

# CHAPTER

## 6.2

# KNOWLEDGE FLOWS

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## KEY FIGURES

**13%**

EU researchers currently employed in another country with large differences between MS

**3<sup>rd</sup>**

place for EU in public-private co-publications after USA and South Korea

**11%**

of EU patents are filed with foreign co-inventors while USA ranks first with 13%

**60%**

of publications in open access for Croatia, the Netherlands and Luxembourg



## What can we learn?

- ▶ **Researchers' mobility remains key to knowledge diffusion**, yet stark disparities remain between countries in international and intersectoral mobility patterns in the EU. In general, countries with a higher R&I performance tend to have a greater inflow and outflow of researchers.
- ▶ **The US and EU are leading in international technological cooperation**, whilst China and Japan are falling behind. In some EU countries, knowledge diffusion and technological transformation continues to be stimulated through foreign direct investment and foreign business research investment.
- ▶ **In terms of public-private co-publications, the EU is catching up with South Korea and the United States.** Private financing of public research is stagnating at the global level. A few large innovative companies are making the most of international and inter-sectoral cooperation.
- ▶ **The EU continues to lead on open science policy and international scientific collaboration**, with its EU Framework Programme playing an important role.



## What does it mean for policy?

- ▶ Divergence between the EU Member States on researcher's mobility patterns calls for a **better understanding of drivers of and barriers to international and intersectoral mobility** as well as the implementation of **policies to foster brain circulation**.
- ▶ **International technological cooperation policies need to be put into a wider perspective of changing global approaches** to trade and technological sovereignty.
- ▶ There is a need to **strengthen the capacity of small firms to engage in R&I collaborations**, including with academia. Despite digitalisation, the geographical proximity of academia is still paramount for innovative activities in industry.
- ▶ While the open access policy in the EU is well advanced, **efforts in implementing its ambitious European open data policy and mainstreaming open science policies and practices must be stepped up**.

**Knowledge flows are paramount in creating solutions to the challenges that Europe and the world are currently facing** (i.e. from carbon neutrality through sustainable food systems to smart mobility) and in ensuring the competitiveness of European companies. The diffusion of knowledge and technology

across companies, regions and countries helps to address differences in productivity growth and the take-up of digital technologies, and is a pre-requisite to cope with the growing complexity of innovation processes. Free circulation of knowledge has been at the heart of the European Research Area initiative.

## 1. Researchers' mobility remains key to knowledge diffusion, yet stark disparities remain between countries in international and intersectoral mobility patterns in the EU

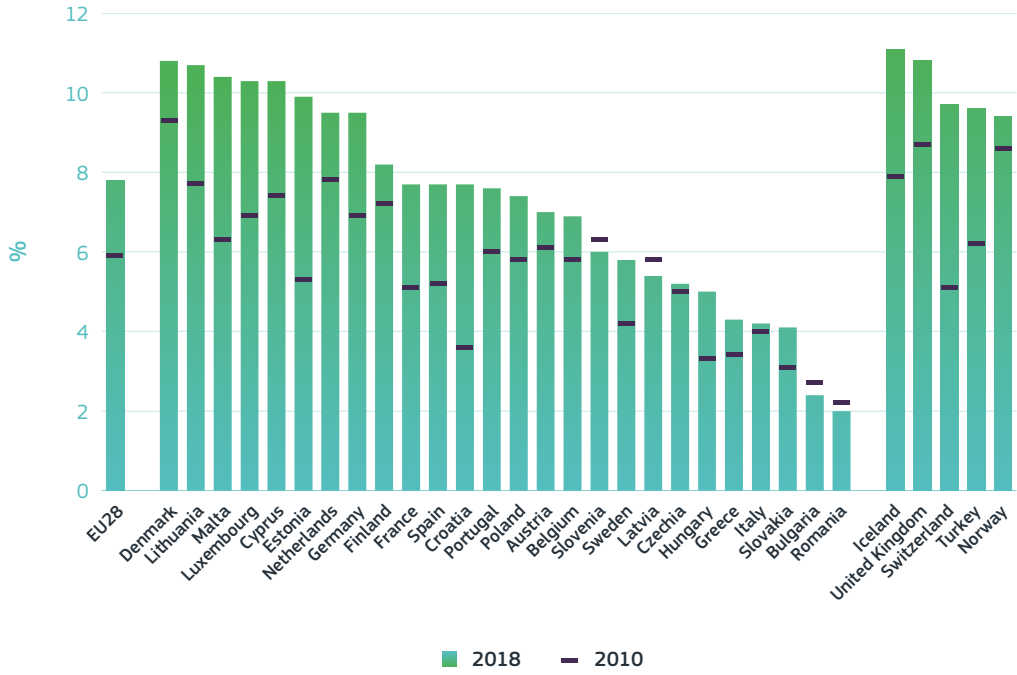
**Researchers – progressively mobile between sectors, disciplines and countries – provide an important channel for knowledge diffusion between research organisations, business, non-profit organisations and public administrations.**

Mobility enables faster absorption and valorisation of knowledge, fosters lasting cooperation and, at the same time, increases researchers' career prospects. Yet, mobility patterns diverge between Member States in terms of mobile human resources in science and technology (HRST), international mobility of researchers as well as intersectoral mobility<sup>1</sup>. Greater asymmetric mobility of high-skilled professionals and academics may exacerbate existing inequalities, thereby further weakening the economy of post-industrial and/or peripheral regions and countries (Iammarino et al., 2019). It may also undermine efforts to raise the quality and efficiency of all European national R&I systems. This calls for a strengthened role of place-based innovation based on the partnership of enterprises, universities and government, as well as a better understanding of drivers of and barriers to international and intersectoral mobility.

**While mobile human resources in science and technology have increased only slightly at the EU level in the last 10 years, they remain a small share of the total R&I workers, with differences between the Member States.** Between 2007 and 2018, the mobility of human resources in science and technology (HRST) increased only slightly in the EU to reach 7.8%, with the majority of countries oscillating between 10% and 5% of the mobile HRST workforce. However, the overall trend remains disappointing and shows a very mixed pattern, as can be seen in Figure 6.2-1. A decline in mobility occurs both in northern countries (Denmark, Finland, Sweden, Iceland and Norway), which were characterised by higher mobility, and eastern and southern countries (Spain, Italy, Latvia, Bulgaria and Romania) that showed lower mobility. Conversely, mobility increased most significantly in Lithuania, Luxembourg, Malta, France, Germany and Switzerland.

1 The (physical) mobility of researchers from one sector (academia) to another (e.g. industry).

Figure 6.2-1 Job-to-job mobility<sup>(1)</sup> of human resources in science and technology (HRST)<sup>(2)</sup> as % of total HRST, 2010 and 2018



Science, research and innovation performance of the EU 2020

Source: Eurostat (online data code: hrst\_fl\_mobsex)

Notes: <sup>(1)</sup>Shows the movement of individuals between one job and another from one year to the next. It does not include inflows into the labour market from a situation of unemployment or inactivity. <sup>(2)</sup>HRST: People with tertiary education and/or employed in science and technology.

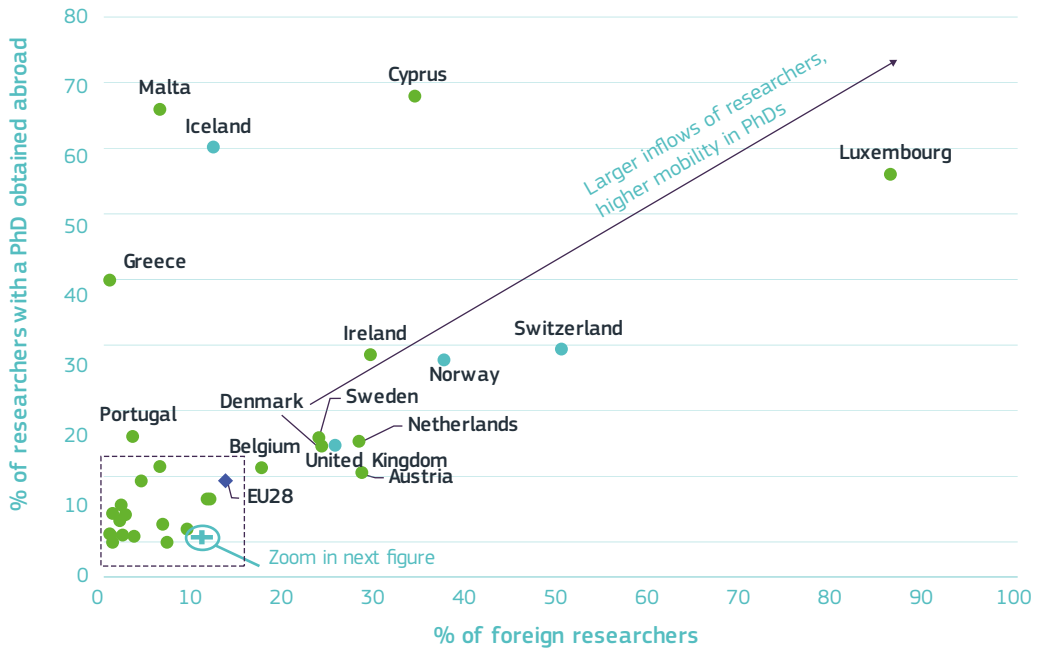
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**As regards the international mobility of researchers, there are vast differences between countries with a higher share of inflow of researchers observed in higher-performing countries and an overall higher mobility of researchers from smaller R&I systems.** Brain circulation across countries and regions continues to be unbalanced. Malta, Greece and Iceland have the highest share of researchers who have obtained PhDs outside of their country of origin, as well as lower inflows of foreign researchers. At the same time, the Nordic countries, Austria, Switzerland and the UK, have the highest share of inflows of researchers. Luxembourg, Ireland and Cyprus – albeit to a lesser extent – present both high

inflows of researchers and high mobility during PhD programmes (Figure 6.2-2).

**In general, countries with higher R&I performances tend to have a higher share of researchers who have obtained their PhD in another country and higher researcher inflows.** Yet, France, Germany, Spain, Italy and Finland report degrees of mobility that are lower than the EU average. The size of the national research system also has an impact on researchers’ mobility. In the case of Cyprus, Malta and Luxembourg, this has resulted in mobility which is higher than EU average, while Germany and France show the opposite trend (Figures 6.2-2 and 6.2-3).

Figure 6.2-2 International mobility of researchers

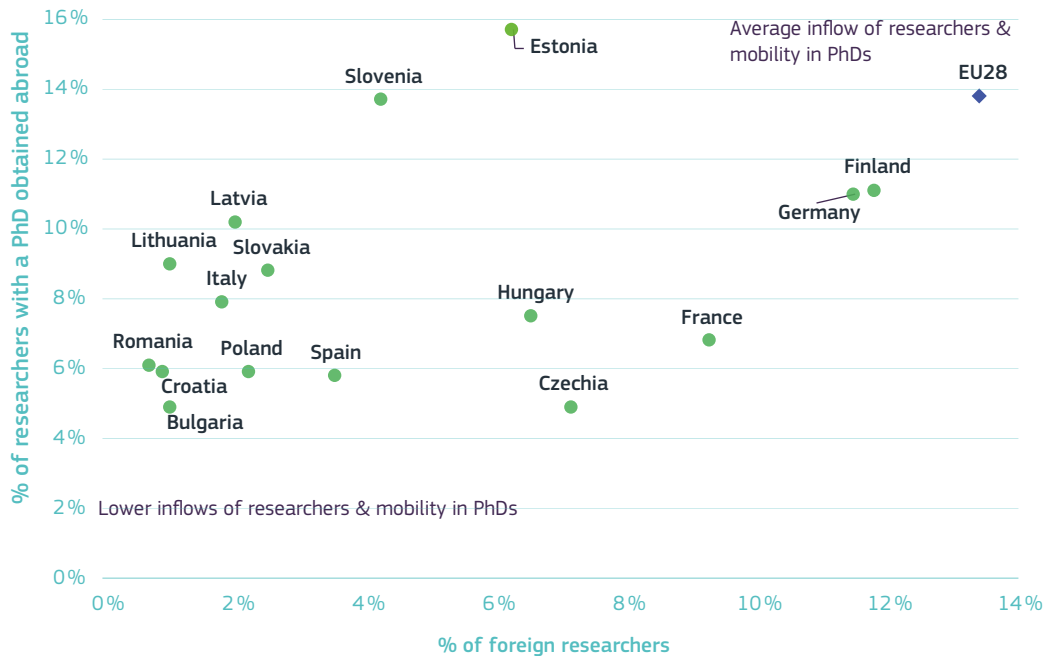


Science, research and innovation performance of the EU 2020

Source: European Commission, MORE3 study (2016)

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Figure 6.2-3 International mobility of researchers - zoom from the previous figure



Science, research and innovation performance of the EU 2020

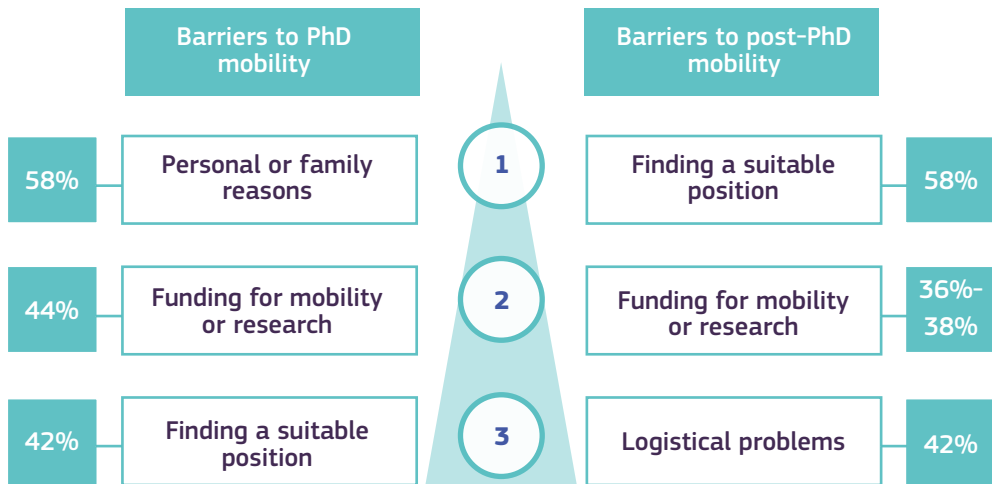
Source: European Commission, MORE3 study (2016)

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The asymmetry in mobility flows, while highly beneficial for hosting countries, may prove detrimental to lower-performing research systems if mobility is one directional (Veugelers, 2017). This calls for an active strategy of enticing international researchers while providing attractive opportunities for returning researchers. There is ample evidence that returning researchers are more productive and maintain collaborative links with their previous institutions (Jonkers and Cruz-Castro, 2013). Wagner et al. (2018) point to the correlation between a country’s internationalisation in terms of international co-authorship of scientific articles and the mobility of researchers and the high impact of scientific work.

Dedicated studies<sup>2</sup> report various factors that act as barriers to researchers’ international mobility, such as personal or family reasons, funding, and finding a suitable position. The MORE3 study<sup>3</sup> also notes that 16% of mobile researchers have experienced ‘forced mobility’ – i.e. the extent to which researchers feel forced to move to another country due to the lack of career options in their home country or the requirements of the system. At the EU level, 16% of the researchers report international mobility during their PhD and 13% are currently employed in a country other than their country of citizenship.

Figure 6.2-4 Top three barriers to mobility of researchers (%)



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on MORE3 study

Stat. link: <https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter62/figure-62-4.xlsx>

2 The MORE3 study, funded by the EC, collects detailed information and data on the mobility patterns and career paths of EU researchers.

3 [https://cdn1.euraxess.org/sites/default/files/policy\\_library/final\\_report\\_2.pdf](https://cdn1.euraxess.org/sites/default/files/policy_library/final_report_2.pdf)

**Intersectoral mobility of researchers increased by 6 percentage points compared to 2010. In 2017 51 % of EU researchers worked in the private sector, only 20% of those researchers were female.** Intersectoral mobility, understood as the mobility of researchers from academia to industry (and vice versa), is an important mechanism for fostering knowledge transfer and valorisation (in addition to graduates working in industry, collaborative and contract R&D, and (informal) consulting).

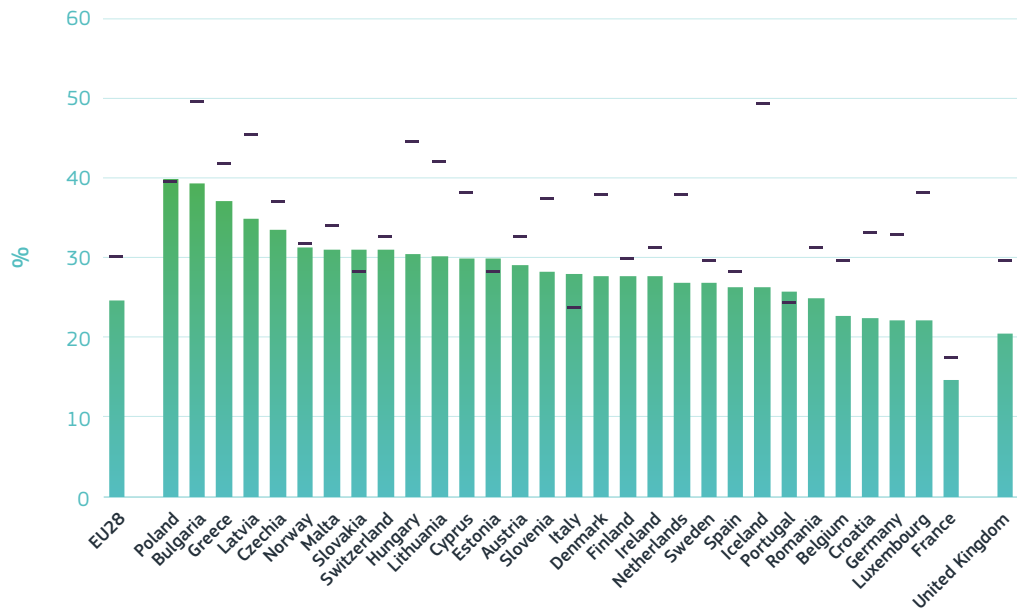
**Based on Eurostat data<sup>4</sup>, 51% of EU researchers worked in the private sector in 2017 (not including not-for-profit organisations) compared to 45% in 2010.** In terms of gender, only one fifth (20%) of researchers in the private sector are female (She Figures 2018). More specifically, women researchers were under-represented in 35 of the 39 countries examined by the report. In the majority of European countries, women researchers are more likely to work in the higher education sector or in government. However, between 2008 and 2015, in the business enterprise sector, the annual growth rate among women researchers was higher than that of men (6.5% for women and 5.6% for men in the EU28). The proportion of women researchers was within the 40% to 60% range in only four countries (North Macedonia, Bosnia and Herzegovina, Croatia and Latvia), while all the other countries failed to reach the 40% threshold.

Figure 6.2-5 presents the intersectoral mobility of researchers currently working for a higher education institution and shows the share of researchers moving to another sector at some point in their research careers. The highest levels of mobility are observed in the eastern and southern Member States, with Poland, Bulgaria, Greece, Czechia and Latvia, while the lowest levels of mobility are seen in the northern and western Member States. Therefore, there is a clear pattern of higher intersectoral mobility in the lower-performing countries that may be due to poorer prospects for the exclusively academic path. Interestingly, Norway, Croatia and Romania are all outliers to this trend. More granular data from the MORE3 study show that later-career-stage researchers are more inclined to take positions in government organisations, postdoctoral researchers tend to move to private industry and, in particular, to small and medium-sized enterprises (SMEs) and start-ups, while established researchers are more likely to move to the not-for-profit sector.

**The EU Framework Programme's Marie Skłodowska-Curie Actions (MSCA) support intersectoral mobility via co-funding of doctoral programmes and the MSCA Research and Innovation Staff Exchange (RISE), which are based on flexible intersectoral (within Europe) and international (with third countries) exchanges of highly skilled R&I staff.**

4 Based on Eurostat, total R&D personnel (researchers) by sectors of performance, occupation and sex (rd\_p\_persocc); cf. indicator 1.6 in the MORE3 Indicator report on researchers.

Figure 6.2-5 Evolution of intersectoral mobility, 2012 and 2016



Science, research and innovation performance of the EU 2020

Source: European Commission (2017), MORE3 study

Note: Data from MORE3 EU HE survey (2016) and MORE2 EU HE survey (2012).

Stat. link: <https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter62/figure-62-5.xlsx>

## 2. In academia-industry co-publications, the EU is catching up with South Korea and the United States while privately financed public research is stagnating at the global level

**Collaboration between enterprises and with public research-performing organisations enables faster knowledge diffusion and valorisation; it is a strong driver of innovation.** Companies can benefit from highly qualified human resources, access – often tacit – knowledge and technology, as well as from using research infrastructures. Higher education institutions can gain

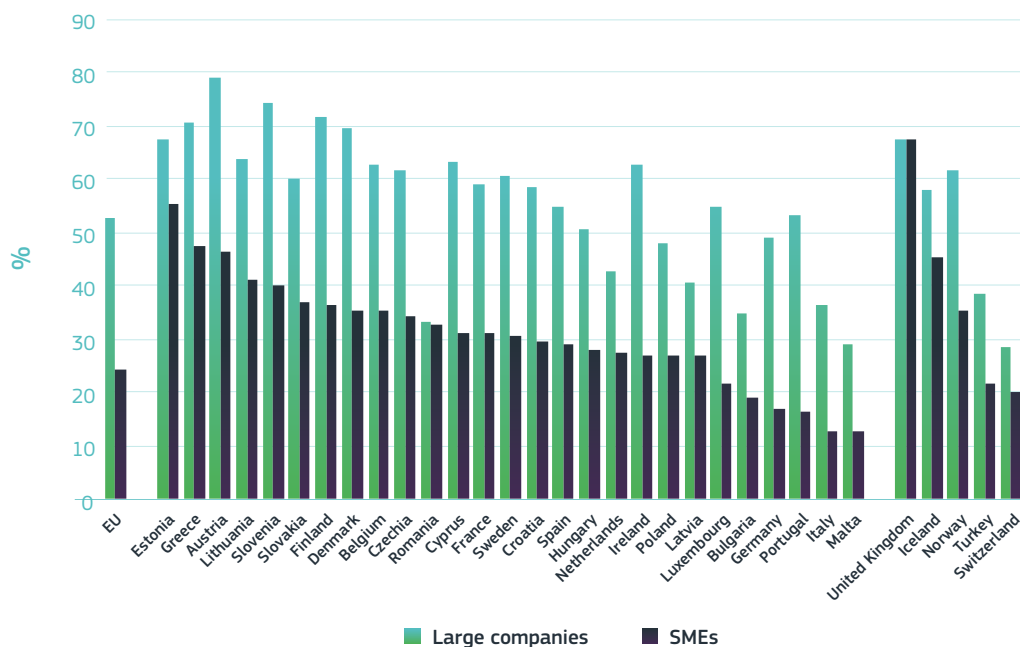
additional revenue streams from consultancy work, licensing or patenting, equip their researchers with new skills and gain insights into the innovation process (Rybnicek and Königsgruber, 2018). In a globalised world, this collaboration is enabled and further stimulated by digitalisation and is becoming increasingly international. This type of intersectoral, interdisciplinary and international collaboration

will be crucial to achieve the UN's Sustainable Development Goals (SDGs)<sup>5</sup>, given the need for the participation of private companies, non-profit organisations, citizens and public administrations to achieve systemic transitions for sustainable growth.

**All EU countries have a higher share of large innovative companies engaging in cooperation than innovative SMEs, although the differences between the Member States are stark for both types of enterprises.** Figure 6.2-6 depicts the degree of business cooperation with other enterprises or organisations divided between

large and small and medium-sized enterprises (SMEs). More than half of the innovative large companies engage in cooperation activities with third parties across the EU, compared to one in three innovative SMEs. All countries are characterised by higher shares of collaboration among large enterprises (with the exception of the UK where the shares are almost equal between large companies and SMEs). The highest participation of SMEs is noted in Estonia, Greece and Austria as well as in the UK and Iceland, while Austria, Slovenia, Finland, Denmark, Ireland and Norway display the highest shares of participation by large companies.

**Figure 6.2-6 Share of innovative enterprises<sup>(1)</sup> involved in any type of cooperation (%), 2016**



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: inn\_cis10\_coop)

Note: <sup>(1)</sup>Product- and/or process- innovative enterprises, regardless of organisational or marketing innovation (including enterprises with abandoned/suspended or ongoing innovation activities).

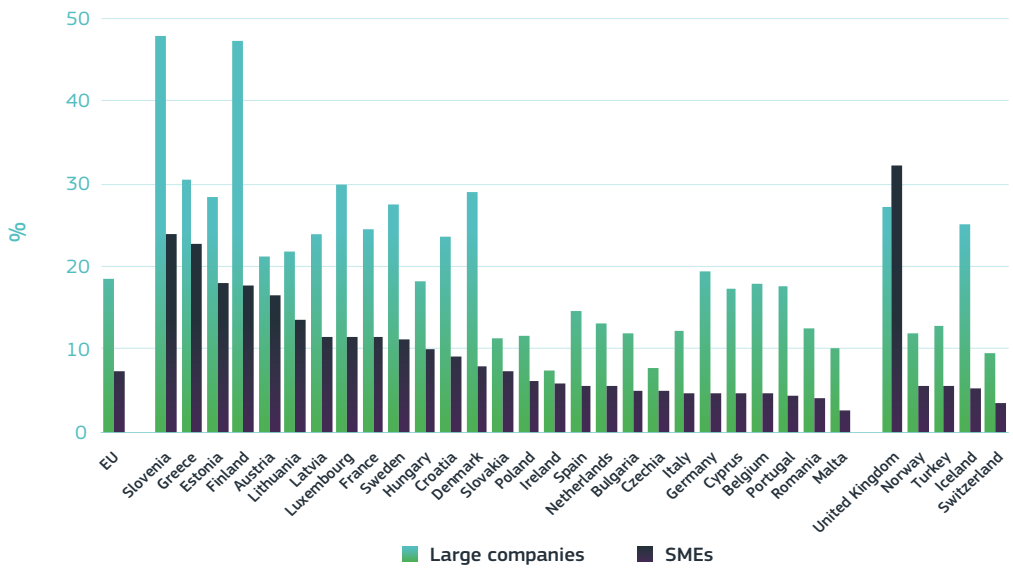
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**When looking at the innovative companies involved in collaboration with competitors or other enterprises in the same economic sector, in all countries except the UK, where the shares are equal, large companies tend to be more collaborative within their economic sectors than SMEs.** While in all countries except the UK, where the shares are almost equal at around 30%, large companies tend to be more collaborative within their sectors than SMEs in cooperation that is very often organised vertically around supply chains. However, the differences between countries are very important with almost 50% of large companies in Slovenia and Finland involved in cooperation, compared to only 7% in Czechia and Ireland. SMEs display a much lower tendency to collaborate in their sector, with two-digit figures only in Baltic countries,

Greece, Slovenia, Austria, Luxembourg, France and Sweden and less than 5% in Czechia, Italy, Germany, Cyprus, Belgium, Portugal, Romania and Malta (Figure 6.2-7).

**In all EU countries, the number of public-private co-publications continues to rise although the EU still lags behind the United States and South Korea. Japan and China occupy the fourth and fifth position, respectively. The EU's good standing has to be considered in the context of important differences between the Member States.** A public-private co-publication involves R&D staff in businesses, or other private-sector organisations, co-authoring a research publication with partners in a public-sector organisation. In addition to inter-firm cooperation, this type of collaboration represents a successful channel for knowledge transfer ('knowledge spillover').

**Figure 6.2-7** Share of innovative enterprises<sup>(1)</sup> cooperating with competitors or other enterprises in the same sector (%), 2016



Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Eurostat (online data code: inn\_cis10\_coop)

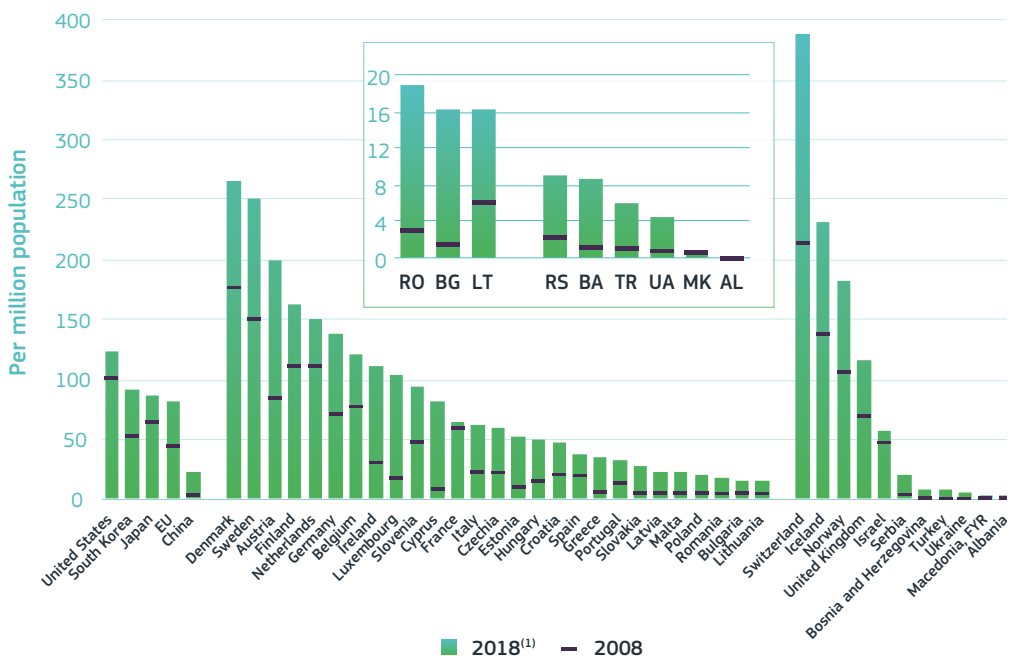
Note: <sup>(1)</sup>Product- and/or process- innovative enterprises, regardless of organisational or marketing innovation (including enterprises with abandoned/suspended or ongoing innovation activities).

Stat. link: <https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter62/figure-62-7.xlsx>

Figure 6.2-8 shows that, while the EU improved its position in terms of growth and overtook Japan between 2008 and 2018 (from 47.1 to 86.4 with Japan rising from 65.7 to 86.1 per million population), the United States and South Korea continued to expand their public-private collaboration (from 105 to 122.7 and from 53.4 to 92.6, respectively). Although China also noted very important growth (from 4 to 22.5), it remains relatively far from other countries. There are major differences within the EU, with Denmark, Sweden and Austria featuring impressive rates of 267.1, 257 and 200.5 per million population. Eastern and southern

European countries are mainly situated at the bottom of the ranking with Poland, Romania, Bulgaria and Lithuania registering the lowest rates at 20.9, 19.1, 16.5 and 16.4, respectively. The associated countries are also divided between high rankings, such as Switzerland, Iceland and Norway (388.5, 232.5 and 182.4, respectively) and very low rankings, such as Albania (0.7), North Macedonia (4.3) and Ukraine (5.8). These stark differences may be due to the quality of the science base, as well as the absorptive capacity of the private sector and its R&I intensity.

**Figure 6.2-8 Public-private co-authored scientific publications per million population, 2008 and 2018**



Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on Science-Metrix using data from the Scopus database, Eurostat and World Bank data

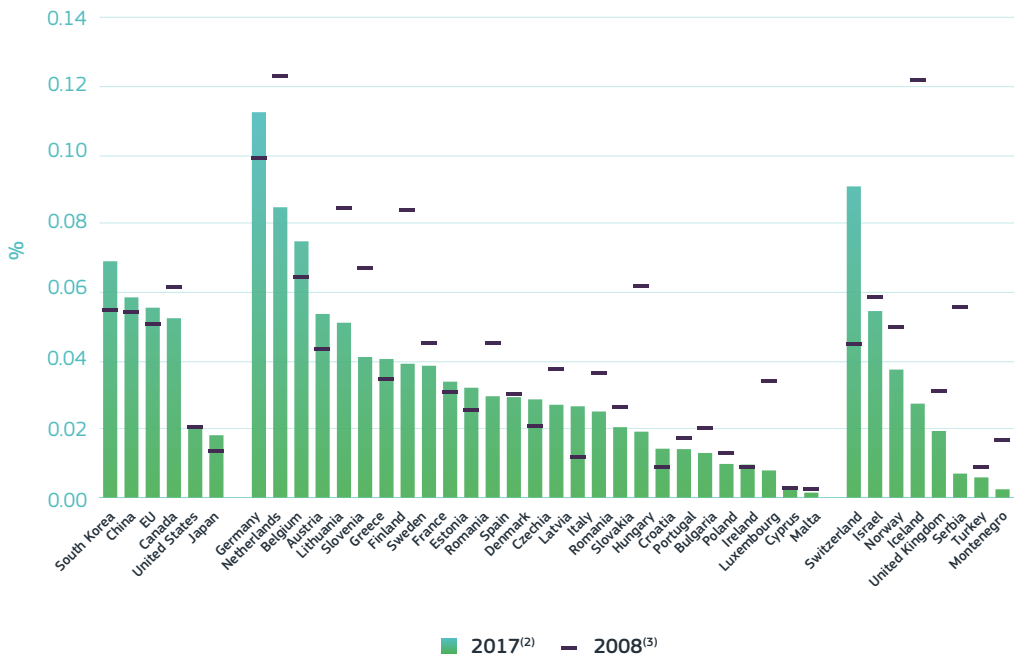
Note: <sup>(1)</sup>US, JP, CN, KR: 2017.

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**In the EU, public expenditure on R&D financed by business enterprises has risen only slightly with important differences between the Member States, associated countries and third countries.** Collaboration between business and academia is often measured by the share of public spending on R&D that is financed by private companies as a percentage of GDP. Figure 6.2-9 shows that while this type of collaboration has risen slightly in the EU over the last 10 years, several countries face a sharp decline in this value. The Netherlands, Finland, Lithuania, Slovenia

and Hungary as well as Iceland and Serbia report significant declines, while Germany and Belgium as well as Switzerland and Bosnia and Herzegovina note relatively important increases. Among third countries, South Korea and China are the best performers, putting the EU average into third place while far outperforming both the United States and Japan. Although the international comparison confirms the EU's good position, the stark differences and decline in some Member States call for enhanced linkages between the public and private sectors.

**Figure 6.2-9 Public expenditure on R&D financed by business enterprise<sup>(1)</sup> as % of GDP, 2008 and 2017**



Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit  
 Data: Eurostat (online data code: rd\_e\_gerdfund), OECD  
 Notes: <sup>(1)</sup>Public expenditure on R&D financed by business enterprise does not include financing from abroad. <sup>(2)</sup>SI, UK, IS, IL: 2016.  
<sup>(3)</sup>DK, LU, NL, AT, SE, NO, RS: 2009; EL, ME: 2011. <sup>(4)</sup>US, JP, CN, CA, BE, FR, NL, RO, SI, IS, RS: breaks in series occur between 2008 and 2017.  
 Stat. link: <https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter62/figure-62-9.xlsx>

### 3. The US and EU are leading in international technological cooperation. In some EU countries, foreign direct investment and foreign business research investment still play an important role in knowledge diffusion

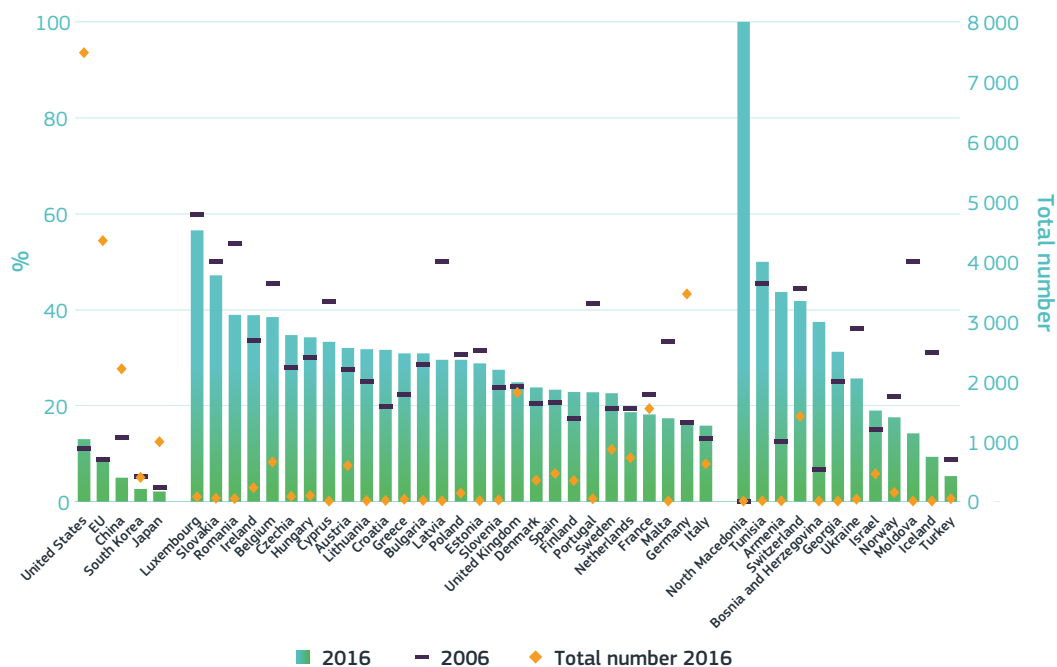
**In some European Member States, as well as globally in catching-up economies, knowledge diffusion and technological transformation are driven by foreign business research investment and foreign direct investment (FDI).**

**The intensity of knowledge flows can be proxied by the share of foreign value added in exports** (share of foreign value added in exports shows how much of a country's value added of inputs were imported in order to produce intermediate or final goods/services to be exported). A high share of added value shows a high amount of knowledge flowing into a given country. It can also be measured by the share of patents with foreign co-inventors in the total number of patents.

**The United States and EU are leading in international technological cooperation, while China and Japan are falling behind, as shown by the share of patents with foreign co-inventors in the total number of patents.** Figure 6.2-10 shows European countries' performance including extra and intra-European collaboration, while the EU performance refers only to collaboration with extra European inventors. As for other indicators of collaboration, large variations are observed between the Member States, with Luxembourg and the eastern European countries taking the lead. The smallest shares

are reported by larger Member States with a strong industry base, such as Germany, Italy and France, as well as Malta which relies heavily on the - less patent-intensive - information and communications technology industry. For countries associated with the Framework Programme, this variation is important, although given the very low absolute values for many of them, the results are difficult to interpret (e.g. only two patents for North Macedonia).

**Figure 6.2-10** Share (%) of PCT<sup>(1)</sup> patents with foreign co-inventor(s) in total number of patents<sup>(2)</sup>, 2006 and 2016 and total number of patents with foreign co-inventor(s) in 2016



Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on OECD (International co-operation in patents) data

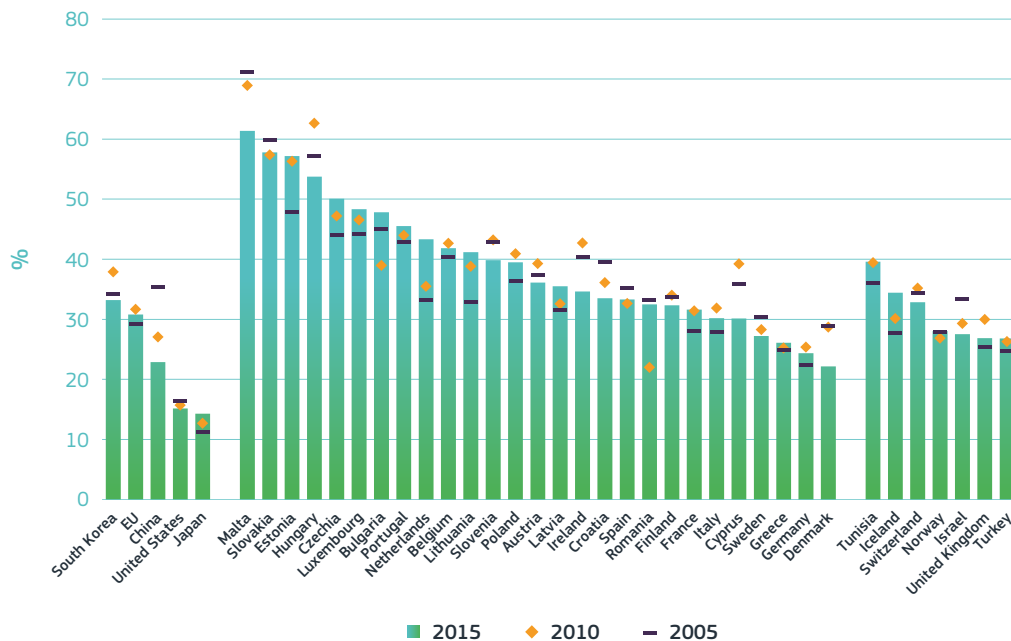
Notes: <sup>(1)</sup>Patent Cooperation Treaty (PCT) patents, at the international phase designating the European Patent Office. <sup>(2)</sup>Full counting method used.

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**The foreign value-added share of gross exports in high-tech and medium-high-tech sectors is still very important in Europe, notably for southern and central eastern European countries. At the global level, it is still significant for South Korea and China, with China having an active policy in place to reduce its needs for foreign-based technology.** In the EU, Slovakia, Estonia, Hungary, Czechia and Bulgaria, together with Malta and Luxembourg, exhibit the highest share of foreign value added at between 61% and 48%. Germany, Denmark, Greece and Sweden exhibit the lowest share (under 30%, which is the EU average) in the EU. For Slovakia, Hungary and Czechia – with its strong manufacturing base – FDI is still a major

source of external R&D financing. With their open economies, both Malta and Luxembourg attract foreign investment in specific tech sectors. At the global level, South Korea and China’s shares are still significant albeit declining (in 2015, 33% for South Korea and 23% for China, a fall of 35% over 10 years). The EU shares remain high at 31%, while the United States and Japan rank lower (15% and 14%, respectively). The gradual decrease for China will most probably continue given the ‘Made in China 2025 strategy’ (2015) which seeks to steadily reduce the need for foreign-based technology by fostering domestic competitiveness and to further facilitate the access of Chinese companies to international markets (JRC 2019).

**Figure 6.2-11 Foreign value added share (%) of gross exports in high-tech and medium-high-tech sectors, 2005, 2010 and 2015**



Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on OECD (Trade in Value Added - TiVA) data

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## 4. The EU continues to lead on open science policy and international scientific collaboration with its Framework Programme playing an important role

### Advances in technology make science both an increasingly open and global enterprise.

Technological advances, including digital infrastructures, strong open science bottom-up activism as well as funders and institutional policies, drive these changes in science practices.

### The progress both in data production and its availability through open data standards

is speeding up the research process, addressing the reproducibility crisis (e.g. Ioannidis and Khoury, 2011) and increasing the efficiency of public investment in research.

Sharing publicly funded scientific results openly democratizes the access to science across countries and widens it to companies and citizens. Open access<sup>6</sup> and transdisciplinary data reuse and interoperability (FAIR principles<sup>7</sup>)

<sup>6</sup> Immediate, online, free availability of research outputs without restrictions on use commonly imposed by publisher copyright agreements – OpenAIRE definition.

<sup>7</sup> The FAIR data principles define a minimal set of community-agreed 'aspirational' guidelines for the publication of digital resources such as datasets, code, workflows, and research objects, to achieve a state of 'FAIRness' (Wilkinson et al., 2018).

are vital for addressing the interconnected and pressing socio-economic and environmental challenges we are currently facing (UN SDGs). While open access policies are already mature within existing European, national and institutional policies, advances in data sharing face many obstacles, given the lack of data-sharing valorisation (journal impact factors and citations; Scheliga and Friesike, 2014). Changing the reward and incentive system for researchers is key to ensuring higher take-up and demands the involvement of major stakeholders (higher education institutions, funding agencies, ministries of science and higher education). The Commission has already made provisions for cost eligibility for open science activities in its next Framework Programme.

**Several EU Member States and associated countries are ahead of the United States, leading the transition to the open access of research outputs, while China and South Korea are lagging behind.** Research stakeholders are pursuing a global process of facilitating the transition to open science, which is most visible in mature policies of open data and open access to scientific publications. As shown in Figure 6.2-12, country performances regarding open access to scientific publications made available through online repositories (green access)<sup>8</sup> is very disparate with lower shares in lower-performing countries, while the performance on open access to scientific

publications made available through publishers' websites (gold access)<sup>9</sup> oscillates at around 10% for most countries. The differences in performance in open access through online repositories may be due to differences in the availability of national and university research repositories and the existence of national and institutional policies.

As observed in Figure 6.2-12, Croatia, the Netherlands, Luxembourg, Sweden, Austria, the UK, Norway and Switzerland are ahead of the United States, while China and South Korea are lagging behind.

**The European Commission co-designed and co-implemented an ambitious and holistic open science policy<sup>10</sup>.** It introduced a strong open access and open data mandate in Horizon 2020 and has included potentially stricter requirements in Horizon Europe (research data open by default, mandatory data management plans, mainstreaming of FAIR principles, strengthened requirements on open access) as well as support for citizen involvement in research (citizen science). The European Commission's approach was endorsed by several funders and institutions and inspired international, national and regional policies (e.g. the Australian Research Data Commons<sup>11</sup> or the African Open Science Platform<sup>12</sup>). The Commission also supports the efforts of cOAlition S<sup>13</sup> to accelerate the full transition to open access to scientific

8 Research outputs that are not made open access from the publisher's website but from an open access repository, whether institutional or thematic. This is commonly referred to as green open access.

9 Research outputs are made openly accessible on the journal website by the publisher. This is commonly referred to as gold open access.

10 For example, laid out in the Commission Communication: European Cloud Initiative - Building a competitive data and knowledge economy in Europe: <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016DC0178&from=EN> and Commission Recommendations on access to and preservation of scientific information: <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32018H0790&from=EN>

11 <https://ardc.edu.au/about/>

12 <http://africanopenscience.org.za/>

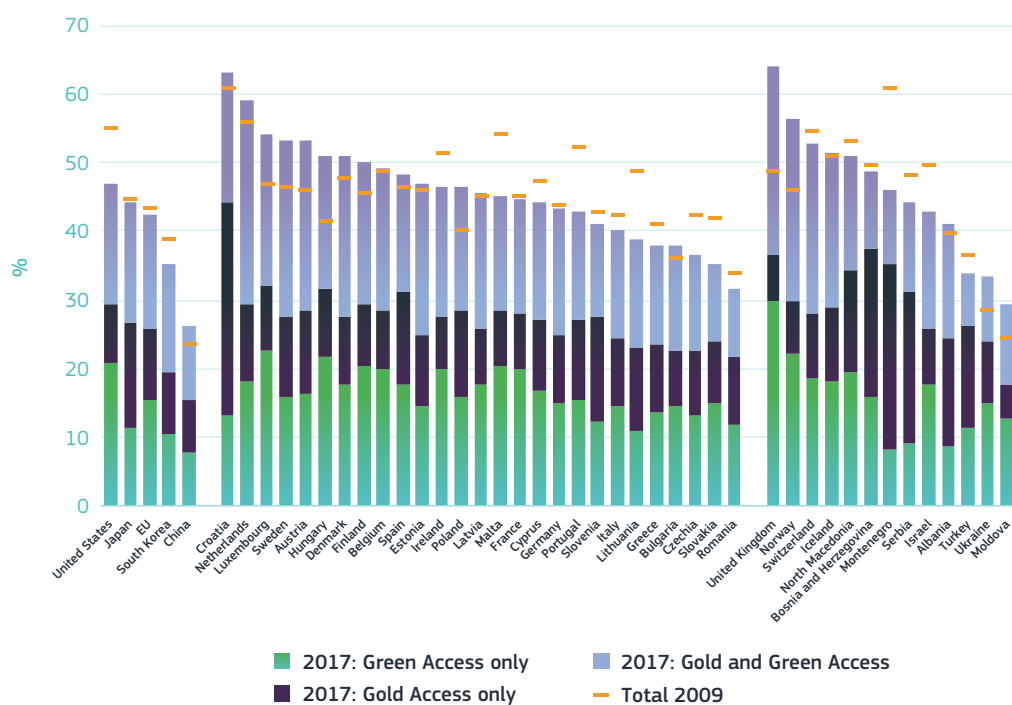
13 <https://www.coalition-s.org/>

publications. Open science principles and practices are an integral part of EU policy, including the new Directive on open data and the reuse of public-sector information<sup>14</sup>, the revised Recommendation on access to and preservation of scientific information<sup>15</sup> and the General Data Protection Regulation<sup>16</sup>. National initiatives in the Netherlands, Finland and Italy show that Member States are taking up these policies and activities. Recent evidence finds that – as a direct result of directional policies by research funders – open science activities

have structuring effects on both scientific outputs and knowledge flows, as well as on institutional research structures and practices, increasing research performance and economic performance (Tennant et al., 2016; Fell, 2019).

**The work on open science principles and incentives is also spreading globally through the work of the G7, OECD and under the auspices of the Research Data Alliance (RDA)<sup>17</sup>.**

**Figure 6.2-12 Open access scientific publications<sup>(1)</sup> with digital object identifier (DOI) as % of total scientific publications with DOI, 2009 and 2017**



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

Note: <sup>(1)</sup>Data produced by Science-Metrix using data from Scopus and 1fndr databases. The full counting method was used.

Stat. link: <https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter62/figure-62-12.xlsx>

14 <https://ec.europa.eu/digital-single-market/en/european-legislation-reuse-public-sector-information>

15 <https://ec.europa.eu/digital-single-market/en/news/recommendation-access-and-preservation-scientific-information>

16 [https://ec.europa.eu/info/law/law-topic/data-protection/data-protection-eu\\_en](https://ec.europa.eu/info/law/law-topic/data-protection/data-protection-eu_en)

17 <https://rd-alliance.org/>

## BOX 6.2-1 The European Open Science Cloud

**Most of the underlying data of scientific work is not published and therefore not accessible to the research community or the public.** If relevant data was findable, accessible and interoperable for scientists, these combinations would lead to (unforeseen) reuse and to faster developments in science. This is the aim of the European Open Science Cloud (EOSC).

**The EOSC will enable data sharing and offer Europe a trusted and open environment for the scientific community, provide seamless access to data and interoperable services addressing the whole research data life cycle.** The development of the EOSC achieves EU policy objectives such as Open Science, FAIR data implementation and the Digital Single Market.

**The EOSC will be a virtual commons** (resources accessible to all researchers) **where science producers and science consumers come together for greater insights, new ideas and more innovation.** By federating research data and services, the EOSC adds value. The EOSC uses information technologies to change the way scientists conduct research, and how collective scientific knowledge is created across disciplines and borders. The EOSC will evolve into a system that is flexible by design and can adapt to

the changing landscape and technological advances.

A minimal viable EOSC environment is planned for the end of 2020, including agreed rules of participation, supporting services for the EOSC federation, an initial set of data services for researchers, a persistent identifier policy, metrics for FAIR data and certified services, and strategic orientations for financing models, the legal set-up and governance of the EOSC after 2020.

The resulting EOSC environment will then be progressively extended and scaled up while building on the following **common values**:

- ▶ Focus on research and innovation needs
- ▶ Community-driven
- ▶ Inclusive and respectful of diversity
- ▶ Accessible to all from large equipment, large computers and ‘big data’ to ‘small data’ and long-tail research
- ▶ Open by default – closed where necessary
- ▶ Hands-on and participatory
- ▶ Transparent and trustworthy.

**Two thirds of researchers in the EU have collaborated or worked in more than one discipline, which is key to addressing the economic, social and environmental transitions required for a more sustainable Europe.** Interdisciplinary collaboration, understood as collaboration between researchers working in different

disciplines, is key to fostering knowledge and technology circulation across Europe. In addition, interdisciplinary research is needed to address the SDGs, enhance the ability to understand the complex challenges the world currently faces (Eagan, Cook and Joeres, 2002) as well as bring diverse perspectives together to find solutions and establish and exploit synergies.

**The MORE3 survey shows that 73.5% of researchers have collaborated with researchers in other fields.** In the EU, 60% of researchers collaborate with other researchers working in other disciplines but within the same institute, and 57% in other universities or research institutes. However, only 31% have collaborated with the non-academic sector. This limited knowledge flow outside of academia is one of the key issues to tackle in order to strengthen the valorisation of knowledge in Europe. More efforts are needed to

embed a ‘valorisation culture’ in publicly funded research. The same study shows that 34% of researchers working in the EU have switched to another (sub-)field of science during their research career. Overall, researchers tend to have a positive view on this type of mobility in spite of the debates on the caveats of interdisciplinarity – e.g. difficulties in publishing articles based on interdisciplinary approaches, limitations over the peer-review process and scientific standards.

**Figure 6.2-13 Share of researchers who have collaborated with or worked in more than one field in their current position**

<i>Of all researchers (n=9,412)</i>				
	<b>EU28 total</b>	<b>Per career stage</b>	<b>Per FOS</b>	<b>Per gender</b>
2016	73.5%	R1: 66.2%	NAT: 74.4%	F: 74.0%
		R2: 73.7%	ENG: 75.5%	M: 73.2%
		R3: 73.2%	MED: 76.2%	
		R4: 77.5%	AGR: 84.7%	
			SOC: 67.7%	
			HUM: 71.6%	

Science, research and innovation performance of the EU 2020

Source: DG Research and Innovation, Chief Economist - R&I Strategy & Foresight Unit based on MORE3 study

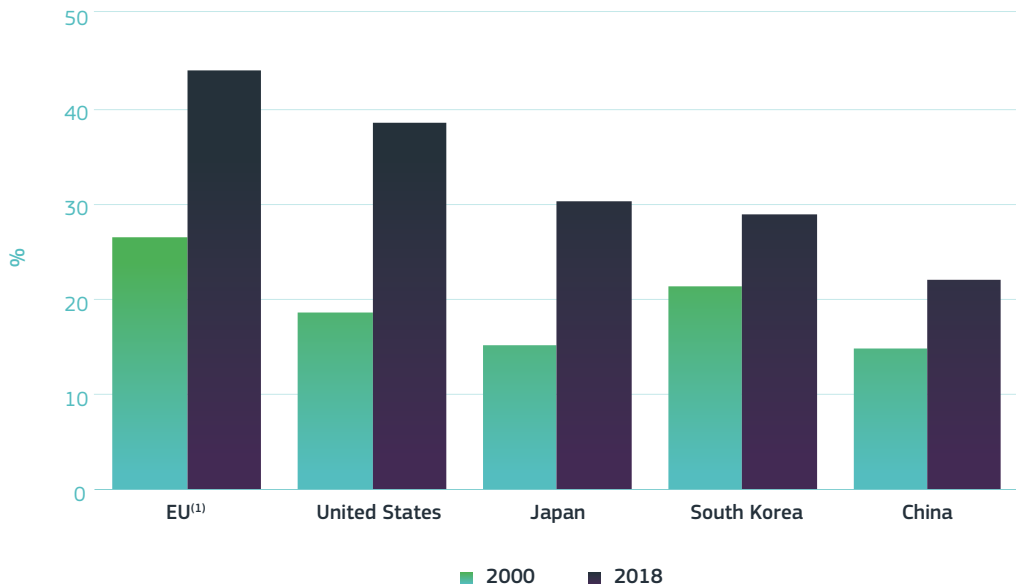
Stat. link: <https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter62/figure-62-13.xlsx>

**The EU has secured its leading position in international scientific collaboration, which has seen sharp increases both in the EU and in the United States and Japan.**

The EU28’s share of international scientific co-publication almost doubled between 2000 and 2018 (from 24.6% to 43.7%, including intra-EU collaborations), with an even more significant rate of growth observed in the United States (from 18.7% to 38.3%) and Japan (from 15% to 30.3%). South Korea and China also increased their shares of international co-publications (from 21.2% to 28.9% and

14.8% to 22%, respectively). This trend leads to improved scientific quality since scientists achieve greater impact from their international collaborations. This is actively supported at the European level through specific Framework Programme funding and initiatives such as Marie-Curie Skłodowska Actions (MSCA). However, granular data on EU Member State collaboration shows that several eastern European countries (Romania, Bulgaria, Poland) still report lower levels of international exposure and collaboration (Figure 6.2-14).

**Figure 6.2-14 International scientific co-publications as % of total scientific publications, 2000 and 2018<sup>(1)</sup>**



Science, research and innovation performance of the EU 2020

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

Data: Science-Metrix based on Scopus database

Note: <sup>(1)</sup>EU average includes intra-EU collaborations.

Stat. link: <https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter62/figure-62-14.xlsx>

**Horizon 2020 demonstrates broad international outreach attracting talent from around the world. Countries with strong R&I performances, such as Switzerland, Norway and Israel, are the most active associated countries in Horizon 2020, while almost one third of the participation from non-associated third countries comes from the United States.** As per Figure 6.2-15, Switzerland is the most active associated country in terms of participation, with 2 808 – i.e. A share of 37% of all associated countries. Norway, Israel and Turkey account for 23%, 17% and 9%, respectively. The associated countries with the lowest participation (less than

1% participation from associated countries) are Tunisia, Moldova, Georgia, Montenegro, Albania, Armenia and the Faroe Islands. Moreover, the networked analysis shows that Switzerland occupies a very central position in the collaboration network amongst participants in Horizon 2020, next to other EU28 countries such as Sweden, Greece and Austria<sup>18</sup>.

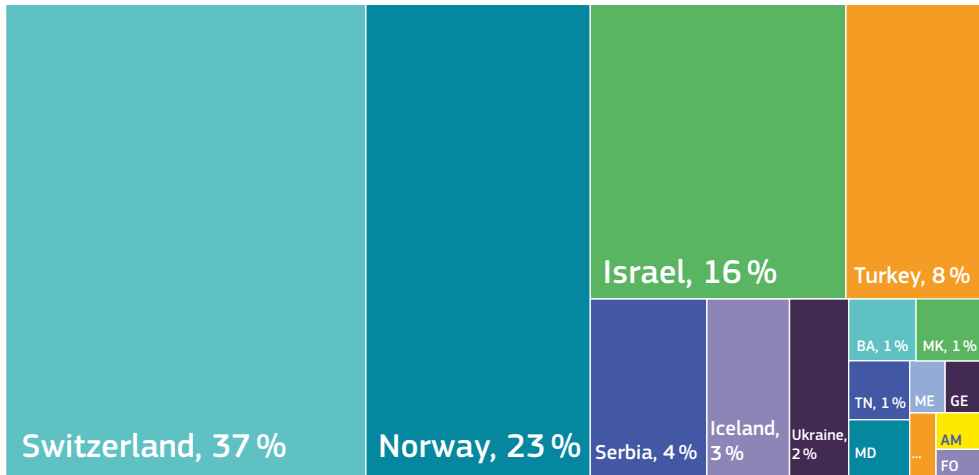
**With applicants from 163 non-associated third countries to date, Horizon 2020 demonstrates a broad international outreach.** Currently, with over 1 100 participations, the US accounts for about 30% of the participation from non-associated third countries (Figure 6.2-16). The United States

18 [https://ec.europa.eu/info/sites/info/files/research\\_and\\_innovation/knowledge\\_publications\\_tools\\_and\\_data/documents/h2020\\_monitoring\\_flash\\_022019.pdf](https://ec.europa.eu/info/sites/info/files/research_and_innovation/knowledge_publications_tools_and_data/documents/h2020_monitoring_flash_022019.pdf)

is followed by China (9% of participations from non-associated third countries), Canada (6%), Australia (5%), South Africa (4%) and Brazil (4%). Overall, the top-20 participant

non-associated third countries gather 81% of these participations, with a lower level of participation from many developing economies.

**Figure 6.2-15** Share of participations from associated countries in Horizon 2020 (% of all associated countries' participation)

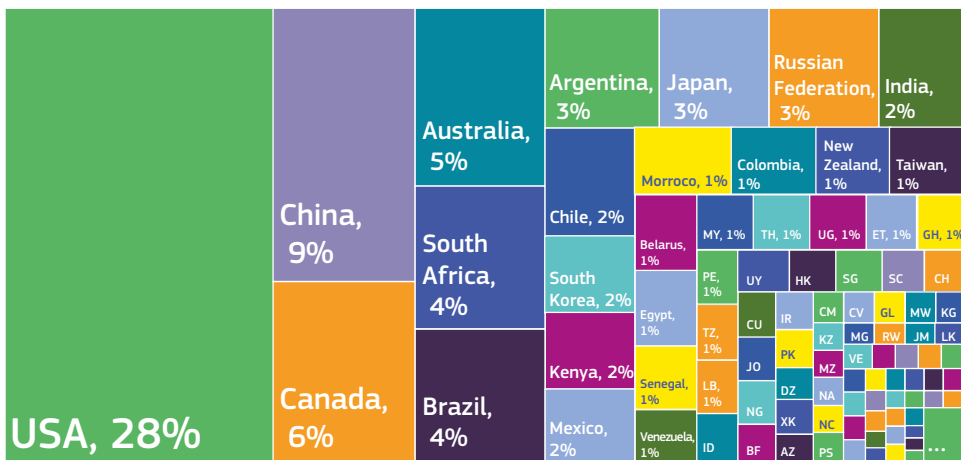


Science, research and innovation performance of the EU 2020

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

Stat. link: <https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter62/figure-62-15.xlsx>

**Figure 6.2-16** Share of participations from non-associated third countries in Horizon 2020



Science, research and innovation performance of the EU 2020

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

Note: Cut - off date - January 2020.

Stat. link: <https://ec.europa.eu/info/sites/info/files/srip/2020/parti/chapter62/figure-62-16.xlsx>

**Most of the collaborations are with countries with advanced R&I capabilities, in particular through researcher mobility schemes such as MSCA but also through specific projects and multilateral initiatives to support sustainable development and address global societal challenges.** Countries with strong R&I performances, such as Switzerland, Norway and Israel, are the most active associated countries, while almost one third of participations from non-associated third countries come from the United States (partly due to its significant participation in MSCA schemes).

**Interestingly, an analysis of the EU's R&I Framework Programme participation patterns shows specific preferences for cross-country collaborations.** Geographical and cultural proximities among participants seem to play an important role in shaping the structure of collaboration networks, at least in the case of the EU Framework Programme (Balland et al., 2019).

## 5. Conclusions

**Although researchers' mobility remains key to knowledge diffusion, stark disparities remain between countries in international and intersectoral mobility patterns in the EU.** In general, countries with a higher R&I performance tend to have higher inflows and outflows of researchers and the size of the R&I system also plays an important role. Those divergences call for a better understanding of drivers of and barriers to international and intersectoral mobility as well as the implementation of policies to foster brain circulation.

**The EU is catching up with South Korea and the United States in terms of public-private co-publications.** However, private financing of public research remains stagnated at the global level, with large disparities between EU countries. Collaboration patterns show that a few large innovative companies are making the most of international and intersectoral cooperation. In order to raise the competitiveness of European SMEs, the capacity of small firms must be strengthened to enable them to engage in R&I collaborations. As the geographical proximity of academia is still paramount for industry's innovative activities – in spite of the importance of digitalisation policies – the interaction between industry and academia must continue to be facilitated and strengthened.

**The United States and the EU are leading in international technological cooperation, while China and Japan have taken a step back.** In some EU countries, as well as in globally catching-up economies, knowledge diffusion and technological transformation continues to be stimulated through foreign direct investment and foreign business research investment. International technological cooperation data points to an active policy in China which is trying to reduce its need for foreign-based technology through domestic competitiveness and to further facilitate Chinese companies' access to international markets. This places international technological cooperation policies in a wider perspective of changing global approaches to trade and technological sovereignty.

**The EU continues to lead in open science policy.** Among the global trend for intensification of international scientific collaboration, the EU has secured its leading position with its Framework Programme playing an important role by involving participants from third countries. While the EU's open access policy is well advanced, there is a need to step up efforts to implement Europe's ambitious open and FAIR data policy.

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