudulent messages (known as ‘phishing’) was reported by 30% of EU internet users in 2019. Redirection to fake websites asking for personal information (‘pharming’) was experienced by 15% of EU internet users. Other problems are less common. For example, 3.6% of internet users lost documents, pictures or other data due to a virus or other computer infection. 1.7% of internet users experienced misuse of their personal online information resulting in issues such as discrimination, harassment, bullying, and 1.3% experienced online identity theft. Only 1.5% of internet users experienced financial losses resulting from identity theft, receiving fraudulent messages, or being redirected to fake websites.

[34] Hereafter referred as ‘internet users’.

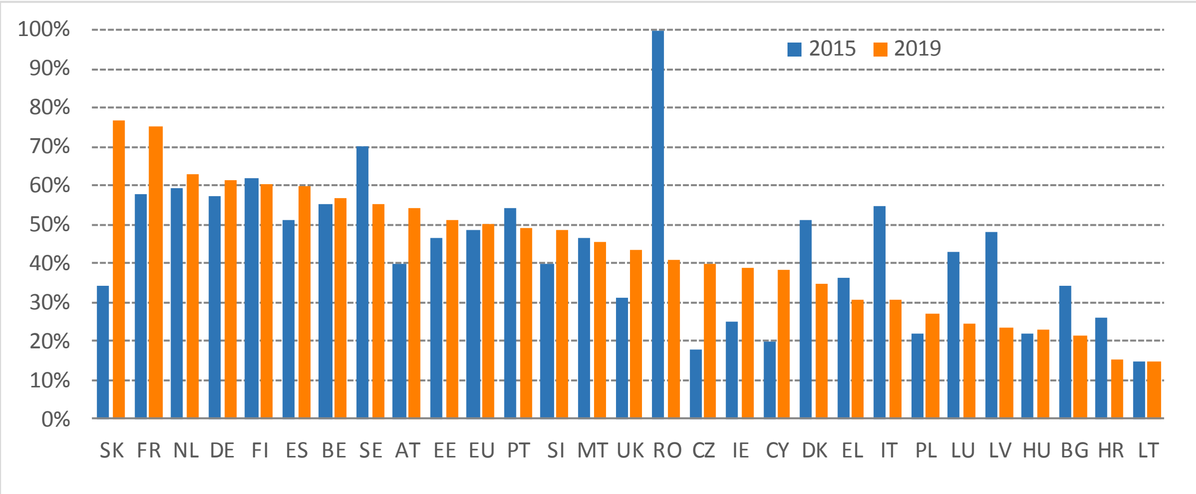
Figure 66: Type of security-related problems experienced (% of internet users) 2019



Source: Eurostat, Community survey on ICT usage in Households and by Individuals.

Security concerns remain high among internet users, and have slightly increased over the last 5 years. In 2019, security concerns limited or prevented 50% of EU internet users from performing online activities, an increase from 48% in 2015. However, there are large differences among Member States. In 2019, internet users reporting security concerns ranged from 77% in Slovakia and 75% in France, to 15% in both Croatia and Lithuania. Moreover, the comparison between 2015 and 2019 shows a scattered picture. Although the overall percentage of internet users expressing security concerns slightly increased in the EU over this period, 12 Member States recorded a decline.

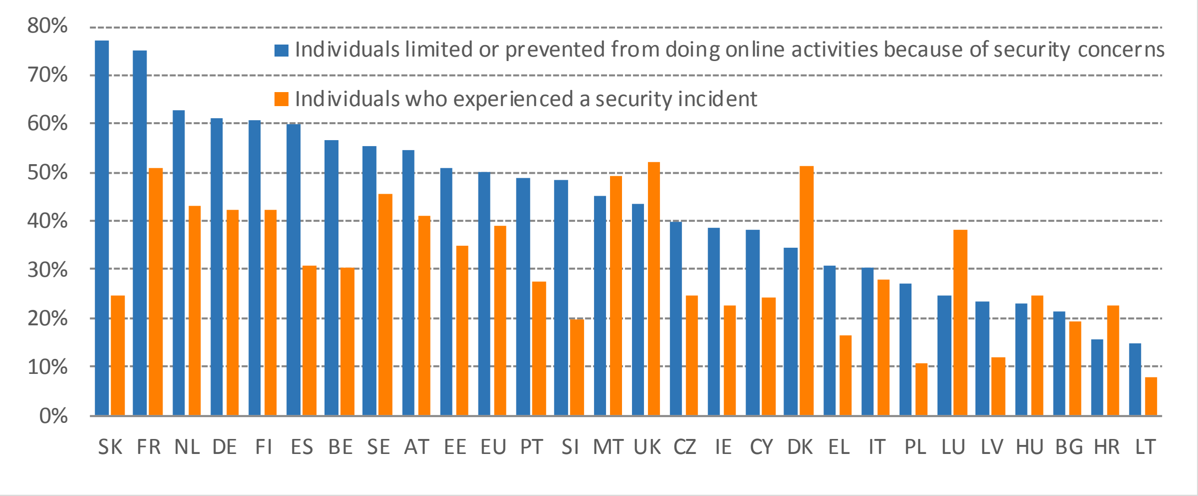
Figure 67: Individuals who were limited or prevented from performing selected online activities because of security concerns (% of internet users) 2015 and 2019



Source: Eurostat, Community survey on ICT usage in Households and by Individuals.

The incidence of security concerns among internet users does not necessarily correspond to the actual number of people experiencing security issues. In the EU as a whole and in most of the Member States, the percentage of internet users who expressed security concerns exceeded the percentage of users who actually experienced a security incident while online.

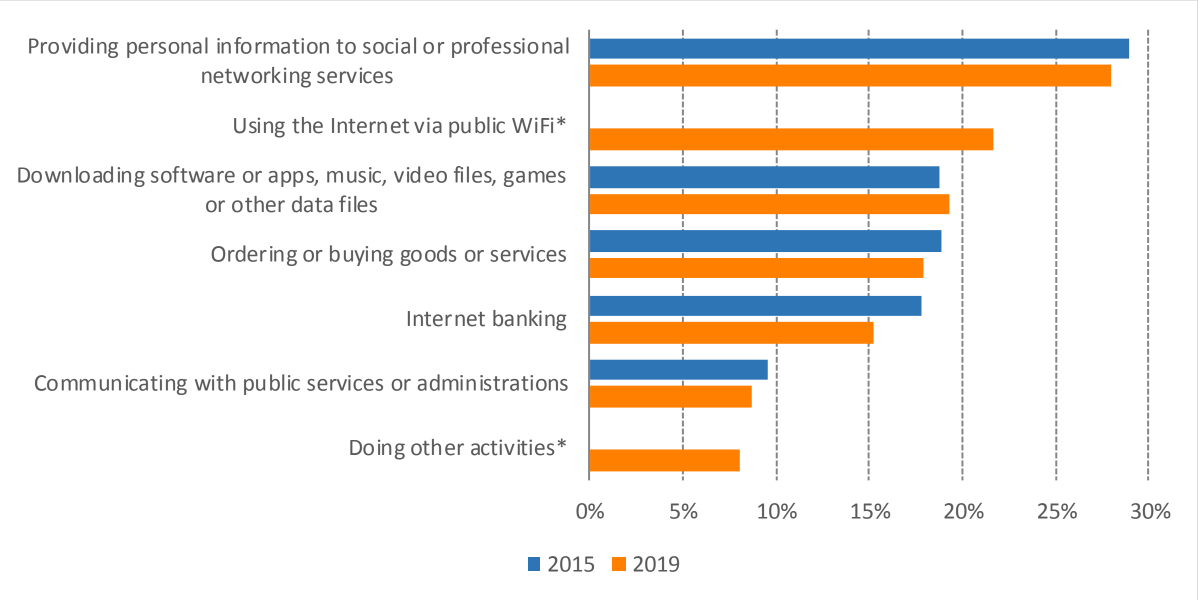
Figure 68: Security incidents and security concerns (% of internet users) 2019



Data not available for Romania
Source: Eurostat, Community survey on ICT usage in Households and by Individuals.

There is a general reluctance to provide personal information to social or professional networks: 28% of internet users expressed this concern, slightly less than in 2015. Moreover, 22% of internet users are reluctant to use public WiFi, and 17.9% to engage in ordering or buying goods or services online. Security concerns also limited or prevented 15.2% of internet users from using online banking.

Figure 69: Online activities limited or prevented because of security concerns (% of internet users) 2015 and 2019



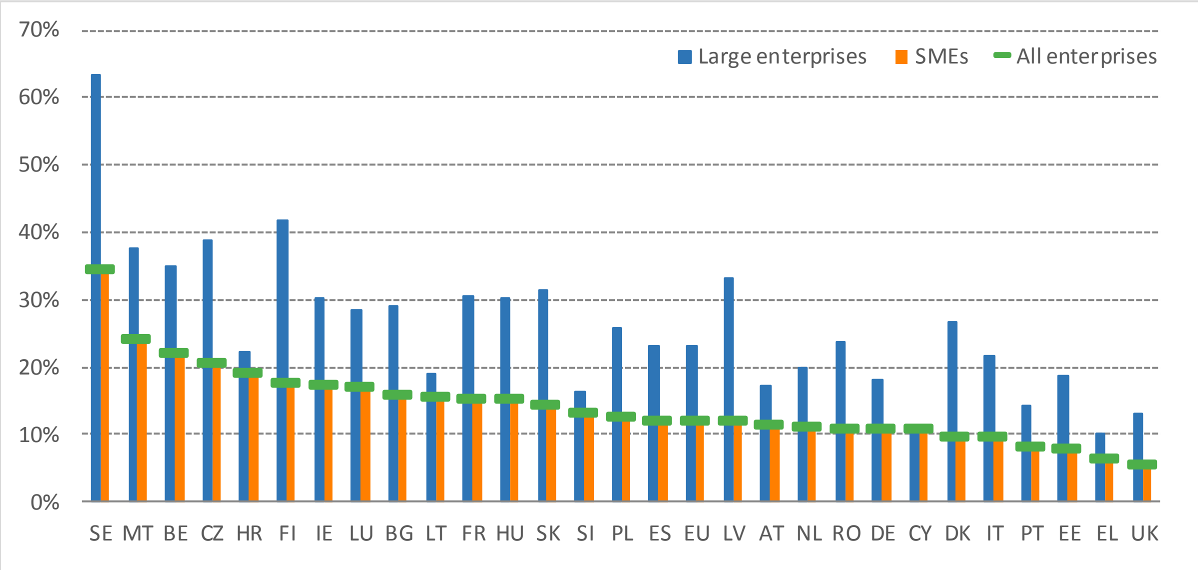
** Data not available for 2015*
Source: Eurostat, Community survey on ICT usage in Households and by Individuals.

6.2 ICT security: Incidents and measures taken by EU enterprises

In 2018, 12.3% of all EU enterprises experienced problems due to ICT security incidents at least once. This percentage was higher among large companies. ICT security incidents were reported by 23% of large enterprises, against 12% of SMEs. Their use of more complex digital systems and services – but also their greater capacity to register and report attacks and failures – might explain the higher rate of incidents among large enterprises.

Country-level analysis shows a mixed picture, with no clear link between the level of business digitisation in the country and the incidence of ICT security issues among enterprises. For example, although Sweden and the UK have similar levels of business digitisation, 35% of Swedish enterprises reported ICT security incidents, against only 5.7% of British enterprises.

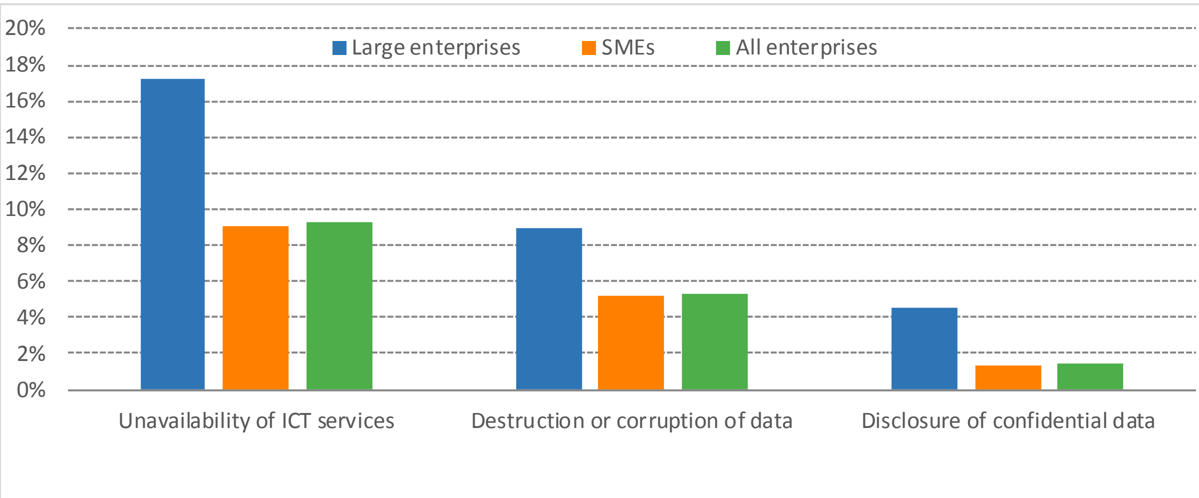
Figure 70: Enterprises that experienced at least once problems due to an ICT related security incident (unavailability of ICT services, destruction or corruption of data, disclosure of confidential data) (% of enterprises) 2019



Source: Eurostat, Survey on ICT usage and e-commerce in enterprises.

The most frequently reported problem was the unavailability of ICT services (reported by 9.3% of all enterprises in the EU), followed by the destruction or corruption of data (reported by 5.3%) and the disclosure of confidential data (reported by 1.4%).

Figure 71: Problems experienced due to ICT security incidents (% of enterprises) 2019

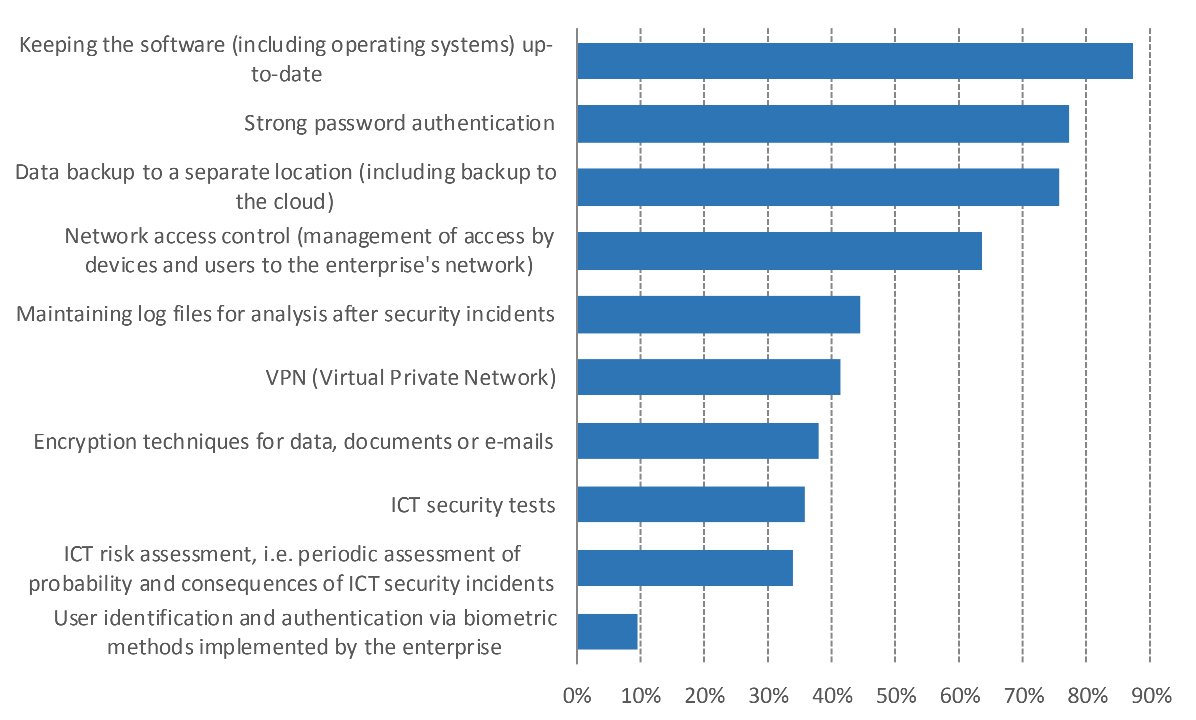


Source: Eurostat, Survey on ICT usage and e-commerce in enterprises.

One in three EU enterprises (34%) have ICT security documents setting out measures, practices or procedures. However, 93% of EU enterprises have adopted at least one ICT security measure. The adoption of ICT security measures is widespread among both large enterprises and SMEs: 99% of large enterprises and 92% of SMEs deploy some ICT security measures.

The types of security measures taken vary. Most EU enterprises have put in place basic measures such as keeping software up-to-date (87%); requiring strong password authentication (77%); and backing up data in a separate location including backing data up to the cloud (76%). A smaller percentage of enterprises use more sophisticated measures such as ICT risk assessments (34%) or ICT security tests (36%), and only a few enterprises use biometric methods for user identification and authentication (9.5%).

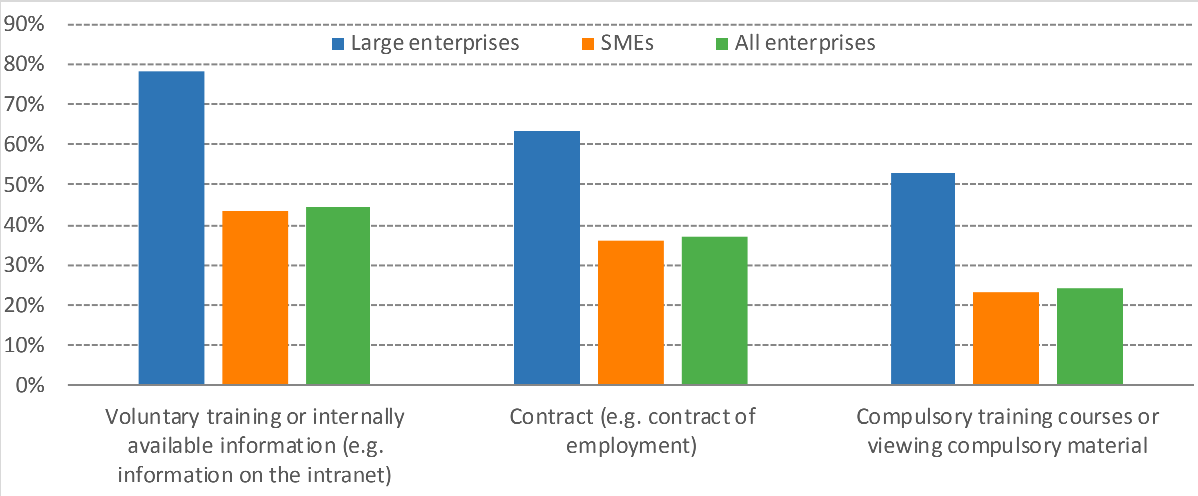
Figure 72: Type of ICT security measures adopted by EU enterprises (% of enterprises) 2019



Source: Eurostat, Survey on ICT usage and e-commerce in enterprises.

Most EU enterprises make their employees aware of ICT security obligations, but only 24.2% of enterprises plan compulsory training on this subject. 62% of EU enterprises make employees aware of their obligations in ICT security, mainly through voluntary training or internally available information (44% of enterprises do this) and by contract (37%).

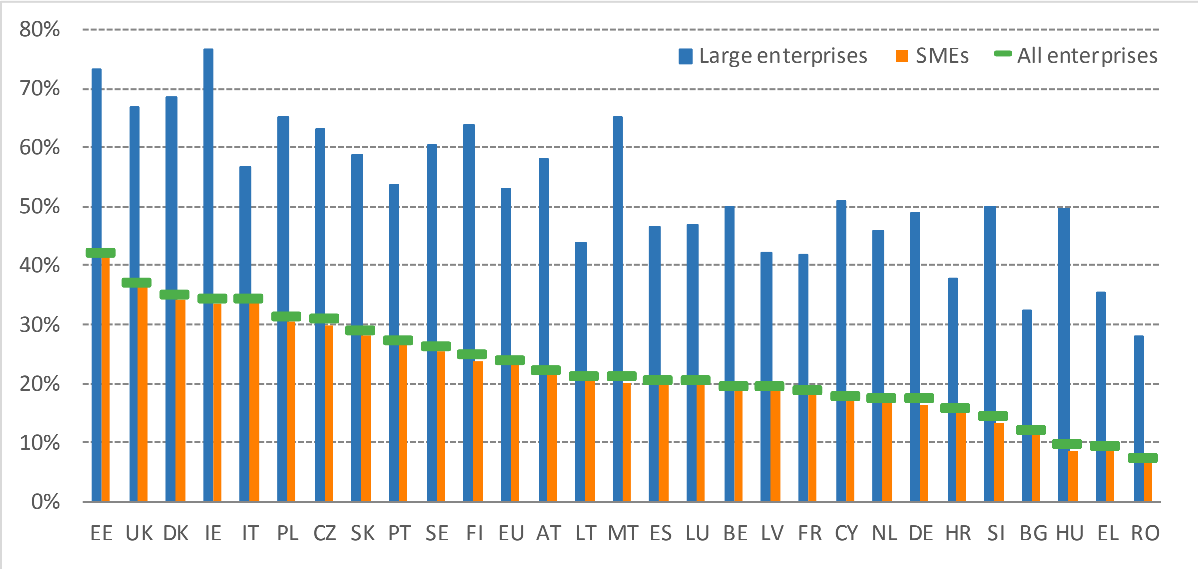
Figure 73: Enterprises that make persons employed aware of their obligations in ICT security issues (% of enterprises) 2019



Source: Eurostat, Survey on ICT usage and e-commerce in enterprises.

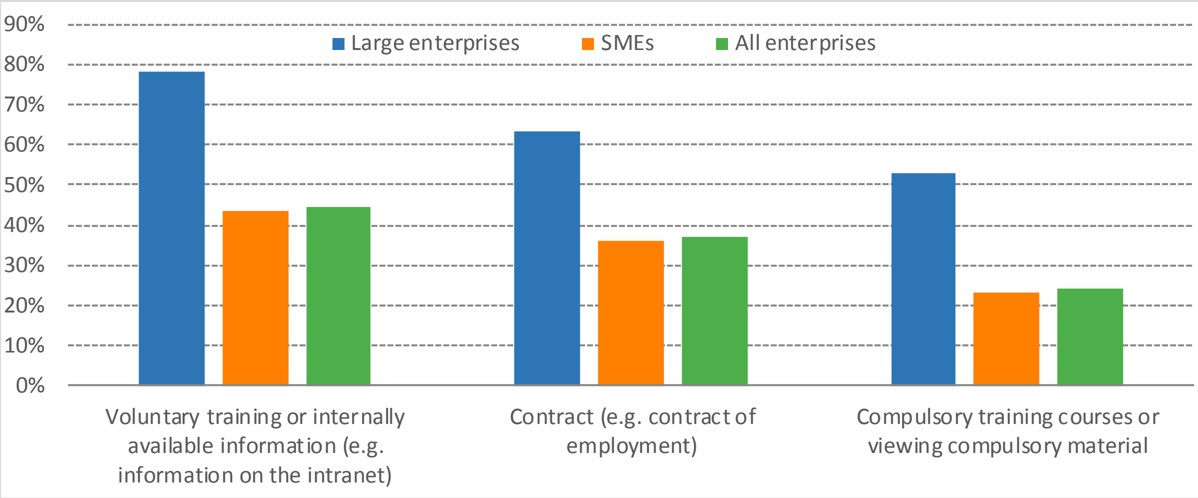
On compulsory training courses, there are significant disparities across Member States. More than 35% of enterprises provide compulsory training in Estonia, the UK and Denmark, while less than 10% of enterprises do so in Romania, Greece and Hungary.

Figure 74: Enterprises make persons employed aware of their obligations in ICT security issues by compulsory training courses or compulsory material (% of enterprises) 2019



Source: Eurostat, Survey on ICT usage and e-commerce in enterprises.

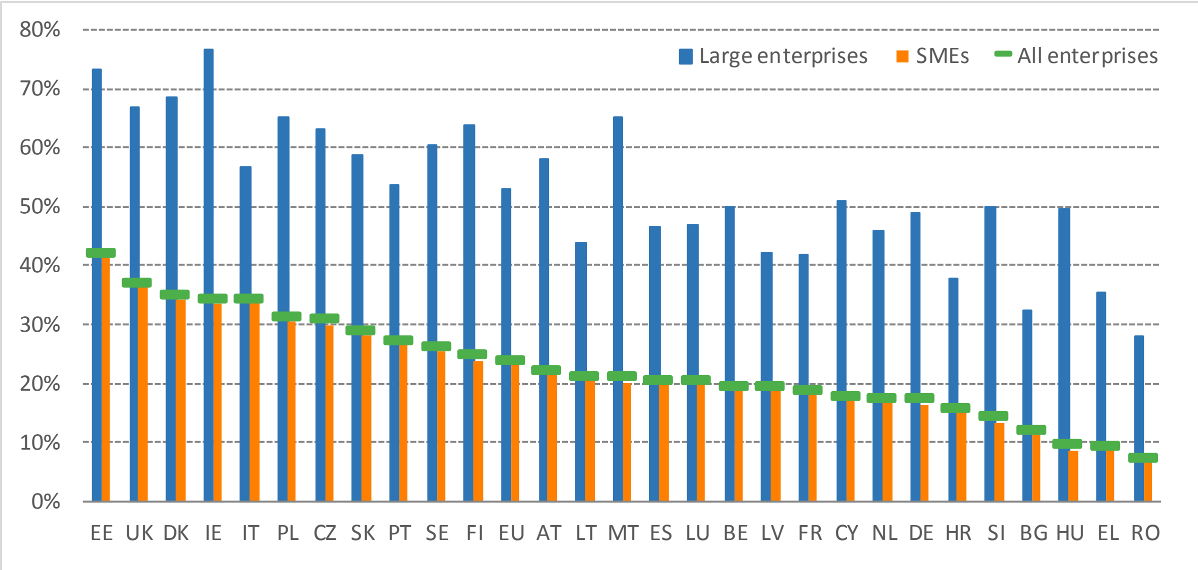
Figure 75: Enterprises that make persons employed aware of their obligations in ICT security issues (% of enterprises) 2019



Source: Eurostat, Survey on ICT usage and e-commerce in enterprises.

Regarding compulsory training courses, there are significant disparities across Member States. The percentage of enterprises providing compulsory training is above 35% in Estonia, the UK and Denmark, while it is below 10% in Romania, Greece and Hungary.

Figure 76: Enterprises make persons employed aware of their obligations in ICT security issues by compulsory training courses or compulsory material (% of enterprises) 2019



Source: Eurostat, Survey on ICT usage and e-commerce in enterprises.

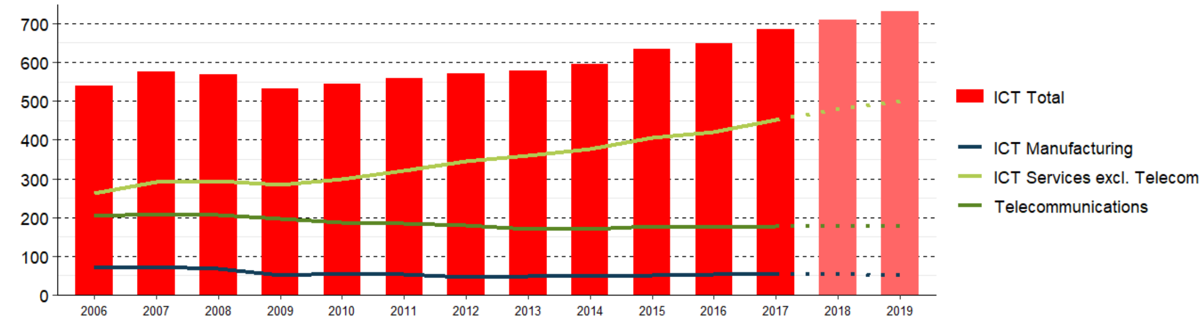
7 The EU ICT Sector and its R&D Performance

7.1 Value added

The value added of the EU ICT sector was €680 billion in 2017, and it is expected to continue to have grown in 2018 and 2019. A breakdown by sub-sector shows the predominance of ICT services (€630 billion and 92% of total ICT sector value added in 2017) over ICT manufacturing.

The ICT services sub-sector (excluding telecommunications) is the only ICT sub-sector that saw an increase in value added between 2006 and 2017, growing to €450 billion. Both the telecommunications and ICT manufacturing sub-sectors experienced a decline in the same period, only slightly recovering some of this decline in the last 2 years.

Figure 77 ICT sector Value Added, € billion, 2006-2019

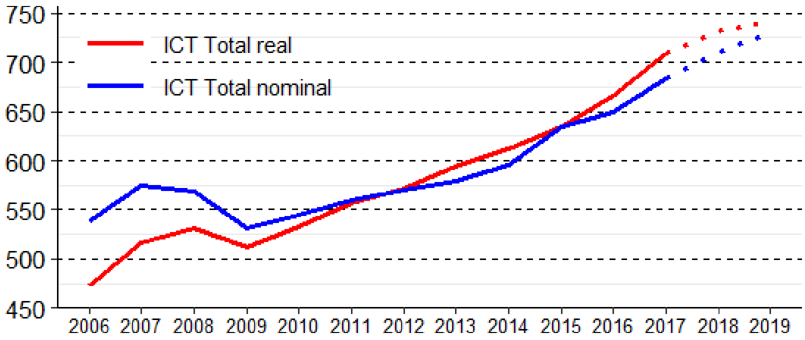


Note: Values for the years 2018 and 2019 are nowcasted data.

Source: Commission calculations and estimates based on PREDICT project.

The value added of the ICT sector grew much faster in real terms than the rest of the economy. Although the value added of the ICT sector increased by 27% in nominal terms (in line with GDP, which grew by 26%), it increased by 50% in real terms in 2006-2017. These trends are explained by the decline in prices in the ICT sector in 2006-2017 (see *Prices*).

Figure 78 ICT sector Value Added, nominal and deflated, € billion, 2006-2019

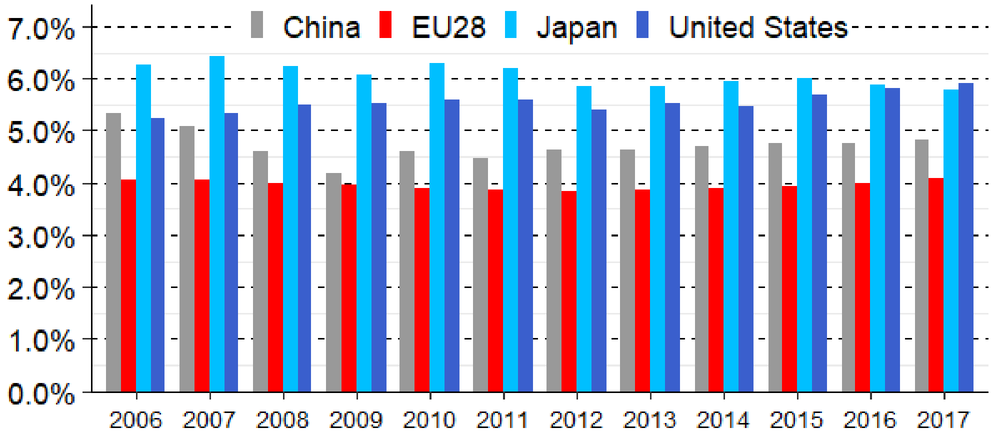


Note: Values for the years 2018 and 2019 are nowcasted data.

Source: Commission calculations and estimates based on PREDICT project.

The value added of the ICT sector accounted for 4.4% of EU GDP in 2017 according to the comprehensive definition (*see Methodological note*). According to the operational definition (*see Methodological note*), which enables world comparisons, the value added of the ICT sector in the EU (4.1%) was lower than that of the US (5.9%), Japan (5.8%) and China (4.8%) in 2017. The EU's ICT sector only grew marginally as a percentage of GDP in 2017 compared to 2016, but so did most of its competitors, except Japan where decreased (this meant that Japan was superseded by the US as the country where the ICT sector accounts for the highest percentage of GDP).

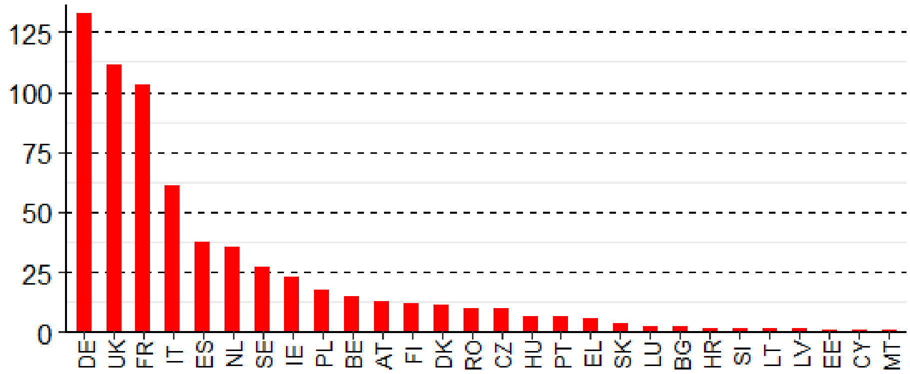
Figure 79 ICT sector share of GDP 2006-2017



Source: Commission calculations and estimates based on PREDICT project.

The EU's five largest economies (Germany, the UK, France, Italy, and Spain) were the five biggest contributors to ICT sector value added in 2017: Germany (€133 billion or 19.5% of EU value added in ICT), the UK (€111 billion or 16%), France (€103 billion or 15%), Italy (€61 billion or 9%), and Spain (€37 billion or 5%). Together, these five countries accounted for 65% of total EU ICT sector value added in 2017.

Figure 80 ICT sector Value Added, EU28, € billion, 2017

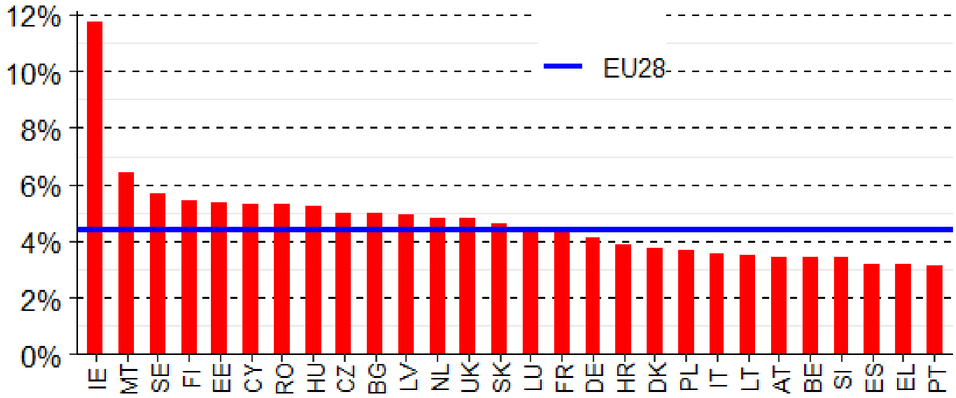


Note: Data for Ireland refers to 2014.

Source: Commission calculations and estimates based on PREDICT project.

However, Ireland had by far the largest ICT sector as a percentage of GDP, at 11.6% in 2014 (the latest year for which data were available), while Portugal lagged behind at 3%. After Ireland, the countries with the largest ICT sector as percentage of GDP were Malta (6.4%), Sweden (5.6%), Finland (5.4%), and Estonia, Cyprus and Romania (all at around 5.3%). Hungary and Czechia also had a large ICT as percentage of GDP (5% or higher). ICT as a percentage of GDP remained broadly unchanged between 2006 and 2017, except in Ireland where it grew by 3.8 percentage points and in Finland, where it fell by 3.2 percentage points.

Figure 81 ICT sector share of GDP, EU28, percentage, 2017



Note: Data for Ireland refers to 2014.

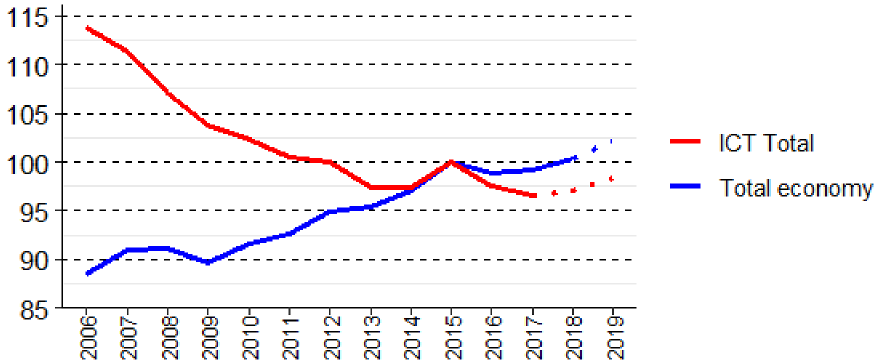
Source: Commission calculations and estimates based on PREDICT project.

7.2 Prices

ICT prices continued to fall in 2016-2017 after a spike in 2015. However, the decline in prices is forecast to have slowed down in 2018.

Prices in the ICT sector fell by 15% between 2006 and 2017, while prices in general grew by 12% over the same period. This highlights the particular nature of product prices in the ICT sector, which also incorporates improvements in the quality of products. This different price dynamic in the ICT sector compared with the overall economy explains why the share of the ICT sector in total EU GDP remained stable (at around 4%) between 2006 and 2017.

Figure 82 Price index, ICT sector and overall economy, index base 2015=100, 2006-2019

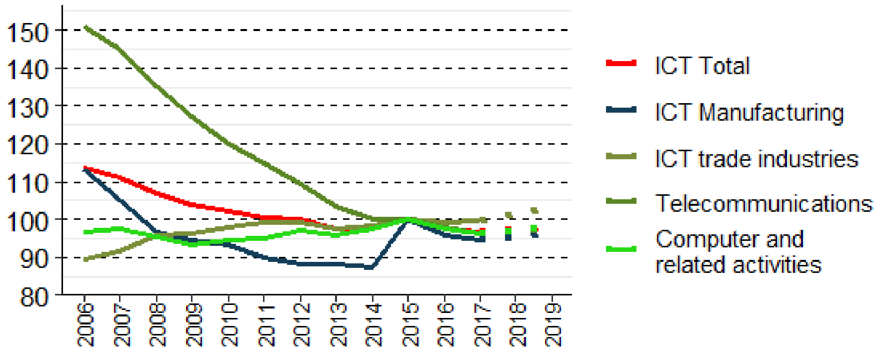


Note: Values for the year 2019 and ICT sector in 2018 are nowcasted data.

Source: Commission calculations and estimates based on PREDICT project.

An analysis by sub-sector shows a contrast: while some sub-sectors experienced a dramatic drop in prices (in telecommunications, prices fell 36%; in ICT manufacturing, they fell 16%), others saw moderate growth (prices in the ICT trade industry increased 12%) or stagnation (prices for computers and related activities fell only 0.3%) between 2006 and 2017. In addition, prices in the ICT sector stabilised somewhat in 2013-2017.

Figure 83 Price index, ICT by sub-sector, index base 2015=100, 2006-2019

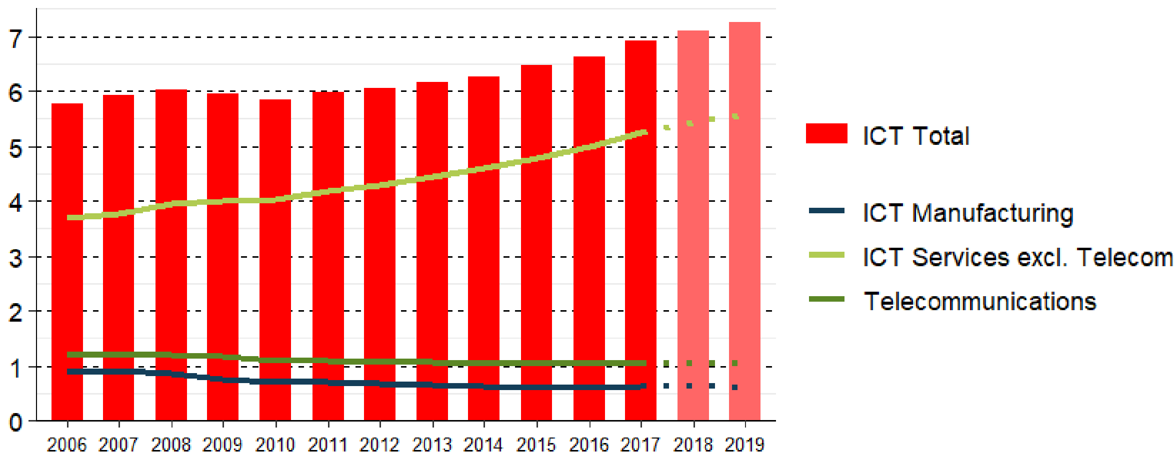


Note: Values for the years 2018 and 2019 are nowcasted data.
Source: Commission calculations and estimates based on PREDICT project.

7.3 Employment

The ICT sector employed 6.9 million people in 2017, continuing on an upward trend since 2010. The ICT services sub-sector (excluding telecommunications) was the main employer with 5.3 million people in 2017, accounting for 76% of total ICT employment. This is the only sub-sector that recorded growth (of 43%) between 2006 and 2017. The telecommunications sub-sector employed 1 million people in 2017, down by 14% since 2006. The ICT manufacturing sub-sector employed 623,000 people in 2017, a drop of 30% since 2006. Employment in the ICT sector accounted for 2.9% of total EU employment in 2017 (for a comprehensive definition – see *Methodological note*), a marginal increase compared to 2006.

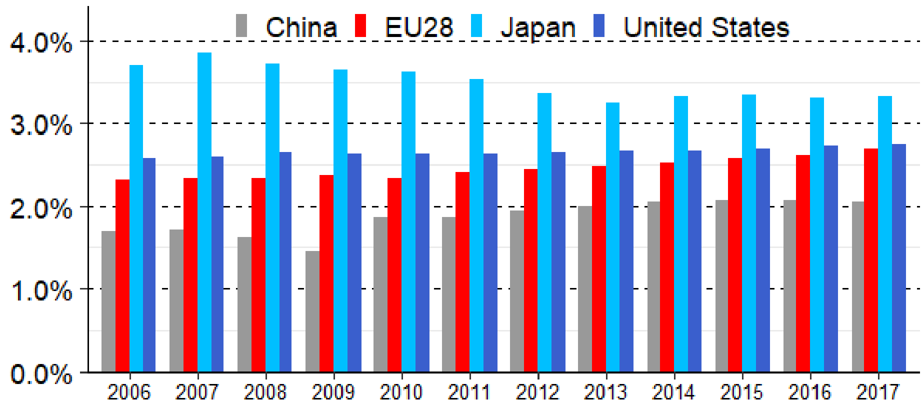
Figure 84 Employment in the ICT sector, million individuals, 2006-2019



Note: Values for the years 2018 and 2019 are nowcasted data.
Source: Commission calculations and estimates based on PREDICT project.

In the operational definition (see *Methodological note)*, which makes it possible to compare countries, the US (where the ICT sector accounts for 2.7% of total employment) was slightly ahead of the EU (2.68%), which in turn was ahead of China (2.1%). However, all three lagged well behind Japan (3.3%) in 2017.

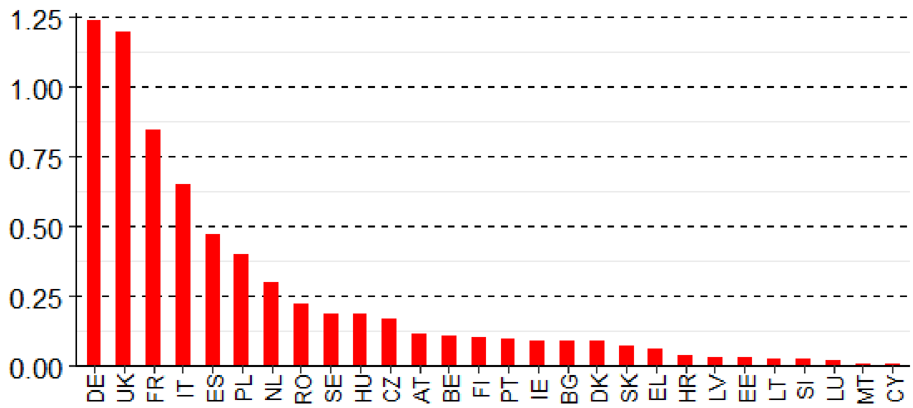
Figure 85 ICT sector share of total employment, percentage, 2006-2017



Source: Commission calculations and estimates based on PREDICT project.

As was the case for value added, the EU's five largest economies were also the five largest employers in the EU ICT sector in 2017 (Germany, the UK, France, Italy and Spain). Germany (over 1.2 million people, or 18% of total EU ICT sector employment), the UK (1.2 million people or 17%), France (848,000 people or 12%), Italy (651,000 people or 9%), and Spain (474,000 people or 7%). Together, the five largest economies accounted for 64% of total ICT sector employment in the EU in 2017.

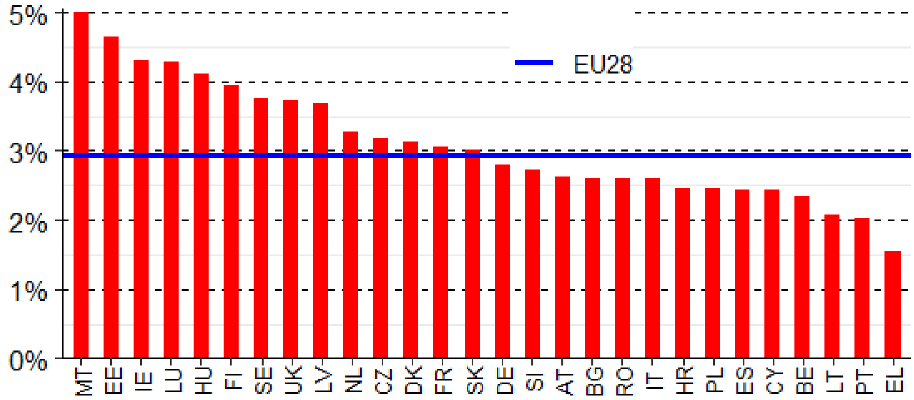
Figure 86 Employment in the ICT sector, EU28, million individuals, 2017



Source: Commission calculations and estimates based on PREDICT project.

In 2017, Malta had the largest ICT sector as a percentage of total employment (5%) and Greece the smallest (1.5%). Other countries that performed well in 2017 included Estonia (4.6%) and Ireland (4.3%). Luxembourg and Hungary were close behind at around 4%. Between 2006 and 2017, ICT sector employment as a share of total employment remained stable in most countries, although, small countries like Estonia and Latvia made significant progress, showing growth of 2 percentage points each.

Figure 87 ICT sector share of total employment, EU28, percentage, 2017

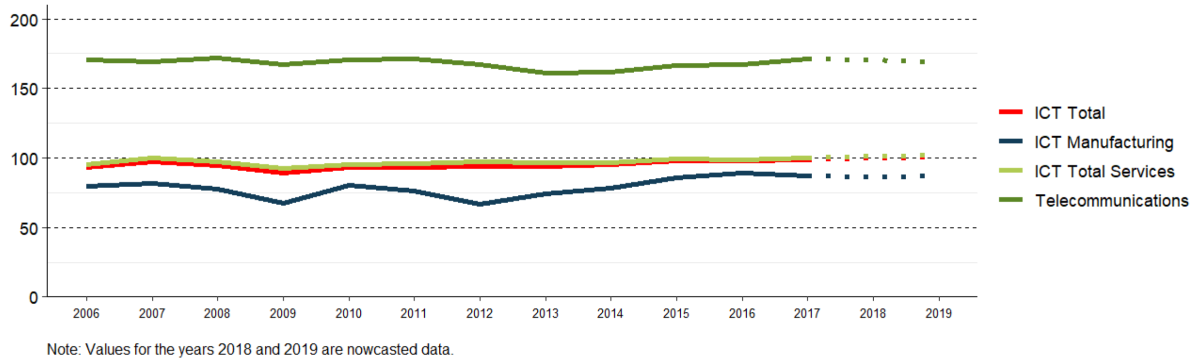


Source: Commission calculations and estimates based on PREDICT project.

7.4 Productivity

Labour productivity in the ICT sector (for a comprehensive definition - see *Methodological note*) was €99,000 per person employed in 2017, a 6% increase compared to 2006. Labour productivity in the ICT manufacturing sub-sector (€87,000 per person employed in 2017) was below the average for the broader ICT sector. Labour productivity in ICT services (i.e. services and trade), which was €100,000 per person employed in 2017, is less sensitive to business cycles and was closer to the total ICT sector average than that of ICT manufacturing. Labour productivity in the telecommunications sub-sector was by far the highest (at €171,000 per person employed in 2017), but it is on a downward trend that is expected to continue in the coming years.

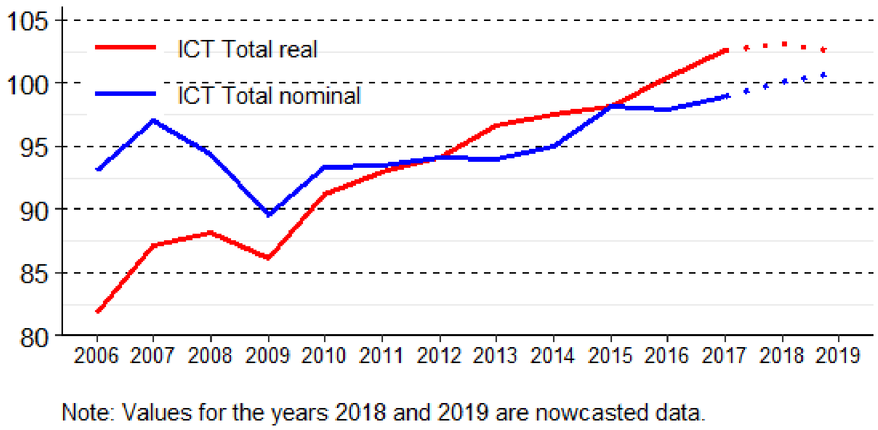
Figure 88 Productivity in the ICT sub-sector, thousand € per individual employed, 2006-2019



Source: Commission calculations and estimates based on PREDICT project.

The ICT sector had higher labour productivity (in nominal terms) and grew faster (in real terms) between 2006 and 2017 than the overall economy. Labour productivity in the ICT sector was greater than in the rest of the economy (€99,000 per person employed versus €65,000 per person employed in 2017). Although it grew less quickly in nominal terms (up 6.3% against 19% nominal growth between 2006 and 2017), labour productivity in the ICT sector grew faster than that of the overall economy in real terms (up 25% against 7% real growth between 2006 and 2017).

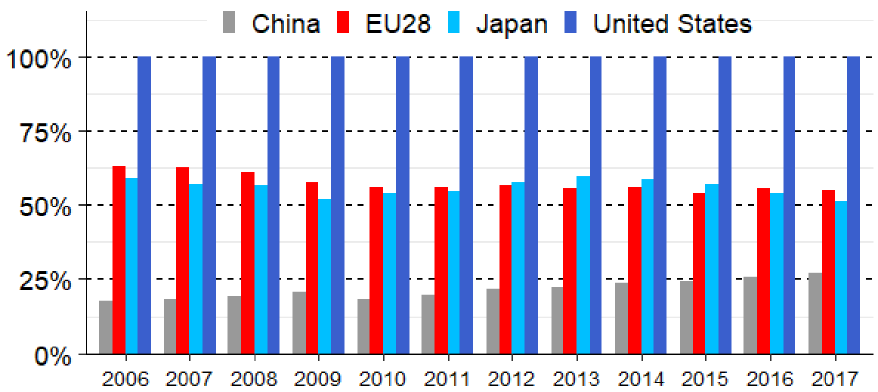
Figure 89 Productivity, nominal and deflated, thousand € per individual employed, 2006-2019



Source: Commission calculations and estimates based on PREDICT project.

According to the operational definition (see *Methodological note*), which makes it possible to compare countries, labour productivity in the EU ICT sector is considerably below that of the US (the EU index is 55 against the US index of 100). Labour productivity in the EU ICT sector is ahead of Japan (which has an index of 51.3) and far ahead of China (index of 27.3). Nevertheless, China is rapidly catching up.

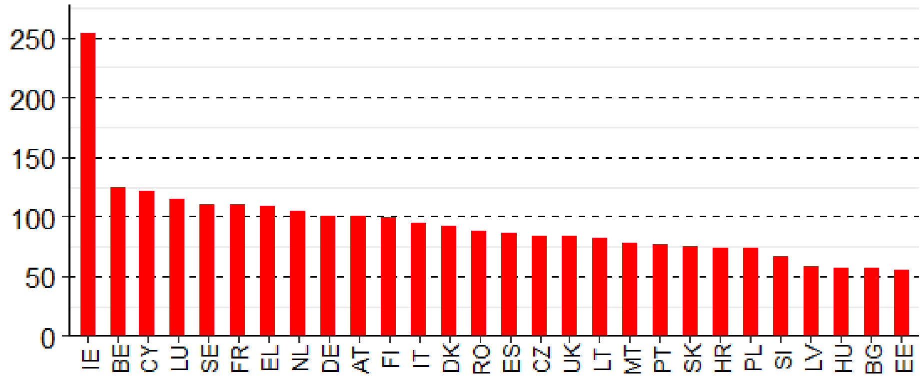
Figure 90 ICT sector productivity, thousand € PPS per individual employed, index US=100, 2006-2017



Source: Commission calculations and estimates based on PREDICT project.

In terms of labour productivity in the ICT sector, Ireland (PPS €254,000 per person employed) by far led the way in 2014 (the latest year for which data were available), but Belgium (PPS €124,000 per person employed) and Cyprus (PPS €122,000 per person employed) also fared well in 2017. At the opposite end of the scale were Estonia (PPS €56,000 per person employed), Bulgaria (PPS €56,500 per person employed), and Hungary (PPS €57,000 per person employed).

Figure 91 Productivity in the ICT sector, EU28, thousand € PPS per individual employed, 2017

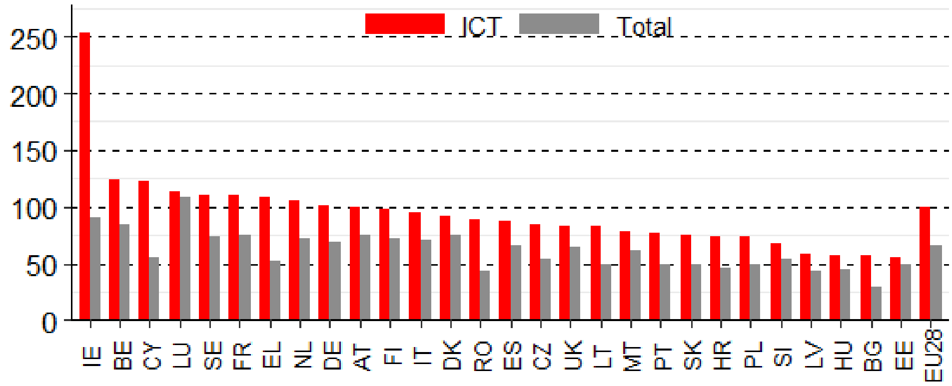


Note: Data for Ireland refers to 2014.

Source: Commission calculations and estimates based on PREDICT project.

The picture for labour productivity in the economy as a whole was similar. Luxembourg (PPS €108,000 per person employed), Ireland (PPS €90,500 per person employed) and Belgium (PPS €84,000 per person employed) were the best-performing countries, while Bulgaria (PPS €30,000 per person employed) and Romania (PPS €43,000 per person employed) were at the bottom of the scale. However, the ratio of labour productivity in the ICT sector over the economy as a whole indicated a good performance of countries at the bottom of the scale (e.g. Romania and Bulgaria).

Figure 92 Productivity, ICT sector and total, EU28, thousand € PPS per individual employed, 2017



Note: Data for Ireland refers to 2014.

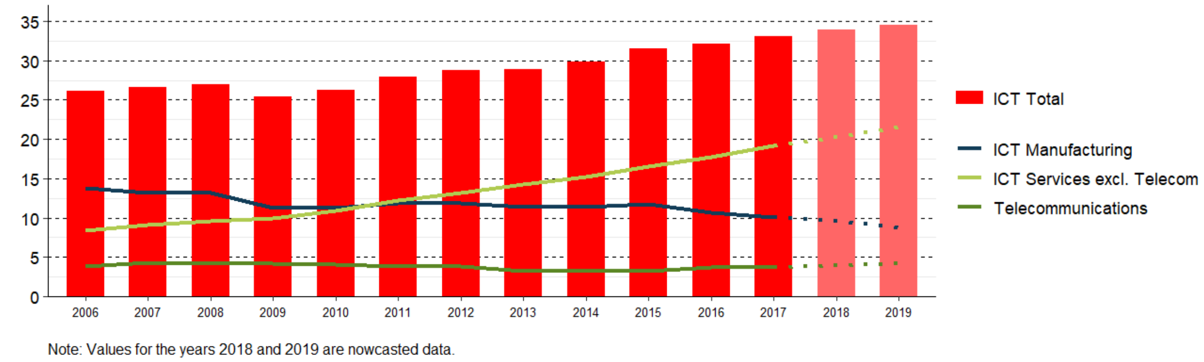
Source: Commission calculations and estimates based on PREDICT project.

7.5 R&D expenditure

R&D expenditure by business enterprises (BERD) in the ICT sector amounted to €33 billion in 2017, its highest value in the 2006-2017 period, and well above its low point of €25 billion in 2009. A breakdown by sub-sector reveals a more balanced situation for BERD than for value added. Despite accounting for only 8% of ICT sector value added, the ICT manufacturing sub-sector was responsible for 30% of total ICT BERD (€10 billion), while the ICT services sub-sector was responsible for 70% (€23 billion) of ICT BERD in 2017.

Between 2006 and 2017, there was a divergence in R&D expenditure in the ICT sector. The ICT manufacturing sub-sector experienced structural decline in R&D expenditure over this period (falling by 27% between 2006 and 2017), whereas the ICT services sub-sector saw a structural increase in R&D expenditure (rising by 86% between 2006 and 2017). The ICT services sub-sector excluding telecommunications saw particularly strong growth with R&D expenditure between 2006 and 2017.

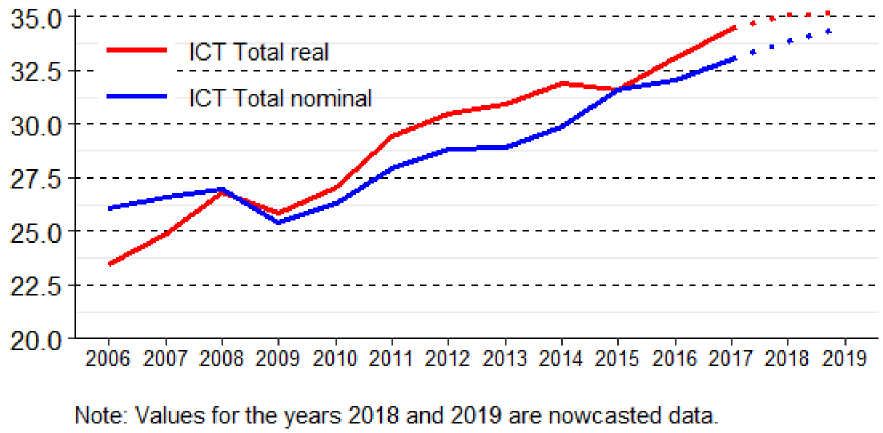
Figure 93 R&D expenditure by business enterprises (BERD) in the ICT sector, € billion, 2006-2019



Source: Commission calculations and estimates based on PREDICT project.

In real terms, R&D expenditure by business enterprises in the ICT sector grew faster than in the general economy (by 46% versus 37% in 2006-2017).

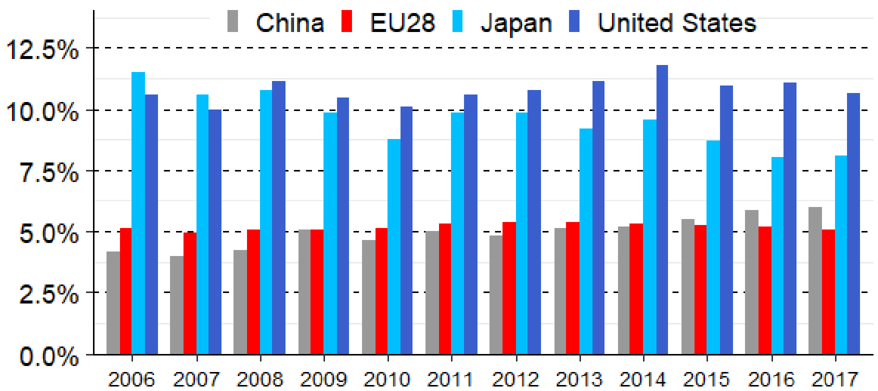
Figure 94 R&D expenditure by business enterprises (BERD) in the ICT sector, nominal and deflated, € billion, 2006-2019



Source: Commission calculations and estimates based on PREDICT project.

R&D intensity (BERD/VA) in the ICT sector (for a comprehensive definition - see *Methodological note*) was 4.8% in 2017. According to the operational definition (see *Methodological note*), which makes it possible to compare countries, China (at 6% R&D intensity) is gaining over the EU (at 5.1%), while both the EU and China lagged behind the US (11%) and Japan (8.1%) in R&D intensity in 2017.

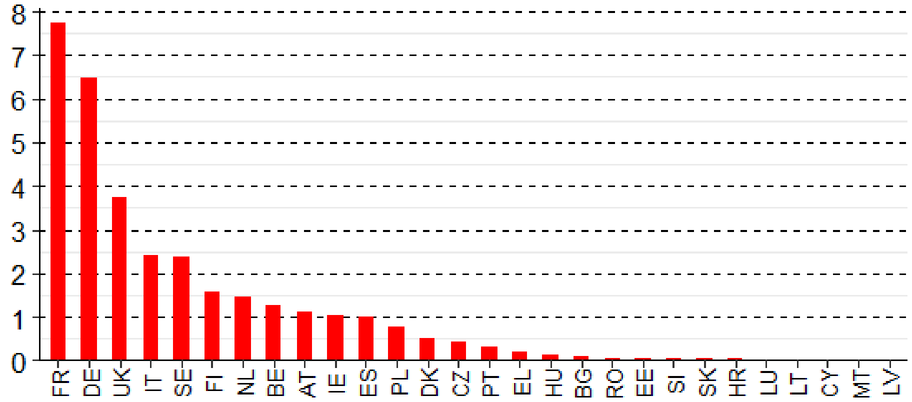
Figure 95 ICT sector R&D Intensity (BERD/VA), percentage, 2006-2017



Source: Commission calculations and estimates based on PREDICT project.

The EU's six main contributors in terms of R&D expenditure by business enterprises in the ICT sector in 2017 were the four largest economies in the EU (France, Germany, the UK and Italy), followed by Sweden and Finland. R&D expenditure in France was €7.7 billion or 23% of the EU total; in Germany it was €6.5 billion or 20% of the EU total; in the UK it was €3.7 billion or 11% of the EU total; and in Italy it was €2.4 billion or 7% of the EU total. In Sweden, R&D expenditure in the ICT sector was €2.4 billion or 7% of the total, and in Finland it was €1.6 billion or 5% of the total. Together, these six countries accounted for 73% of total R&D expenditure by business enterprises in the ICT sector in the EU.

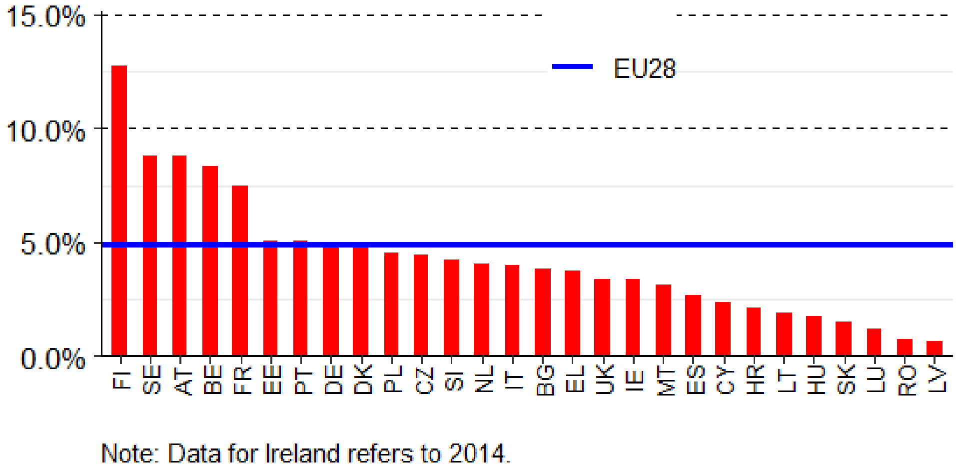
Figure 96 R&D expenditure by business enterprises (BERD) in the ICT sector, EU28, € billion, 2017



Source: Commission calculations and estimates based on PREDICT project.

Finland led the EU with a 12.7% R&D intensity rate (BERD/VA) in ICT in 2017. Sweden and Austria had rates close to 8.8%. Other strong performers included Belgium (8.3%) and France (7.4%). Between 2006 and 2017, R&D intensity in ICT remained broadly stable. But some countries, such as Poland, Belgium and Bulgaria, made significant progress.

Figure 97 ICT sector R&D Intensity (BERD/VA), EU28, percentage, 2017

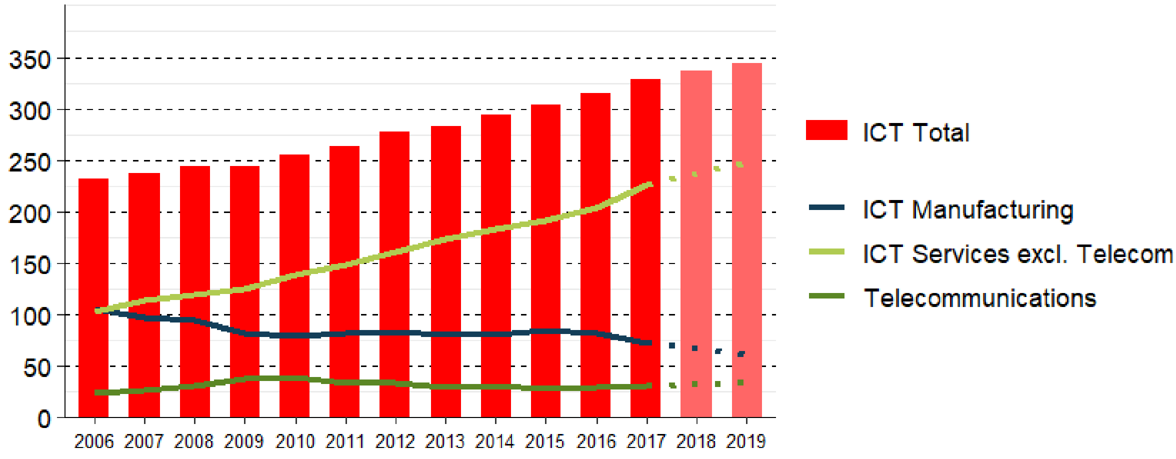


Source: Commission calculations and estimates based on PREDICT project.

7.6 R&D personnel

R&D personnel in the ICT sector accounted for 329,000 full-time equivalents (FTEs) in 2017, a figure which rose between 2006 and 2017, with particularly strong growth after 2009. The ICT services sub-sector (excluding telecommunications) employed 226,000 FTEs in 2017 (accounting for 69% of R&D personnel in the ICT sector, making it the top employer), with a rising trend. The ICT manufacturing sub-sector employed 72,000 FTEs in 2017, fewer than in 2006 despite an increase in the number of people employed in 2015. The telecommunications sub-sector employed 31,000 FTEs in 2017 (9.4% of R&D personnel in the ICT sector), down by about 20% from a peak of 39,000 FTEs in 2010.

Figure 98 R&D Personnel (PERD) in the ICT sector, thousand FTEs, 2006-2019

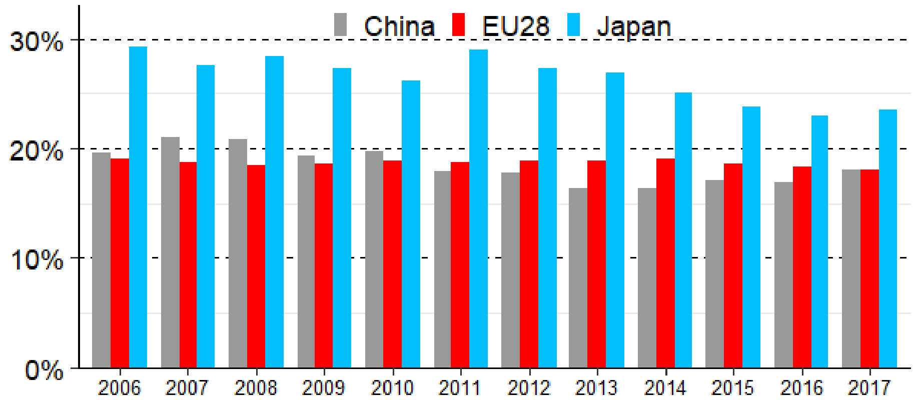


Note: Values for the years 2018 and 2019 are nowcasted data.

Source: Commission calculations and estimates based on PREDICT project.

R&D personnel in the ICT sector (for a comprehensive definition - see *Methodological note*) made up 19% of total R&D personnel in 2017, a figure roughly unchanged since 2006. However, according to the operational definition (see *Methodological note*) which makes it possible to compare countries, the EU (where R&D personnel in the ICT sector make up 18% of total R&D personnel) and China (where they also make up 18%) were behind Japan (24%) in 2017. China and the EU also lagged behind Japan on this metric for every year from 2006 to 2016 (no data available for the US).

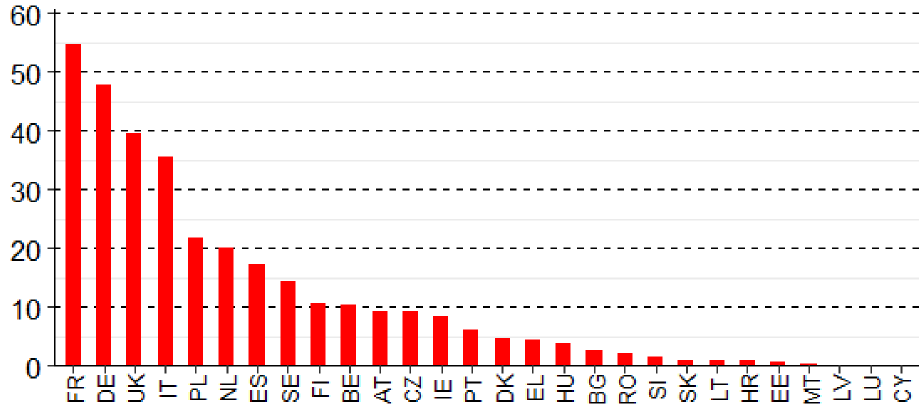
Figure 99 ICT sector share of total R&D personnel, percentage, 2006-2017



Source: Commission calculations and estimates based on PREDICT project.

The EU's four biggest economies were also the four biggest employers of R&D personnel in the ICT sector in 2017. These were France (55,000 FTEs or 17% of R&D personnel in the EU ICT sector), Germany (48,000 FTEs or 15%), the UK (39,500 FTEs or 12%), and Italy (35,500 FTEs or 11%). Together, the four biggest economies represented 55% of total R&D personnel in the ICT sector in 2017.

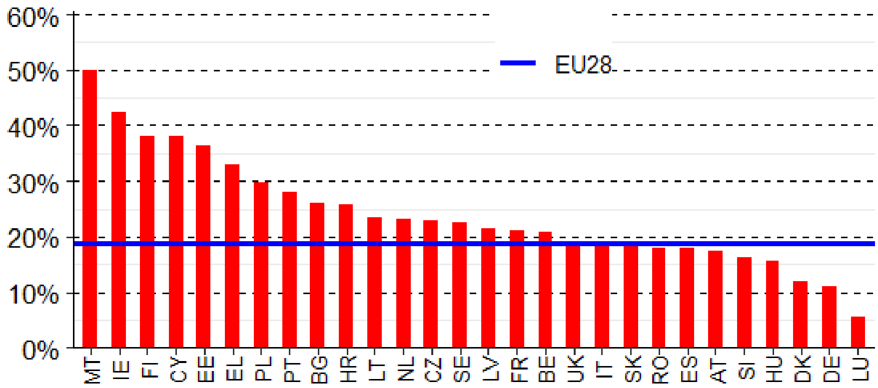
Figure 100 R&D personnel (PERD) in the ICT sector, EU28, thousand FTEs, 2017



Source: Commission calculations and estimates based on PREDICT project.

Malta (50%) and Ireland (43%) were the two EU countries with the highest concentration of R&D personnel in the ICT sector in 2017. Luxembourg had the lowest concentration (6%). Other strong performers were Finland (38%), Cyprus (38%), Estonia (36%), and Greece (33%).

Figure 101 ICT sector share of total R&D personnel (PERD), EU28, percentage, 2017

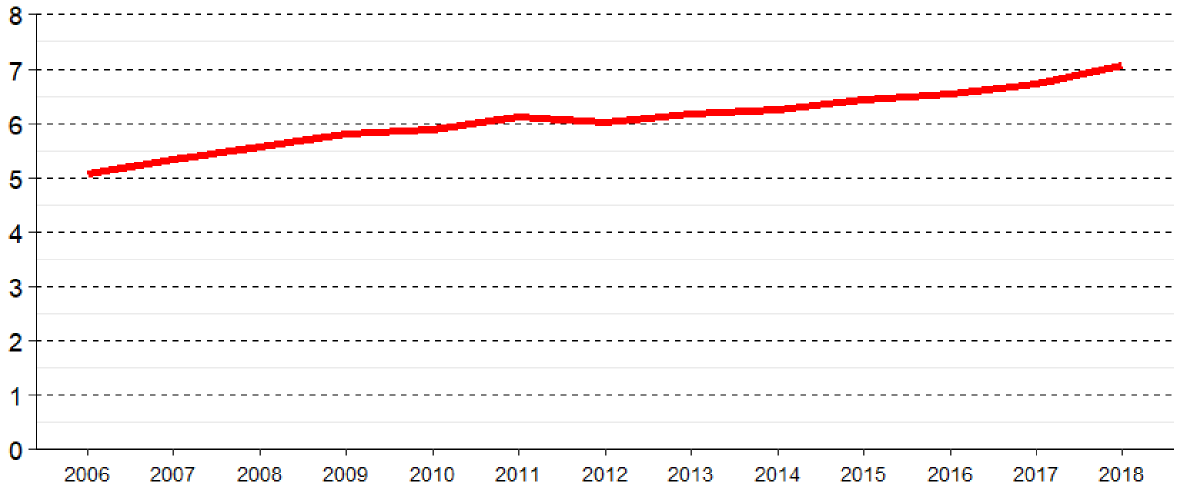


Source: Commission calculations and estimates based on PREDICT project.

7.7 Public funding of ICT R&D

The estimated level of publicly funded expenditure on ICT R&D in the EU increased between 2006 and 2018 interrupted only by a fall in 2012, and reached €7 billion in 2018. The EU's Digital Agenda target of doubling publicly funded ICT R&D between 2007 and 2020 requires an annual growth rate of 5.5% (assuming a constant rate of annual growth). Estimated public, ICT R&D expenditure was below the necessary trend line in 2018, but had still reached 5% annual growth. In 2018, public funding of ICT R&D represented 7.1% of EU total government budget allocations for R&D (GBARD), a percentage broadly unchanged since 2006.

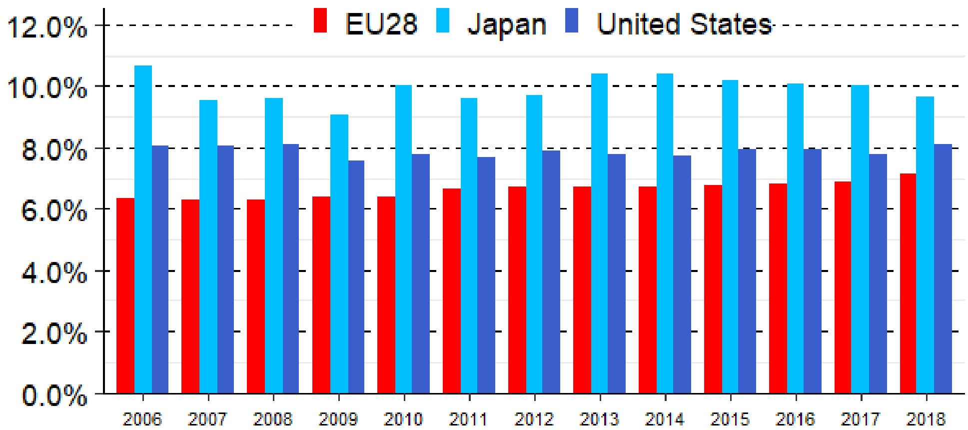
Figure 102 Public funding of ICT R&D (ICT GBARD), € billion, 2006-2018



Source: Commission calculations and estimates based on PREDICT project.

Since 2006, the EU has continuously lagged behind the US (where ICT accounted for 8.1% of GBARD in 2018) and Japan (where ICT accounted for 10% of GBARD in 2018) since 2006 (no data are available for China).

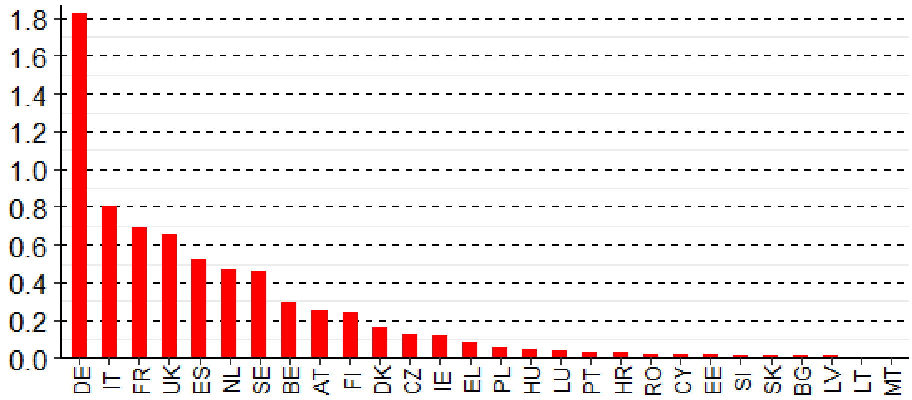
Figure 103 ICT GBARD share of total GBARD, percentage, 2006-2018



Source: Commission calculations and estimates based on PREDICT project.

The EU's five biggest public funders of ICT R&D in 2018 were Germany (€1.8 billion or 26% of public funding in the EU for ICT R&D), followed by Italy (€802 million or 11%), France (€689 million or 10%), the UK (€652 million or 9%) and Spain (€523 million or 7%). Together, those five countries accounted for 63% of total public funding for ICT R&D.

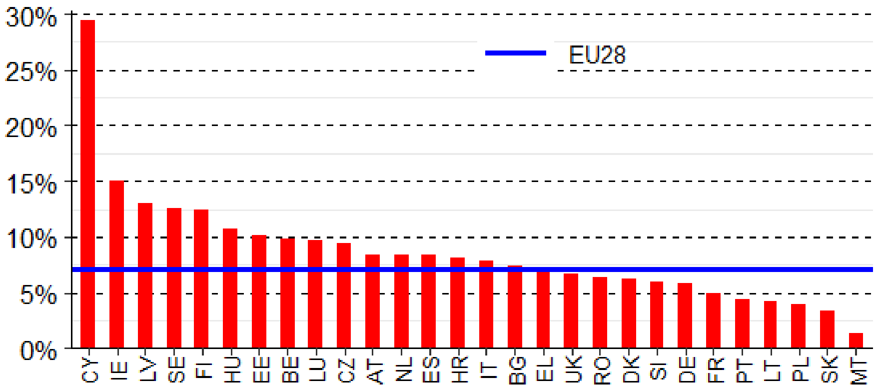
Figure 104 Public funding of ICT R&D (ICT GBARD), EU28, € billion, 2018



Source: Commission calculations and estimates based on PREDICT project.

As in previous years, Cyprus led the way in the EU with the highest rate (29%) of ICT GBARD as a proportion of total GBARD in 2018. The ranking in 2018 again reveals strong performances by Ireland (15%), Latvia and Sweden (both close to 13%). In addition, some other countries also pay special attention to ICT in their public spending on R&D, such as Finland (12%) and Hungary (11%).

Figure 105 ICT GBARD as share of total GBARD, EU28, percentage, 2018



Source: Commission calculations and estimates based on PREDICT project.

7.8 Methodological note

Definition of the ICT sector

In this section, the ICT sector is defined according to the definition provided by the OECD and based on the NACE (Statistical Classification of Economic Activities in the European Community) Rev.2 (2008) nomenclature. The ICT sector has 12 industries:

ICT manufacturing

- C261 Manufacture of electronic components and boards
- C262 Manufacture of computers and peripheral equipment
- C263 Manufacture of communication equipment
- C264 Manufacture of consumer electronics
- C268 Manufacture of magnetic and optical media

ICT services

- G4651 Wholesale of computers, computer peripheral equipment and software
- G4652 Wholesale of electronic and telecommunications equipment and parts
- J5820 Software publishing
- J61 Telecommunications

- J62 Computer programming, consultancy and related activities
- J631 Data processing, hosting and related activities; web portals
- S951 Repair of computers and communication equipment

Comprehensive versus operational definition

The comprehensive definition of the ICT sector applies to EU Member States for the period 2008-2017. It corresponds to the definition provided by the OECD in 2007. The operational definition of the ICT sector enables the EU to be compared with non-EU countries over a longer period (2006-2017), as some of these countries do not have the necessary disaggregated information to estimate all the ICT industries included in the comprehensive definition.

The operational definition does not include the following industries: manufacture of magnetic and optical media (268) and ICT trade industries (465).

Sector analysis

In the previous section, an analysis by ICT sub-sectors is made for each indicator. The 12 industries are aggregated into two sub-sectors: ICT manufacturing and ICT services, the latter being subdivided into ICT services (excluding telecommunications) and telecommunications.

Source

Joint Research Centre – Dir. B Growth and Innovation (JRC– Dir. B). Calculations and estimates from the JRC's PREDICT project are based on Eurostat, the OECD's structural analysis database (STAN), EU-KLEMS data and other national sources. All data contained in these databases come from official sources (e.g. Eurostat, OECD, national statistical institutes). Discrepancies with the original sources are due to updates of the original data or the use of multiple auxiliary sources and variables. For more details, see the 2020 PREDICT Dataset Methodology.

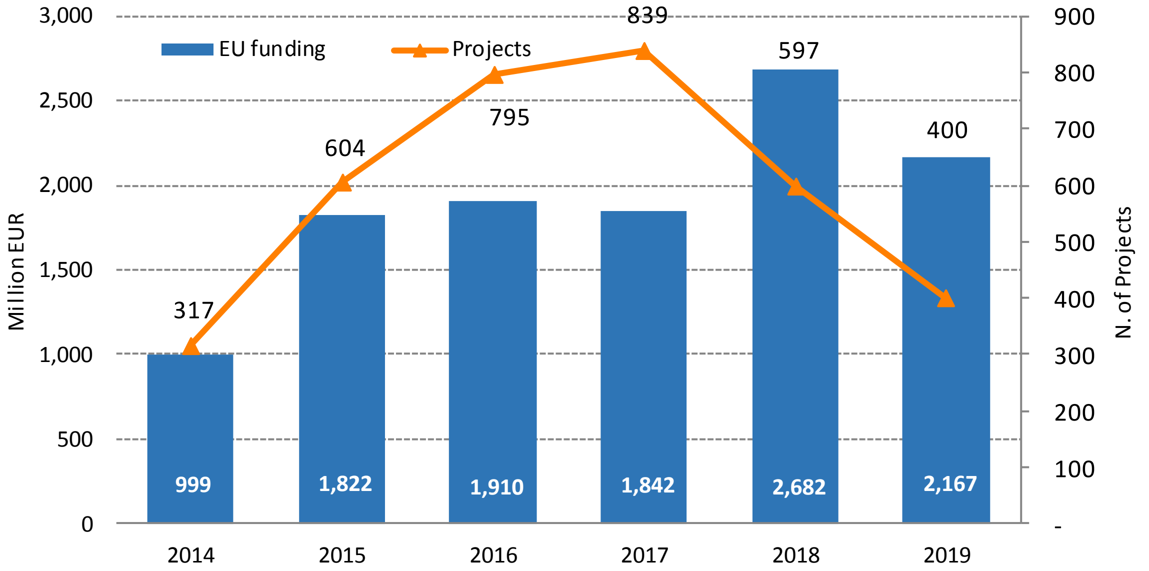
8 Research and Innovation: ICT projects in Horizon 2020

8.1 Projects and EU funding

Between 2014 and 2019, Horizon 2020 has allocated approximately €11.4 billion in EU funding to more than 3,500 projects in ICT-related areas.

In 2019, there were around 400 projects signed, for a total EU funding of approximately €2.2 billion. These figures show a decreasing trend in the number of projects and funding[35].

Figure 106 EU funding and projects by year, 2014-2019



Source: European Commission.

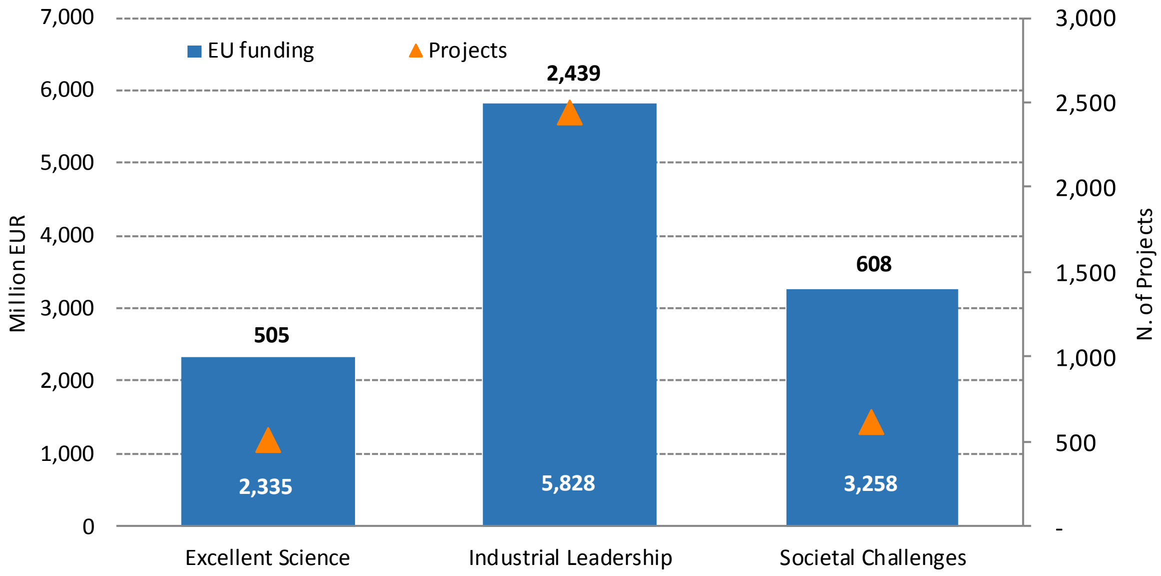
Most of the support has been assigned through the Industrial Leadership pillar, which covers R&I activities on generic ICT technologies driven by either industrial roadmaps or bottom-up processes. This pillar accounts for about €5.8 billion, or more than half of all EU funding for ICT-related projects. Approximately €5 billion (86% of the total under the Industrial Leadership pillar) is allocated under the component for Leadership in Enabling and Industrial Technologies (LEIT). The Industrial Leadership pillar accounts for about 2,400 projects (or 69% of all ICT-related projects). More than half of the Industrial Leadership projects (54%) are LEIT ICT projects.

The Societal Challenges pillar addresses application-driven R&I from a multi-disciplinary perspective. Projects involving ICT to some extent are financed in all of the seven societal challenges, in particular health and wellbeing; clean and efficient energy; smart transport; inclusive and innovative societies; and security and freedom. The Societal Challenges pillar accounts for about 29% of EU funding (€3.2 billion) and 17% of projects (608 projects).

The Excellent Science pillar (e-infrastructures and Future & Emerging Technologies or FET) supports research to uncover radically new technological possibilities and ICT contributions. Areas covered include HPC, quantum technologies and brain science. This pillar accounts for 20% of EU funding (€2.3 billion) and 14% of projects (505 projects).

[35] The data on overall Horizon 2020 implementation follows a partly different trend. Considering all Horizon 2020 projects, the EU funding slightly increased between 2018 and 2019. On the other hand, the increase in EU funding for ICT-related projects between 2017 and 2018 is significantly higher compared to the increase recorded for all Horizon 2020 projects.

Figure 107 EU Funding and projects by pillar, cumulated values 2014-2019



Source: European Commission.

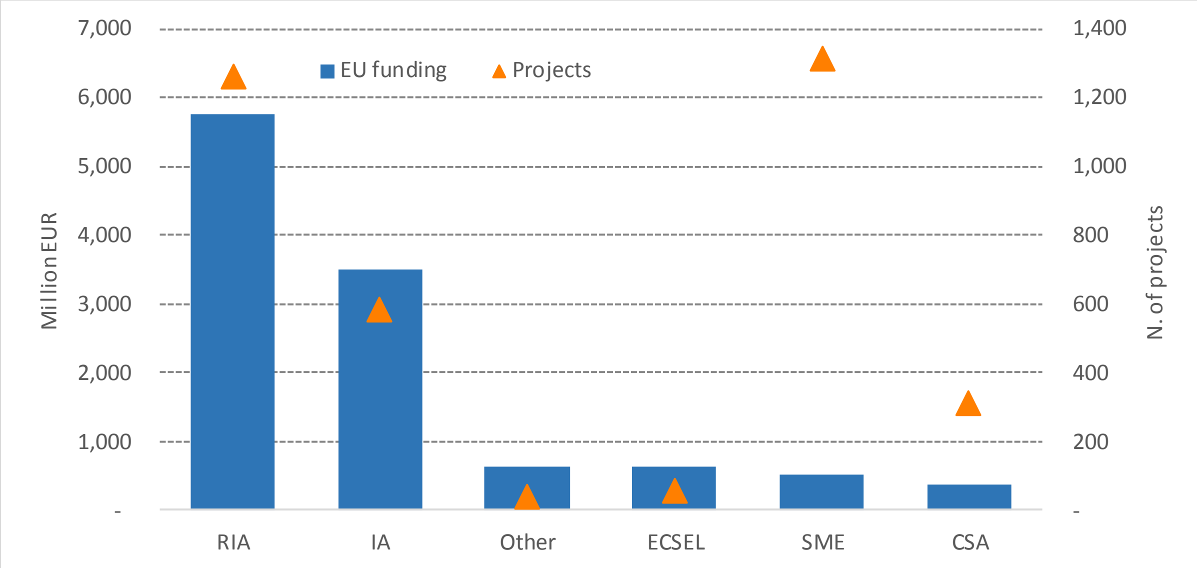
On the distribution of projects and funding by type of actions, Research and Innovation Actions (RIAs) account for the largest share of EU funding in ICT-related projects under Horizon 2020. RIAs aim to uncover new knowledge and/or explore the feasibility of new or improved technology, products, processes, services or solutions. Between 2014 and 2019, 50.5% of total EU funding for ICT-related projects was channelled through RIAs, corresponding to approximately €5.8 billion.

Innovation Actions (IAs) are the second most important instrument for funding ICT-related projects (accounting for €3.5 billion or 30.8% of total EU funding between 2014 and 2019). They aim to produce plans and arrangements or designs, and may include prototyping, testing, demonstrating, piloting, large-scale product validation and market replication.

The other action types are detailed briefly below:

- Actions channelled through the ECSEL Joint Undertaking (i.e. the Public-Private Partnership for Electronic Components and Systems) accounted for about €622 million of the total funding between 2014 and 2019.
- SME instrument projects accounted for a large share of projects between 2014 and 2019 (37%), but given their relatively small size they represented a smaller share of funding (€512 million).
- Coordination and Support Actions (CSAs) involve accompanying measures such as standardisation, dissemination, awareness-raising and communication. They received €371 million between 2014 and 2019.
- The remaining action types, such as Pre-Commercial Procurement (PCP), Public Procurement for Innovation (PPI), and European Research Area (ERA-NET) actions, have a more limited scope of application and accounted for a limited share of both projects and funding.

Figure 108 EU funding and projects by type of action, cumulated values 2014-2019



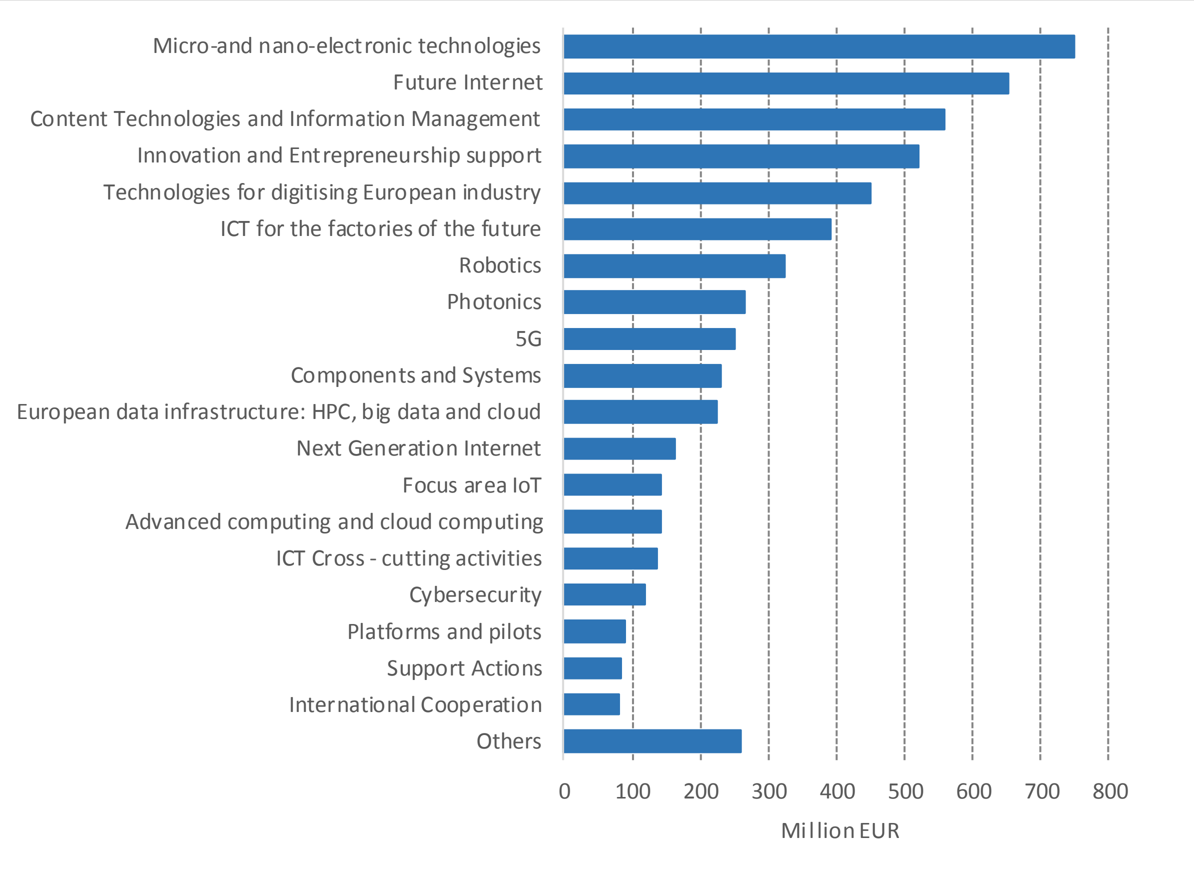
Others include: ERA-NET-Cofund; PCP; SGA-RIA; FPA; COFUND-PCP; PPI; IA-LS; COFUND-PPI.
Source: European Commission.

Looking at the distribution by areas of the work programmes, within the Industrial Leadership pillar, the most funding so far (about €2 billion in total) has gone to projects in the areas of micro- and nano-electronic technologies, future/next generation internet, and content technologies and information management.

Under the Excellent Science pillar, e-Infrastructures were a major area of work between 2014 and 2019 (receiving about €662 million), as were the different components of FET. FET Open received approximately €720 million; FET Flagships about €530 million; and FET Proactive slightly more than €400 million.

Many ICT-relevant projects were also financed under the Societal Challenges pillar, with most of the EU funding allocated in the areas of 'secure, clean and efficient energy' (over €1 billion between 2014 and 2019), and 'health, demographic change and wellbeing' (over €790 million).

Figure 109 EU funding, Industrial Leadership pillar, by area, cumulated values 2014-2019



Source: European Commission.

8.2 Participants and geographical distribution

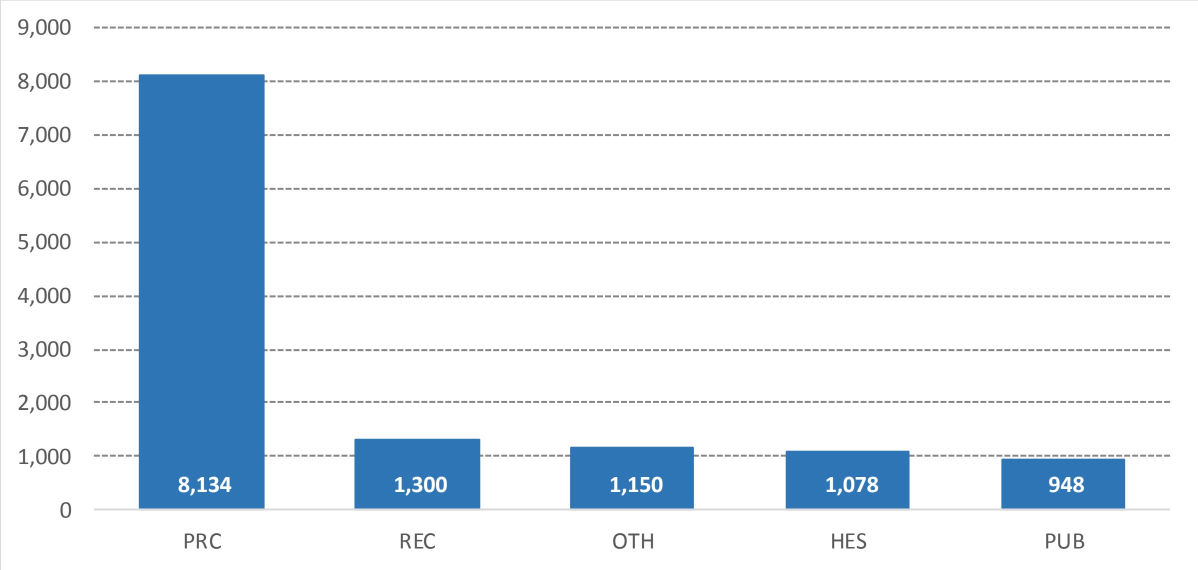
Between 2014 and 2019, there were more than 12,600 participations in Horizon 2020 projects related to ICT topics[36].

Business involvement is significant, with private for-profit companies (PRC) accounting for 39.2% of the funding and 64.5% of participation (the latter figure is the result of a sizable increase recorded during 2019). Secondary and higher education establishments (HES) and research organisations (REC) together account for about 19% of participation and more than half (52.3%) of total funding.

Public organisations (PUB) other than those involved in research and education account for a relatively small share of both funding and participation (about 4% and 7.5% respectively).

[36] Corresponding to around 12,300 organisations (i.e. due to the participation of organisations in more than one project).

Figure 110 Number of participations by category, cumulated values 2014-2019

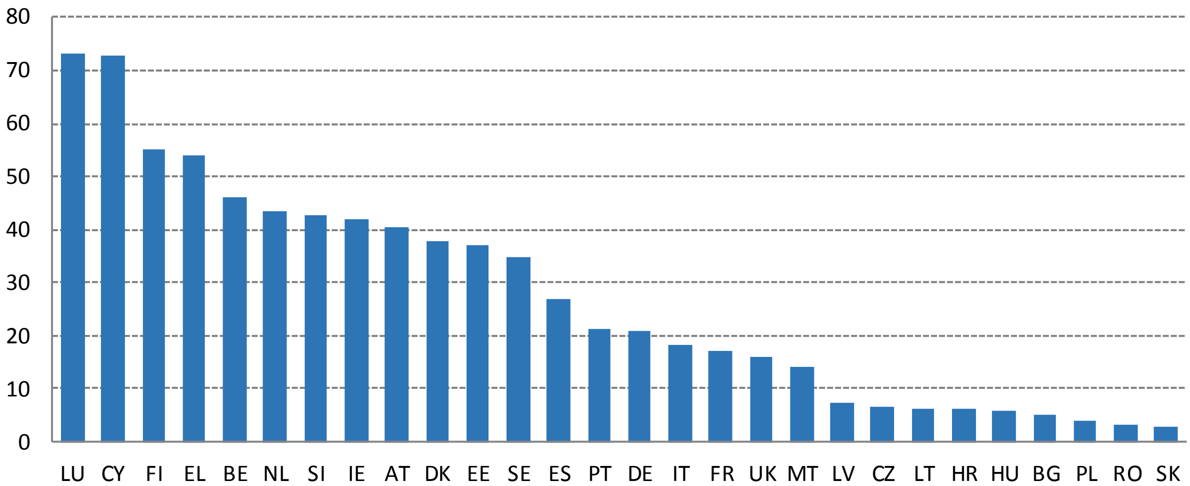


Source: European Commission.

When looking at the geographical distribution, EU Member States account for the vast majority of funding and projects in ICT-related Horizon 2020 projects. Between 2014 and 2019, beneficiaries from EU Member States accounted for 92.4% of funding and 89% of projects.

In absolute terms, the EU's largest economies are the main recipients of EU funding for ICT-related projects under Horizon 2020. Germany, Spain, France, Italy and the UK accounted for about 60% of total EU funding and 56% of participations in the period 2014-2019. When considering country populations, Luxembourg, Cyprus, Finland and Greece are the Member States that received the most funding per capita.

Figure 111 EU funding per capita, cumulated values 2014-2019



Source: European Commission and Eurostat.

Outside the EU, associated countries[37] (primarily Switzerland and Norway) are those, which received most of the funding (7% of total funding, and 95% of funding that went to non-EU beneficiaries).

[37] Associated countries (Art. 7 of the Horizon 2020 Regulation): Iceland, Norway, Albania, Bosnia and Herzegovina, the former Yugoslav Republic of Macedonia, Montenegro, Serbia, Turkey, Israel, Moldova, Switzerland (partial association: Excellent Science Pillar only), Faroe Islands.

8.3 Methodological notes

Source: The report is based on CORDA data elaborated by DG CONNECT.

Coverage: This report considers projects supported through Horizon 2020 funding in ICT-related topics, as defined in the Commission's *Guide to ICT-related activities* covering the period in the scope of the analysis (i.e. 2014-2019). For more details, please see the following documents:

- https://ec.europa.eu/digital-single-market/en/news/guide-ict-related-activities-horizon-2020;
- https://ec.europa.eu/digital-single-market/en/news/guide-ict-related-activities-horizon-2020-work-programme-2018-20.

The Fast Track to innovation pilot and the European Innovation Council pilot are excluded from the analysis.

The report considers projects signed before 31 December 2019. Only projects for which the signature year was known at the time of writing are taken into account.

ANNEX I Abbreviations

Abbreviation	Explanation
4G / 5G	Fourth/Fifth generation technology standard for cellular networks
AI	Artificial Intelligence
BCO	Broadband competence office
BERD	Business expenditure on R&D
CAGR	Compound annual growth rate
CEF	Connecting Europe Facility
CRM	Customer Relationship Management
CSA	Coordination and Support Actions
DIH	Digital Innovation Hubs
DII	Digital Intensity Index
DOCSIS	Data over cable service interface specification
DSL	Digital subscriber line
DTT	Digital terrestrial television
EBP	European Blockchain Partnership
EBSI	European Blockchain Services Infrastructure
eForm	Electronic Form
EFSI	European Fund for Strategic Investments
eID	Electronic Identification
eider's	Electronic Identification, Authentication and Trust Services
EIF	European Investment Fund
ERA-NET	European Research Area
ERM	Enterprise Risk Management
ERP	Enterprise Resource Planning
Euro HPC JU	Euro High Performance Computing Joint Undertaking
FET	Future & Emerging Technologies
FTTB	Fibre-to-the-building
FTTH	Fibre-to-the-home
FTTP	Fibre-to-the-premises
FWA	Fixed wireless access
GBARD	Government Budget Allocations for R&D
GDP	Gross Domestic Product
GHz	Gigahertz
HES	Secondary and Higher Education Establishments
HPC	High Performance Computing
IA	Innovation Action
IaaS	Infrastructure as a service
ICOs	Initial Coin Offerings
ICT	Information and communication technology
IMSI	International mobile subscriber identity
IoT	Internet of Things
JRC	Joint Research Centre
LEIT	Leadership in Enabling and Industrial Technologies
LTE	Long-term evolution
Mbps	Megabits per second
MHz	Megahertz
MNO	Mobile network operator
MVNO	Mobile virtual network operator

NACE	Statistical Classification of Economic Activities in the European Community
NBP	National broadband plan
NGA	Next generation access
NRA	National regulatory authority
OTT	Over-the-top
PaaS	Platform as a Service
PCP	Pre-Commercial Procurement
PERD	R&D personnel
PPI	Public Procurement for Innovation
PPS	Purchasing Power Standards
PRC	Private for-Profit Companies
PSAP	Public safety answering point
QCI	Quantum Communication Infrastructure
R&D	Research and Development
R&I	Research and Innovation
REC	Research Organisations
SaaS	Software as a Service
SMEs	Small and Medium Enterprises
USO	Universal service obligation
VDSL	Very-high-bit-rate digital subscriber line
VHCN	Very high capacity network