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A New European Innovation Agenda

{COM(2022) 332 final}

1 CONTEXT

Europe is facing global long-term challenges such as climate change, loss of biodiversity, ageing population, declining productivity growth and increasing inequalities. Unless these challenges are effectively addressed, they will affect the wellbeing of Europe's population and reduce our choices for the future. Innovation is vital to tackle these challenges. It results from complex relationships among actors in the innovation system, which includes enterprises, universities and research performing organisations, such as government institutions and research and technology organisations (RTOs). Europe needs innovative solutions in areas like health, digital technologies, space & defence, industrial transformation, resilient societies, natural resources, energy, mobility, environment, circularity, food, low-carbon economy and security. For example, the success of our ambition to reach the net-zero emission objective by 2050 crucially hinges on development and widespread use of new technologies. Innovative solutions – including as regards product, organisational, process or social innovation – also enhance both economic and environmental efficiency while developing new sustainable, circular and inclusive ways to satisfy human needs and wellbeing. As a result, innovation is at the core of the sustainable development and competitiveness of our economy and supports the creation of new and better jobs and the development of knowledge-intensive activities. Overall, innovation is key in a global context that can accelerate the transition to sustainable development, while improving our well-being, reducing inequalities and ensuring longer-term prosperity.

1.1 Innovation in EU policy

The EU has recognised the importance of new knowledge and breakthrough innovation for the green and digital transformation that is underway. Innovation policy has been a subject of Commission initiatives in its own right, but has also been addressed in the frame of the work on the European Research Area (ERA), which aims to create a single EU market for research, innovation and technology. Moreover, due to the cross-cutting role of innovation, it is also addressed in a number of sectoral and other cross-cutting policies, including the European Green Deal, digital, economic and education policy and global issues.

1.1.1 Innovation policy: a historical perspective

While the roots of the EU's engagement with **innovation policy** go back to the 1950s and 1960s[1], the policy field took centre stage in the context of the Europe 2020 Strategy.[2] Launched in 2010, in the midst of the financial and economic crisis, the strategy aimed at setting Europe back on track for "smart, sustainable, inclusive growth". One of the seven flagship initiatives announced as part of the Europe 2020 Strategy was the *Innovation Union*.[3] This was the first time the European Commission had presented a comprehensive innovation strategy. It aimed to improve conditions and access to finance for research and innovation and to ensure that innovative ideas are turned into products and services that create growth and jobs.[4] Progress tracked by the annual State of the Innovation Union Reports showed that by 2015, the Innovation Union had succeeded in introducing a more strategic and broad approach

[1] Ulnicane, I. (2016), 'Research and innovation as sources of renewed growth? EU policy responses to the crisis', *Journal of European Integration*, 38(3), pp. 327-341.
[2] An early foray in innovation policy was the European Commission's Green paper on Innovation in 1995.
[3] SEC(2010) 1161, Europe 2020 flagship initiative Innovation Union.
[4] MEMO/10/473, Turning Europe into a true Innovation Union.

to innovation, building momentum and both mobilising stakeholders and mainstreaming innovation on different policy levels (European, national, regional).[5]

In 2014, this approach was complemented by the Communication on *research and innovation as sources of renewed growth*.[6] Noting that the EU had increased its funding for research and innovation in its budget 2014-2020, but that several Member States had cut funding due to their fiscal consolidation efforts (following the global financial and economic crisis), the Communication aimed at enhancing research and innovation as drivers for renewed growth by "raising the quality of investments" and strengthening the overall innovation ecosystem. Building on this, the Commission put forward *a renewed European agenda for research and innovation* in 2018[7] setting out concrete actions: it aimed at ensuring essential public investment and stimulating private investment, making regulatory frameworks fit for innovation, making Europe a frontrunner in market-creating innovation, setting EU-wide research and innovation missions, supporting rapid dissemination of innovation and uptake throughout the Union, and investing in skills at all levels and empowering European universities to become more entrepreneurial and interdisciplinary.

The work of advancing the **European Research Area (ERA)** creating a single EU market for research, innovation, and technology also made important contributions to strengthening innovation in Europe. First launched in 2000, ERA was at the heart of the Europe 2020 Strategy and the Innovation Union flagship. In 2012, the Commission stressed the need to *reinforce ERA* notably by focusing on the role of knowledge for innovation. It put forward the objective of reducing brain drain, especially from weaker regions, and reducing the wide regional variation in research and innovation performance, with the goal of achieving excellence across the whole Union through **smart specialisation**.[8] This approach links innovation policy with regional policy. It aims for regions to develop smart specialisation strategies identifying the areas that offer regions the best chance of strengthening their competitiveness. It promotes more effective use of public funds while stimulating private investment to reach a critical mass of research and development activities as well as innovation resources.[9] In 2020 and twenty years after ERA was first launched, the Commission's Communication *A new ERA for Research and Innovation* took stock of achievements and persisting shortcomings as well as identified new challenges for research and innovation policy such as the green and digital transition (twin transition) and recovery from the COVID-19 pandemic.[10] To meet these challenges, the Commission suggested to prioritise investments and reforms (including reaffirming the target of 3% of EU GDP to be invested in R&D) and to increase competitiveness as well as the speed and depth of the recovery; to aim at making research and innovation systems across the EU excellent and stronger; to improve how research and innovation results are translated into the economy; and by deepening ERA by moving from a policy coordination approach towards deeper integration between national policies. In November 2021, the Council adopted conclusions on ERA governance structure and the 'Pact for research and innovation in Europe', thereby completing a deep reform of ERA.[11]

As this short overview has shown, the toolkit of EU innovation policy has expanded over the years and the institutional landscape has changed with it. With its *Innovative Europe* pillar,

[5] European Commission (2015), *State of the Innovation Union 2015*.
[6] COM(2014) 339, Research and innovation as sources of renewed growth.
[7] COM(2018) 306, A renewed European Agenda for Research and Innovation.
[8] COM(2012) 392, A Reinforced European Research Area Partnership for Excellence and Growth.
[9] COM(2010) 533, Regional Policy contributing to smart growth in Europe 2020.
[10] COM(2020) 628, A new ERA for Research and Innovation.
[11] COUNCIL 13701/21, Council recommendations on a Pact for Research and Innovation in Europe; COUNCIL 14308/21, Council conclusion on the future governance of the European Research Area (ERA).

Horizon Europe has given rise to both existing and new tools to support start-ups, scale-ups[12] and Small and Medium-Sized Enterprises (SMEs). The **European Innovation Council** (EIC), newly established in 2021 and with a budget of €10.1 billion, aims to support innovation throughout the whole innovation lifecycle, from the early stages of research to proof of concept, technology transfer, and the financing and scaling up of start-ups and SMEs. The **European Institute of Innovation and Technology** (EIT) took on additional tasks, building on its well-established and robust pan-European ecosystem, by establishing new Knowledge and Innovation Communities (KICs) such as in the area of culture and the creative sector, putting more emphasis on addressing regional imbalances, and looking at increasing the entrepreneurial and innovation capacity of higher education institutions. Via the **European Innovation Ecosystems** initiative of Horizon Europe, the EU also aims to create more connected and efficient innovation ecosystems to support the scaling-up of companies, encourage innovation[13] and stimulate cooperation among national, regional and local innovation actors

1.1.2 Innovation and EU policies

Next to innovation policy in its own right and the work on the ERA, innovation is also a key element in many policy areas. Recent noteworthy examples include:

- **European Green Deal:** the need for boosting investment and innovation is widely recognised in order to achieve the objectives of the European Green Deal, which is the overarching EU policy driving the green and digital transition. To facilitate new technologies, sustainable and circular solutions and disruptive innovation, the Commission will use the full range of instruments under the Horizon Europe programme as well as four 'Green Deal Mission'.[14] Furthermore, the Fit for 55 package foresees using revenues and regulations to mitigate the impacts of the green transition, while boosting innovation through the new Social Climate Fund and enhanced Modernisation and Innovation Funds.[15] Moreover, the Zero Pollution Action Plan, the Circular Economy Action Plan and the Biodiversity Strategy set out the importance for innovation to achieve their ambitious objectives and the proposals prepared in the context of these policies aim at boosting innovation.
- **Europe's Digital Decade:** in 2020, the Commission presented its approach to the digital transformation[16] and, as follow-up, in 2021 it set common digital targets for Europe, proposing a governance mechanism and new instrument to create multi-country projects to achieve them by 2030.[17] Moreover, it also addressed the role of key digital technologies, including cutting-edge and disruptive ones, such as Artificial Intelligence (AI).[18] The Commission also highlighted the role of the Recovery and Resilience Facility (RRF), Digital Europe Programme and Connecting Europe Facility Digital Programme for the digital transition and for financing investments in innovation and deployment of innovative digital solutions, putting forward concrete

[12] See section 2.4.1 for definitions of start-ups and scale-ups.
[13] The key importance of innovation has been well illustrated during the Covid-19 crisis. The economic performance of innovative firms in the EU has been considerably less affected by the pandemic than non-innovative companies. See Di Minin, A., De Massis, A., Moncada Paterno` Castello, P., Marques Santos, A. and Haegeman, K. (2021), How innovative EU firms faced the COVID-19 downturn, European Commission, JRC126964.
[14] COM(2019) 640, The European Green Deal.
[15] COM(2021) 550, 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality.
[16] COM(2020) 67, Shaping Europe's digital future.
[17] COM(2021) 118, 2030 Digital Compass: the European way for the Digital Decade.
[18] COM(2018) 795, Coordinated Plan on Artificial Intelligence; COM(2021) 205, Fostering a European approach to Artificial Intelligence.

proposals, including making use of European Digital Innovation Hubs (EDIHs) to support SMEs in their innovation activities.

- **Economic and industrial policy:** in light of the effects of the COVID-19 pandemic, the Commission published an update of its industrial strategy one year after its initial publication in 2020.[19] Reiterating the "fundamentals of industry – innovation, competition and a strong and well-functioning single market," it highlighted the role of SMEs as important vehicles of innovation, the effects of regulation and competition rules on innovation, and the tool of innovation procurement. Moreover, it identified inter alia an innovation toolkit – not only higher R&D investments – but also the pooling of public and private resources via Important Projects of Common European Interest (IPCEIs) in areas where market actors alone cannot deliver breakthrough innovation, the increasing use of innovation procurement, or the use of EDIHs. The EU has recognized the special role of SMEs, start-ups and scale-ups as particularly prone for innovative business models and new technologies.[20] Key actions in support of SMEs include increasing the number of Digital Innovation Hubs, engaging with Member States to share and adapt best practices to accelerate growth of high-tech SMEs and start-ups, and establishing an SME IPO fund supporting SMEs through and beyond the listing process.[21] In its landmark paper, the ESIR Expert Group[22] reflects on the future of industrial policy in Europe by highlighting research and innovation as drivers for a transition to a sustainable, human-centric and resilient European industry, moving the focus from shareholder to stakeholder value, with benefits for all concerned.[23]
- **Education:** the EU has recognised that education and innovation interact in many ways. In response, policy documents have focused on the importance of education, training, lifelong learning and digital skills for economic growth and innovation, the positive role innovation can play for education, the modernisation of higher education, and the way that innovation and technological progress reshape society, the labour market and the future of work.[24]
- **Global affairs:** seeing itself as a global leader, the EU presented its *Global Approach to Research and Innovation* in 2021.[25] Noting that global competition was increasing, with other major countries spending more on science than the EU, and geopolitical tensions rising, it pointed to the fact that the EU's prosperity and economic competitiveness are depending on its ability to autonomously source and provide its citizens with crucial technologies and services that are safe and secure, including in space and defence sectors. After Russia's unjustified and unprovoked aggression

[19] COM(2021) 350, Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery.
[20] COM(2016) 733, Europe's next leaders: the Start-up and Scale-up Initiative.
[21] COM(2020) 103, An SME Strategy for a sustainable and digital Europe.
[22] https://ec.europa.eu/info/research-and-innovation/strategy/support-policy-making/shaping-eu-research-and-innovation-policy/esir_en
[23] ESIR (2022), Towards a sustainable, human-centric and resilient European industry. More on https://ec.europa.eu/info/publications/industry-50-transformative-vision-europe_en
[24] COM(2020) 624, Digital education action plan 2021-2027: Resetting education and training for the digital age; COM(2020) 625, Communication on achieving the European Education Area by 2025; COM(2020) 274, European Skills Agenda for sustainable competitiveness, social fairness and resilience; COM(2022) 16 final, A European strategy for universities.
[25] COM(2021) 252 final, Global Approach to Research and Innovation: Europe's strategy for international cooperation in a changing world.

against Ukraine[26], but in a similar vein, the EU in its *Strategic Compass for Security and Defence*[27] pointed to the need to react to the way that emerging and disruptive technologies are re-shaping military affairs and defence markets. It emphasized the need to "stimulate investments and innovation to jointly develop the necessary capabilities and technologies" by drawing on larger research and innovation efforts, but also by establishing a Defence Innovation Hub within the European Defence Agency (EDA) or by developing an EU Defence Innovation Scheme to accelerate security and defence innovation. The Strategic Compass also highlighted the additional efforts needed in reducing strategic dependencies and enhancing Europe's technological sovereignty.

1.1.3 Towards a coherent and joined-up approach

As the above overview has shown, innovation policy is a crucial policy area with significant EU initiatives and investments. This is complemented by the work on ERA aiming to build a true European single market for research and innovation. Innovation is also crucial to achieving other EU policy priorities, first and foremost the green and digital transition, but also supporting other sectoral Commission initiatives. While these often draw on Horizon Europe, they also propose their own instruments and investments, thereby contributing to the larger EU innovation policy in their own right. This raises, however, questions with regard to policy coherence and synergies: one goal of the new *European Innovation Agenda* is thus to bring together the various policies, investments and instruments in a coherent and joined-up approach in order to drive systemic change and deliver real impacts across the whole Union. To provide further evidence for this, the next section will take stock of the EU's innovation performance in comparison with other major global innovators, across Member States as well as in terms of key outputs and economic results.

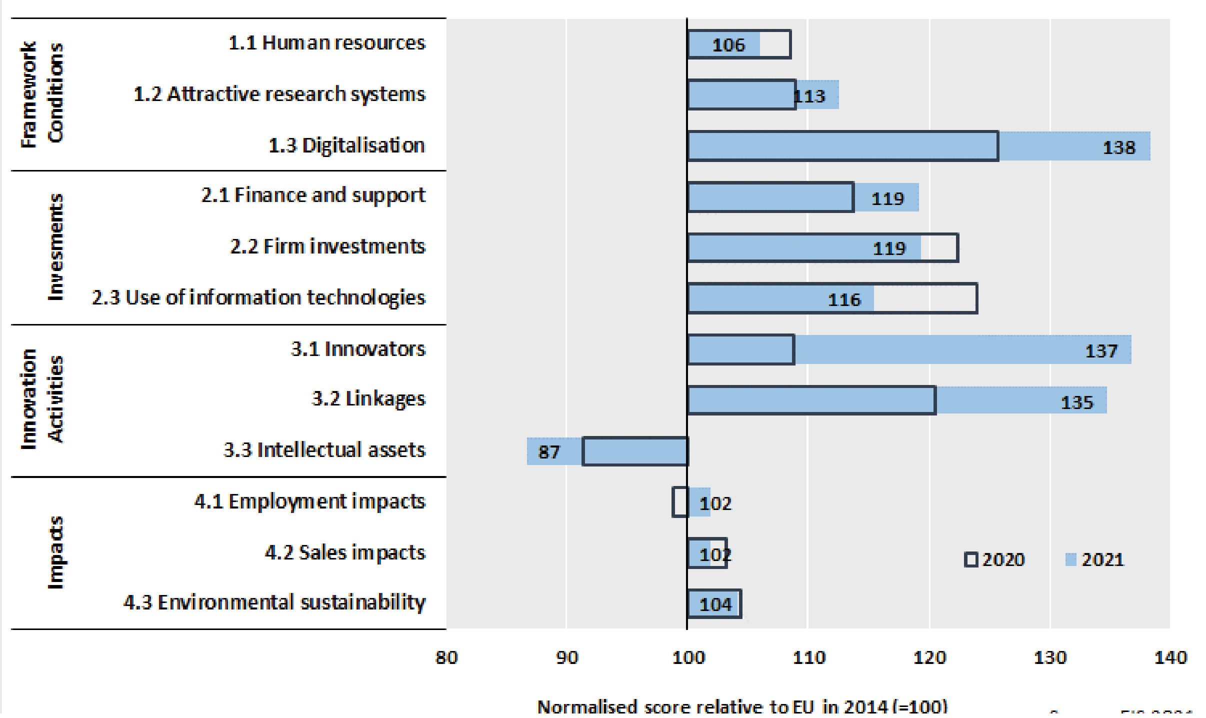
1.2 EU innovation performance

1.2.1 European innovation scoreboard

EU's innovation performance has been increasing over recent years. The latest edition of the European Innovation Scoreboard shows that this performance has increased by 12.5 percentage points since 2014, particularly due to strong performance increases in broadband penetration, venture capital (VC) investments, and international scientific co-publications. In terms of EU performance change in 2021 relative to 2014, the EU performs the best in the dimension of digitalisation with a performance of 38% above the EU average in 2014, followed by the dimension of innovations (+37%) and linkages (+35%). These dimensions comprise indicators such as broadband penetration, share of SMEs product and business process innovations and share of innovative SMEs collaborating with others. In comparison with 2020, the EU improved the most in the innovators dimension from a score of less than 110 to 137, due to recent positive trends related to shares of innovative SMEs. In individual indicators, the EU experienced the largest performance improvement in venture capital investments, which increased by 68% compared to the 2014 average.

[26] Channels of impact of the Russian invasion of Ukraine on EU R&I are identified in Ravet, J., Di Girolamo, V., Mitra, A., Peiffer-Smadja, O., Canton, E., Hobza, A. (2022), *EU research and innovation and the invasion of Ukraine : main channels of impact*, EU Publications Office.
[27] Council 7371/22, A Strategic Compass for Security and Defence - For a European Union that protects its citizens, values and interests and contributes to international peace and security.

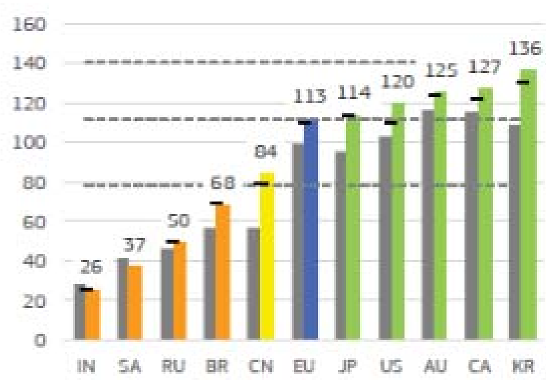
Figure 1. European Innovation Scoreboard – change in 2020 and 2021 compared to 2014



Source: European Innovation Scoreboard 2021.

However, in global terms, the EU continues to lag behind a number of key innovators such as Japan, the United States and South Korea, mainly due to a poorer performance as measured by patent applications and business expenditure in R&D. Between 2014 and 2021, the EU has improved its relative position compared to six of other global players: the performance gap with Australia and Canada has become smaller and the performance lead over Brazil, India, Russia and South Africa has increased. The EU has seen a worsening of its relative position towards four of its global competitors: the performance gap with Japan, South Korea and the United States has increased. The EU is still ahead of China but its performance lead has become smaller.

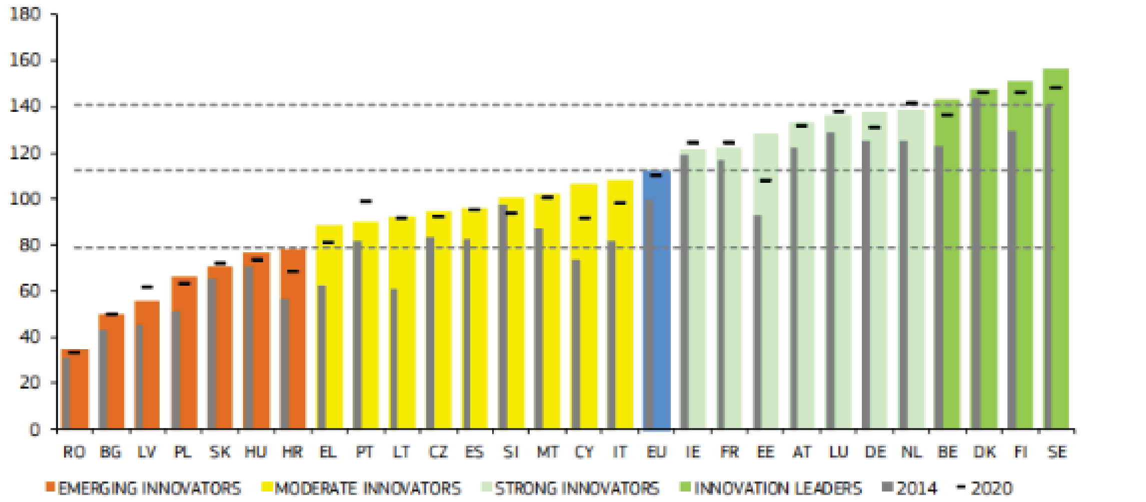
Figure 2. European Innovation Scoreboard – Global Performance



Source: European Innovation Scoreboard 2021. Note: coloured columns show performance in 2021 relative to that of the EU in 2014. The horizontal hyphens show performance in 2020 relative to that of the EU in 2014. Grey columns show performance in 2014 relative to that of the EU in 2014. For all years, the same measurement methodology has been used. The dashed lines show the threshold values between the performance groups, where the threshold values of 70%, 100% and 125% have been adjusted upward to reflect the performance increase of the EU between 2014 and 2021.

The distribution of EU countries across the ranking indicates an innovation gap between Northwest and Southeast Member States (see also Section 2.3 on ecosystems). Sweden is the EU most innovative country, followed by Finland, Denmark and Belgium ('innovation leaders'). Romania, Bulgaria, Latvia, Poland, Slovakia, Hungary and Croatia show a weaker innovation performance ('emerging innovators').

Figure 3. European Innovation Scoreboard 2021



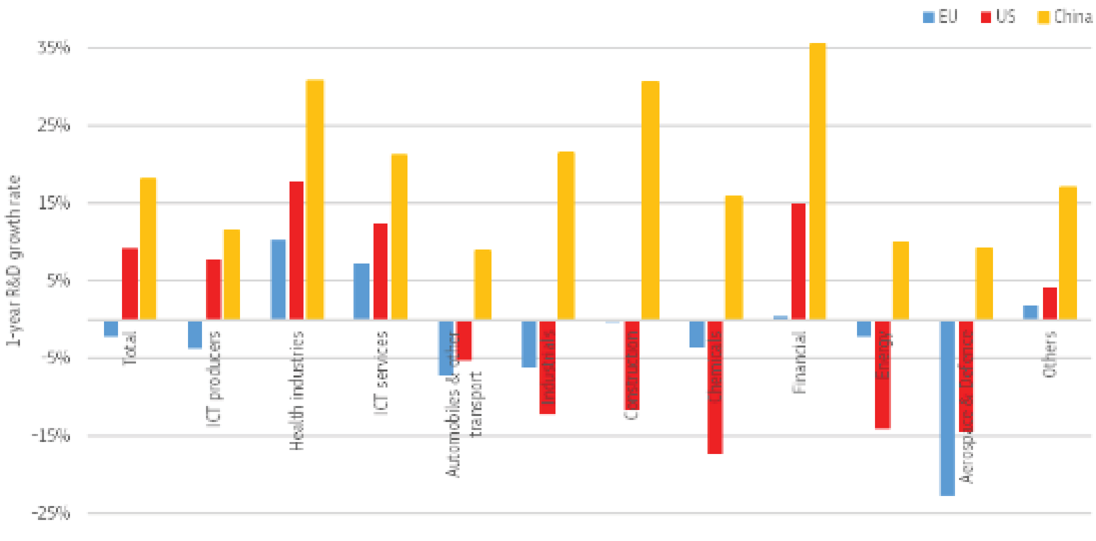
Source: European Innovation Scoreboard 2021. Note: coloured columns show countries' performance in 2021, using the most recent data for 32 indicators, relative to that of the EU in 2014. The horizontal hyphens show performance in 2020 using the next most recent data, relative to that of the EU in 2014. Grey columns show countries' performance in 2014 relative to that of the EU 2014. For all years, the same measurement methodology has been used. The dashed lines show the threshold values between the performance groups, where the threshold values of 70%, 100% and 125% have been adjusted upward to reflect the performance increase of the EU between 2014 and 2021.

1.2.2 Industrial R&D and the global tech race

In the COVID-19 crisis context, the latest R&D figures from the Industrial R&D Scoreboard[28] show the resilience of industrial R&D investments as key for recovery and their potential for industrial transformation towards the green and digital economy. However, the Scoreboard also shows that the crisis further shaped the global tech-race in favour of US and China, for which the R&D values have grown, while the EU's value has not. This is due to increased demand for ICT and health solutions, where these competitors have gained strength in the past decade, together with pressure on the EU Automotive stronghold via mobility restrictions and the need for a profound transition due to the Green policy agenda (Figure 4). Global R&D growth was driven by the ICT services sector (15.5%), followed by the health and ICT producers sectors (12.8% and 5.7% respectively). Most other sectors showed a decrease in R&D investment, particularly those hit hard by the crisis, i.e. aerospace & defence (-17.0%) and automotive (-4.3%). The chemicals sector reduced R&D by 3.4%, continuing the negative trend observed in the past few years.

[28] The Industrial R&D Investment Scoreboard monitors private R&I competitiveness based on timely statistics from companies' latest published accounts. It comprises key indicators on the 2500 parent companies and more than 800 thousand subsidiaries. These companies, based in 39 countries, each invested at least €36.5 million in R&D for a total of €908.9 billion. The 2021 Scoreboard total R&D is equivalent to approximately 90% of the world's business-funded R&D. See https://iri.jrc.ec.europa.eu/scoreboard/2021-eu-industrial-rd-investment-scoreboard.

Figure 4. R&D investment growth 2019-2020 by sector and selected region/country.



Source: The 2021 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD. Note: R&D 2020 growth rates have been computed for 399 EU, 776 US and 597 Chinese companies for which data are available for both years 2019 and 2020. Sectors ordered from left to right in terms of overall R&D investment in 2020.

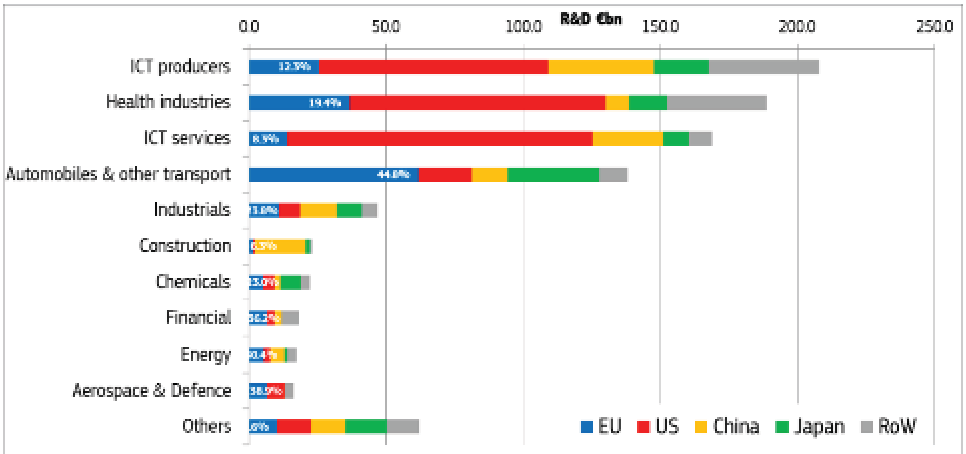
Comparing the 2016 and the 2021 Scoreboard values, the most important development in the global R&D ranking is the increased presence of high-tech companies. There are 779 US-based, 401 EU-based and 579 China-based Scoreboard firms. While the EU maintains a higher share of R&D compared to China (€184.1bn vs €141bn), the number of China-based firms increased very significantly through the addition of 270 companies to the 327 included in the 2016 Scoreboard. Overall decreases in the number of firms from the EU, the US and Japan are of similar magnitude, but their mix is least concerning for the US, which managed to increase its presence in two of the key global sectors, i.e. health industries and ICT services, thanks to its sustained investment in software, internet and computer services technologies as well as in pharmaceuticals and biotechnology. The EU lost both R&D and number of companies in all four key sectors, slightly in ICT and health, more in automotive. However, it increased in industrial machinery and general industrials, which are two sub-sectors that encompass a number of medium-low and medium-high tech industries and some more or less knowledge intensive services – all these are included more generally in the group of "Industrials".

Scoreboard R&D is highly concentrated in four major sectors accounting for 77.4% of global R&D in the Scoreboard: ICT producers (22.9%), Health industries (20.8%), ICT services (18.6%) and Automotive (15.2%) (Figure 5). This concentration is due to the structure of the industry in each country/region which evolve on a rather long-term basis. Besides, both the EU and US have experienced a slower structural transformation than emerging economies.[29] This means there cannot be "business as usual" in the EU, and the transformation of our industry cannot be resolved by young firms alone. Consequently, beyond start-up and scale-up financing, integrating high-tech in medium tech sectors (in which the EU has an excellent basis) is a specific policy challenge in industrial transformation. It calls for special strategies (e.g. including skills, technology infrastructures

[29] Moncada-Paternò-Castello, P. (2022), 'Top R&D investors, structural change and the R&D growth performance of young and old firms', *Eurasian Bus Rev* 12, pp.1–33.

etc.) for R&I as well as to manage the uptake and deployment. An example could e.g. be to strengthen digital capacities in order to capitalise on the existing strengths and to accelerate the benefits of digitisation (e.g. Internet of Things developments, AI with a purpose, using AI in R&D, innovation through high computing power, smart and flexible manufacturing).

Figure 5. R&D intensities by sector group and selected region/country.



Source: The 2021 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

The Scoreboard also shows that the EU companies are among the global leaders on high-value green patents and green patents in energy intensive industries. However, specific efforts will be needed to pursue the requirements of the European Green Deal as well as to sustain leadership and remain competitive on global markets. As described above, China has increased its competitive position especially in the digital sphere, but the R&D-driven Made In China 2025 plan also focuses on the green economy, e.g. energy- and material-efficient production, and the establishment of a circular economy.[30]

1.2.3 Innovation output

According to the Innovation Output Indicator, Ireland, Finland and Sweden were the top three EU countries in terms of innovation output in 2020. The indicator measures the extent to which ideas from innovative sectors reach the market, providing better jobs and making Europe more competitive.[31] While Ireland underperforms in the component of patent applications, it is the top performer when it comes to trade in knowledge-intensive services and innovativeness of high-growth enterprises. Finland and Sweden, on the other hand, are very strong in terms of patent applications. Conversely, Romania, Lithuania and Croatia reported the lowest performance in 2020. Between 2011 and 2020, the innovation output improved in 22 out of the 27 EU Member States, especially in Portugal, Ireland and Finland. Performance declined slightly in Germany, Denmark, Slovakia and France, and stagnated in Czechia. The strong progress of Portugal was mainly due to a significant increase in employment of fast-growing enterprises. According to the Innovation Output Indicator, the EU is lagging behind the United States and, in particular, Japan. These results are mainly due

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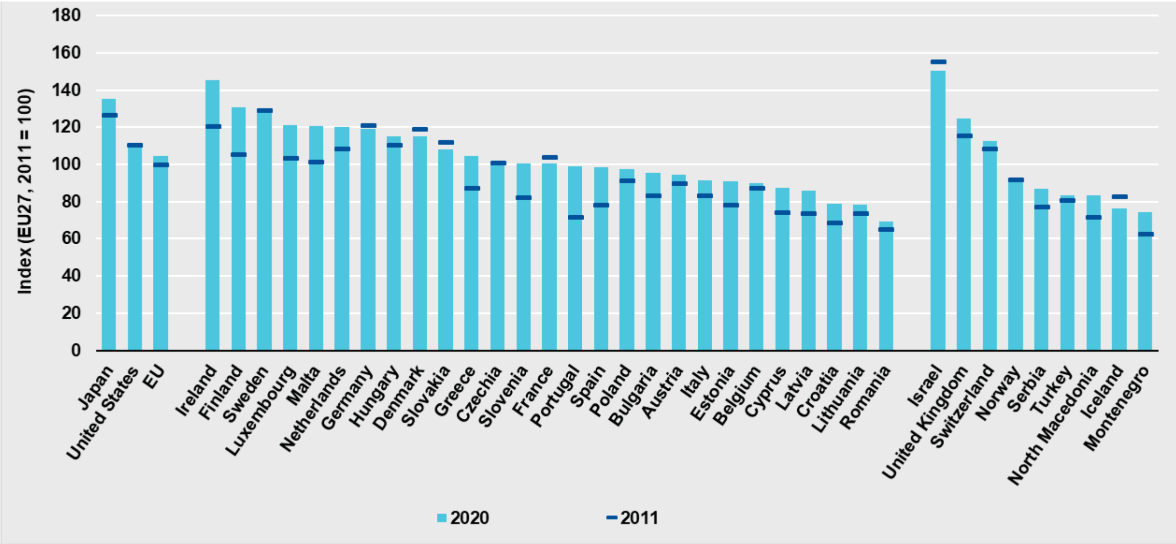
[30] See Preziosi, N. et al. (2019), *China – Challenges and Prospects from an Industrial and Innovation Powerhouse*, EUR 29737 EN, Publications Office, Luxembourg.

[31] The IOI is a composite of four indicators: technological innovation as measured by patents; employment in knowledge-intensive activities as a percentage of total employment; competitiveness of knowledge-intensive goods and services, based on both the contribution of the trade balance of high-tech and medium-tech products to the total trade balance and the knowledge-intensive services as a share of the total services exports; Employment in fast-growing firms of innovative sectors.

to the EU weak performance in patent applications, employment in knowledge-intensive activities, and trade in knowledge-intensive services.

Figure 6. Innovation Output Indicator, 2011 and 2020

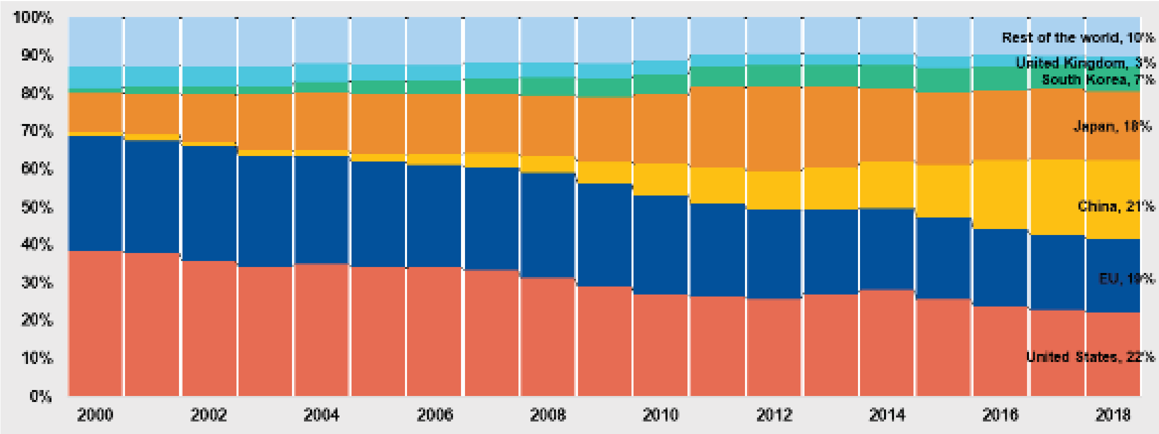


Source: European Commission, DG Joint Research Centre. Note: For the EU, two sets of values are available: values for worldwide comparison and values for European comparison. The values for worldwide comparison, which exclude trade within EU countries, are shown on the graph. The value for European comparison for 2020 is 105.2.

The EU's share in the patent applications worldwide has declined to roughly 20% in 2018, compared to 2000. Around 80% of the patent applications filed under PCT[32] come from Japan, China, EU and the United States. However, the distribution of the shares among these four regions has changed over time. While the EU and the United States accounted, respectively, for 31% and 38% of world's patent applications in 2000, their share declined to 19% and 22% in 2018. China is the country with the largest increase over time, especially after 2008, overtaking both the EU and Japan in 2017. If the trend continues, China will overtake the United States in the coming years. The rise of China, Japan and South Korea in the patent applications, was at the expense of the United States and the EU in terms of world shares.

[32] The Patent Cooperation Treaty (PCT) is an international patent law treaty, which assists applicants in seeking patent protection internationally for their inventions. By filing one international patent application under the PCT, applicants can simultaneously seek protection for an invention in a large number of countries.

Figure 7. World shares (%) of patent applications filed under PCT, 2000-2018



Source: Science-Metrix based on PATSTAT (EPO) database.

Like in the overall innovation activity, there exists a clear geographic divide in the EU in terms of patenting activity. In the EU, Germany accounted for more than 40% of the patent applications filed under the Patent Cooperation Treaty (PCT) in 2018. France came second, but at a distance, with a share of 17%, followed by Italy (8%) and Sweden (7%). Patent applications in the EU are considerably more concentrated than scientific publications, with 95% of the patent applications coming from only ten Member States. However, Southern and Eastern EU Member States like Portugal, Italy, Spain and Poland, increased their share between 2000 and 2018, while the shares for countries like Germany, Netherlands, Sweden and Finland decreased.

The EU applies for comparably more patents in the medium and low-tech sectors, in particular the automotive and machinery sectors. China and the United States apply for comparably more patents in high-tech, such as the pharmaceutical and other chemistry sectors (polymers, materials or nano-technology) and knowledge-intensive services, like the IT sectors (despite the fact that knowledge-intensive services represent a very low worldwide share in patents). Japan, on the other hand, appears to be strong mainly in the medium-tech sector.

The EU is the top worldwide patent applicant in the fields of climate & environment (23%), energy (22%) and transport (28%). However, it has experienced significant losses in terms of world shares in these fields between 2008 and 2018. The biggest decline is in transport, with minus 11 percentage points (p.p.), despite the increase in the absolute number of patent applications over the same period. The United States, while maintaining leadership in the fields of health and food & bioeconomy, witnessed an even stronger decline in their shares in world patents, especially in security (-15 p.p.), health (-14 p.p.) and energy (-13 p.p.). Conversely, China increased its world share in all fields. However, China only tops the rank in security, with an impressive increase of more than 28 p.p., from 3% in 2008 to 31% in 2018. China's performance also improved significantly in the energy sector, with an increase of more than 17 p.p. Japan, despite being weaker in scientific production (based on scientific publications), stands out strongly in technology output, with important shares in the societal challenges of health, energy and transport. [33]

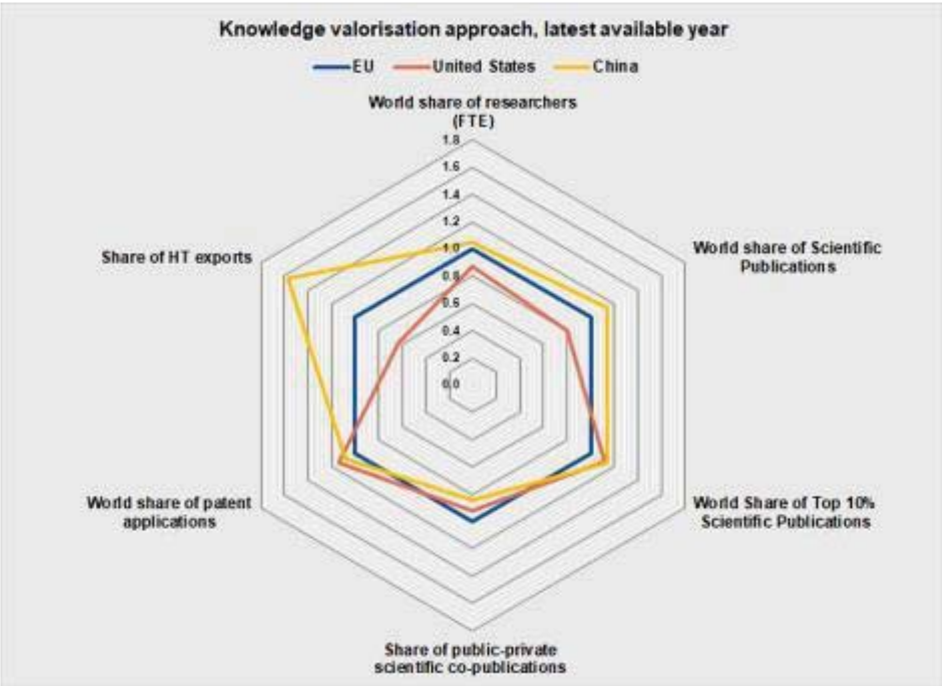
The EU lags behind the US and China in terms of patent applications in digital technologies. The EU's share in digital patents has remained stable since 2012, while the US

[33] Source: Science, Research and Innovation Performance of the EU 2022 based on Science-Metrix and PATSTAT database.

share kept increasing over time, thereby widening the gap between the two economies (EIB, 2022). Although the EU is still ahead of China, Chinese investments in new digital technologies have significantly accelerated over the past ten years. [34] This pattern is also confirmed by an analysis of patent data delving into the uptake of advanced digital technologies such as Artificial Intelligence (AI). An analysis of AI-enabled innovations in such critical economic sectors as health, mobility and manufacturing shows that the US and China vastly outperformed the EU in number of patents filed.[35] For the AI-related patents in these sectors, China is the larger contributor, overtaking also the US. Similarly, the EU lags behind the US in terms of investments in the development and diffusion of AI. In 2020, the US invested EUR 21.2 or about twice as much as the EU in AI-related R&D, data and equipment and intangible assets.[36]

More efforts are also needed to bridge research with innovation and marketable solutions. The comparably low performance of the EU in patent applications and share of high-tech exports (Figure 8), stands in contrast with its large qualified workforce, strong level of collaboration between academia and business sector, and significant scientific production. This calls for addressing deficiencies by promoting a culture of knowledge valorisation in its R&I system, ensuring that the knowledge-based institutions know how to manage their intellectual capital, and by improving the links between academia, industry, citizens and policymakers.[37]

Figure 8. Knowledge valorisation approach, latest available year (EU=1)



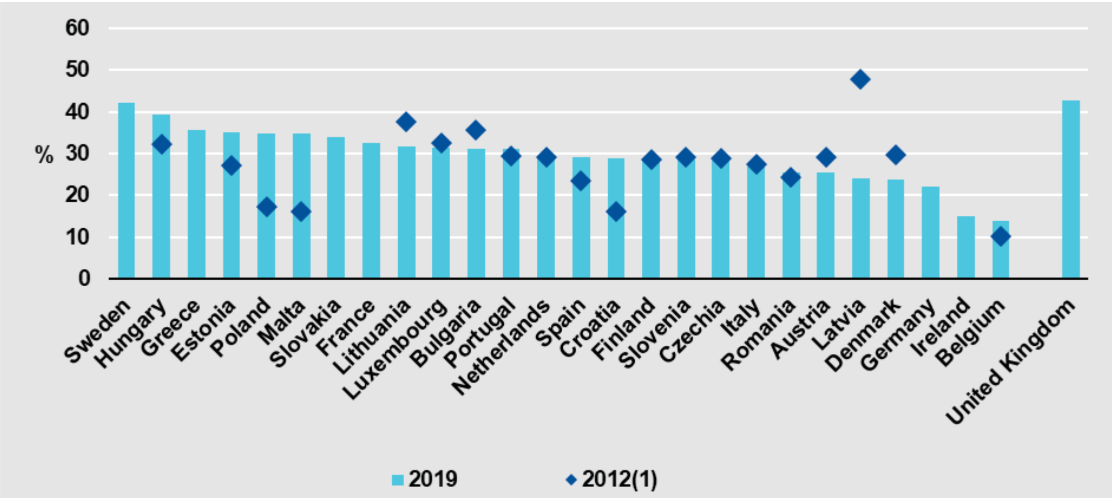
Source: Science, Research and Innovation Performance of the EU 2022. Note: data for USA and China relative to EU, which is normalised to 1.

[34] EIB (2022), Investment Report 2021/2022: Recovery as a springboard for change.
[35] JRC (2020), *AI Watch: AI Uptake in Health and Healthcare*, JRC122675; JRC (2021), *How can Europe become a global leader in AI in health?*, JRC123420; JRC (2021), *AI Watch: AI Uptake in Smart Mobility*, JRC126302; JRC (2022), *AI Watch: AI Uptake in Manufacturing*, JRC129295.
[36] JRC (2022), *AI Watch: Estimating AI investments in the European Union*, JRC129174.
[37] Science, Research and Innovation Performance of the EU 2022.

1.2.4 *Startups, scaleups and unicorns*

Venture capital backed start-ups and scale-ups[38] represent a key driver of economic growth and job creation, playing a critical role in fostering innovation. Such start-ups and scale-ups[39] foster aggregate investment activities, in particular in intangible assets.[40] These companies report on average significantly higher investment levels per employee than older firms. Furthermore, they are also catalysts for innovation and generate spill-over effects that benefit the society at large. These start-up and scale-up companies offer new products and/or services, new delivery modes, and also carry new ideas when it comes developing new ways of generating revenues from products and services sold, and to branding and advertisement strategies implemented on the market.[41] In 2019, the share in total employer enterprise of a much broader category of start-ups (i.e., newly created firms)[42] in EU ranged between about 14% (Belgium) to about 42% (Sweden). Compared to 2012, the number of such firms increased in several countries, notably in Belgium, Croatia, Estonia, Hungary, Malta, Poland, Portugal, Romania and Spain. Croatia and Poland are the Member States that experienced the largest increase over the period considered, with the share of start-ups almost doubling compared to 2012. On the contrary, Latvia experienced a significant contraction, reporting almost 50% less young enterprises than in 2012, followed by Denmark with -20%.

Figure 9. Share of start-ups up to 5 years old in total employer enterprises between 2012 and 2019, per Member State



Source: Science, Research and Innovation Performance of the EU 2022 based on Eurostat [bd_9fh_sz_cl_r2]

Note: (1) Data in 2012 not available for FR, DE, EL, IE, SK, SE, UK. (2)Data for CY is not available.

Innovative start-ups play a pivotal role in addressing the challenges of the twin transition. In order to meet its policy objectives, the EU calls for an acceleration of the development and diffusion of innovative ideas and inventions, thereby supporting EU enterprises with high-growth potential. The EU aims at creating a fertile innovation

[38] Please note that diverging data and definitions (as well as a number of different methodologies) are typically adopted to define start-up and scale-up companies. As such, it is extremely challenging to provide a comprehensive overview of the European landscape, and the information reported in this chapter builds upon different definitions used across different studies and report. For more information on data necessary to monitor innovation activities, please refer to section 2.4.1.
[39] Defined as firms younger than 10 years old and with high growth potential. The definition excludes, for instance, young businesses that do not intend to grow beyond their solo founder or already reach a wide geographical market (EIB, 2019).
[40] EIB (2019), *Investment Report 2019/2020.*
[41] EIB (2019), *Investment Report 2019/2020.*
[42] Here defined as enterprises up to 5 years old.

landscape, for firms to scale-up and grow. **The EU keeps lagging behind its main international competitors in terms of start-up ecosystems[43]**, with North America dominating the international scene, hosting 50% of Top 30 ecosystems in the world. Asia follows with 27%, after having outranked Europe between 2019 and 2021.[44] **Nevertheless, the EU performance is improving** and, in 2020, the EU was in the lead in terms of emerging ecosystems[45], accounting for 37% of global emerging start-up ecosystems, followed by North America and Asia, with a share of 30% and 19%, respectively.

The number of EU scale-ups has also increased in recent years, but the gap with the US remains. There are **three times more tech scale-ups in the United States** than in Europe.[46] Despite the contraction experienced with the outbreak of the COVID-19 virus, European fast-growing companies showed a good degree of resilience to the COVID-19 shock[47]: after a 20% contraction in the level of scale-up investment, in 2021 the European scale-up landscape has been able to almost double the investment value reported in 2019.[48]

European scale-ups[49] are strongly concentrated in few countries, notably UK and France which account for about 50% of total scale-ups in Europe[50]. In 2021, UK remains the leading country in terms of scale-up performance, counting around 33% of the European scale-up force. London maintains its record as Europe's scale up capital, with 145 scale-up companies. Paris follows with 50 fast-growing firms, accounting for the 17% of total scale-ups in France. Berlin ranks third, with 25 scale-ups.

EU underperforms as compared to its main international competitors in terms of number of deep-tech[51] start-ups and unicorns firms. In 2021, **the US reported almost seven times more unicorns than Europe, while China outperformed the EU by a factor of more than two** (Figure 10). By the end of 2021, there were 742 companies worldwide with unicorn status. Of those, more than 60% (470) are based in the United States, more than one fifth in China (or 169), and about 9% (69) are in the EU. Furthermore, EU unicorns are typically older than US and Chinese ones. On average, it takes about ten years for an EU unicorn to reach the $ 1 billion valuation, against the eight and five years reported by US and China[52]. One of the main reasons behind the gap between the EU and the US is the significant difference in the functioning of capital markets, which calls for the creation of a more efficient and diversified capital ecosystem enabling EU firms to scale-up in the EU.

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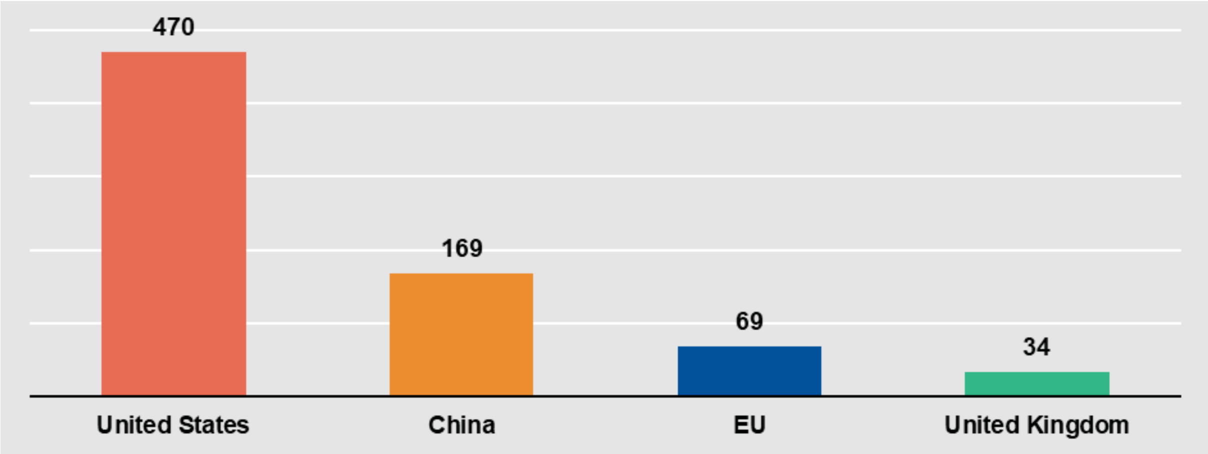
[43] A start-up ecosystem is defined as a cluster of start-ups (and related entities) which pool together resources and reside within a 100-kilometer radius from a central point (Startup Genome, 2021).
[44] The study is based on 280 startup ecosystems worldwide (Startup Genome, 2021).
[45] Emerging ecosystems are defined as ecosystems at the early-stage of their growth (Startup Genome, 2021).
[46] Mind the Bridge (2019), *Tech Scale ups EU.*
[47] For a discussion on the COVID-19 effects on high-growth enterprises in Europe, see also Coad, A., Amaral-Garcia, S., Bauer, P., Domnick, C., Harasztosi, P., Pál, R. and Teruel M. (2022), *High-Growth Enterprises in times of COVID-19: an overview*, JRC Working Papers on Corporate R&D and Innovation No 01. Additionally, evidence shows that R&D investors may be more likely to be pessimistic about investment plans as a consequence of the COVID shock (Coad, A., Amaral-Garcia, S., Bauer, P., Domnick, C., Harasztosi, P., Pál, R. and Teruel M. (2022b), *Investment expectations by vulnerable European firms in times of COVID: a difference-in-difference approach*, EIB Working Papers, No. 2022/04, ISBN 978-92-861-5235-1, European Investment Bank (EIB), Luxembourg, https://doi.org/10.2867/19683).
[48] European Scaleup Monitor (2021), *European scaleups got knocked down, but are up again*.
[49] Here defined as young fast-growing companies (10 years old or younger) that have received at least €1 million within the past 10 years (January 2011 - December 2020) (European Scaleup Monitor, 2021).
[50] European Scaleup Monitor (2021), *European scaleups got knocked down, but are up again*.
[51] According to BCG and Hello tomorrow (2021), deep technologies are defined as novel technologies offering significant advances over those currently in use.
[52] Testa, G., Compano, R., Correia, A. and Rückert, E. (2022), *In search of EU unicorns -What do we know about them, EUR 30978 EN, Publications Office of the European Union*, Luxembourg, 2022, ISBN 978-92-76-47058-8, doi:10.2760/843368, JRC127712.

Furthermore, US funds alone are estimated to provide capital to around 75% of European growth companies, thereby making their relocation more likely.[53]

Figure 10. Number of unicorns across world regions per headquarter, 2021

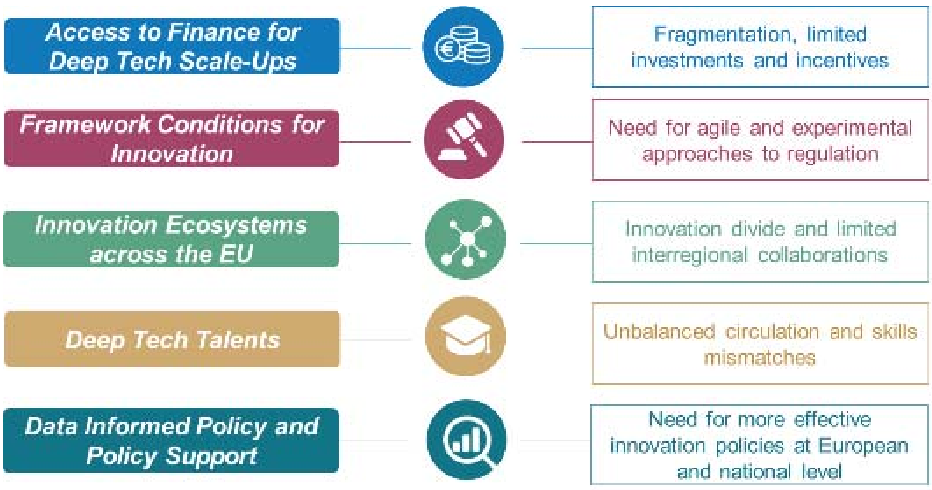


Source: Science, Research and Innovation Performance of the EU 2022 based on CBInsights, updated up to Aug 2021. Note: The figure reports the number of unicorns headquartered in the different geographical regions.

2 KEY AREAS FOR EU INNOVATION

Improving EU's innovation performance requires exploring the underlying drivers of such performance. Longstanding issues related to innovation, despite partial improvements not yet sufficiently evenly spread in the EU, call for action with renewed vigour, such as: (i) shortcomings in access to finance (in particular in relation to the above-mentioned scale-up gap), (ii) innovation-averse regulatory framework, (iii) a persistent innovation divide, accompanied by insufficiently connected innovation ecosystems, (iv) the need to improve innovation policy-making at EU and Member State level, and (v) difficulty in attracting and retaining talent.

Figure 11. Five key areas for innovation



[53] Pitchbook data, October 2021.

2.1 Access to finance for deep tech scale-ups

One of the main structural barriers faced by deep-tech and innovative companies is limited access to finance. First, the output from innovation activities has public good properties and is partly non-rival and non-excludable, i.e. other economic actors can benefit without paying for it.[54] As a result, the risk of not being able to reap the full return on innovation investments may discourage investors from allocating funds to R&D-intensive firms. Second, innovation activities typically result in the production of technological knowledge, which is a non-tangible asset. As such, it cannot be easily deployed or used as collateral to obtain financing.[55] In addition, innovation projects are typically riskier as they can also lead to negative outcomes[56]. The uncertainty naturally embedded in innovation activities typically leads to high-risk premia in financing costs or financial frictions that limit firms' abilities to secure financial resources from external investors[57]. The short-term orientation of many financial investors constitutes another constraint to innovation investments. The declining trend in innovation investment observed in Western countries[58] in the last decades can be partially attributed to the increase of short-term investment in the private sector.[59] "Patience" in innovation investments is a key ingredient as innovative activities typically take time to deploy their results in terms of both market products and financial returns.

2.1.1 Limited EU private investment and venture capital

Equity investments are critical for innovative start-ups to grow and reinforce a firm's development path at different stages. Europe is amongst the fastest growing regions in private capital investment[60]. Between 2016 and 2020, it experienced a faster growth than China and the US[61], albeit from a lower base. European startups also accounted for 33% of all capital invested globally in rounds of up to USD 5 million compared to 35% for the US[62]. In 2021, private equity (PE) investments in EU portfolio companies experienced a significant increase, after the mild contraction reported in 2020. Investments from PE funds located all over the world (including Europe) to portfolio companies based in the EU increased by about 41%, from € 64.3 billion to € 90.8 billion[63].

Venture capital (VC) is a type of private equity investment focusing on start-up companies with high growth potential.[64] VC investment positively affects the growth of

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[54] Hahn, D., Minola, T., Vismara, S.,De Stasio, V. (2019), 'Financing Innovation: Challenges, Opportunities, and Trends', *Foundations and Trends® in Entrepreneurship,* Vol. 15: No. 3-4, pp 328-367. http://dx.doi.org/10.1561/0300000085-1

[55] Hall, B. H. and J. Lerner (2010), *The financing of R&D and innovation,* In: Handbook of the Economics of Innovation. Ed. by B. H. Hall and N. Rosenberg. Amsterdam: Elsevier. 609–635

[56] Hahn, D, Minola, T., Vismara S., De Stasio, V. (2019), 'Financing Innovation: Challenges, Opportunities, and Trends', *Foundations and Trends® in Entrepreneurshi,* Vol. 15: No. 3-4, pp 328-367. http://dx.doi.org/10.1561/0300000085-1

[57] Hall, B. H., P. Moncada-Paternò-Castello, S. Montresor, Vezzani, A. (2016), 'Financing constraints, R&D investments and innovative performances: New empirical evidence at the firm level for Europe', *Economics of Innovation and New Technology,* 25(3): 183–196

[58] US and European countries.

[59] Mazzucato M. (2016), 'Innovation, the State and Patient Capital', *The Political Qaurterly*, https://doi.org/10.1111/1467-923X.12235

[60] Data from Invest Europe, 2022.

[61] A Compound Annual Growth Rate (CAGR) of 49%, against the 34% for China and 28% for the US.

[62] The State of Tech in Europe 2021.

[63] Data from Invest Europe, 2022

[64] Flachenecker, F., Gavigan, J. P. Goenaga Beldarrain, X., Pasi, G., Preziosi, N., Stamenov, B. and Testa, G. (2020), *High Growth Enterprises: demographics, finance and policy measures*, EUR 30077 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-10615-9, doi:10.2760/34219, JRC119788

target companies, in terms of both total assets and number of employees. [65] In addition, VC support is not limited to the provision of financial resources, but may also include management advice, technical assistance, networking and expertise on supply, production and sales/marketing.[66]

Private equity and venture capital can provide a significant contribution to the financing of the green transition. Technological innovation to decarbonise the EU's energy system is considered a key enabler of the net-zero targets.[67] Equity finance to European innovative firms in the field of environmental technologies has already increased in the recent years, and continued to grow steadily during the COVID-19 period.[68] Recent research documents the attractiveness of green patenting for venture capital investment over the medium term in Europe, which is suggestive of a strong potential for facilitating the adoption and diffusion of environmental technologies.[69]

Venture capital in the EU is mainly concentrated in a few EU Member States that are either 'innovation leaders' or 'strong innovators' as classified in the European Innovation Scoreboard. VC investors are often regional actors[70] or appear to focus only on some European regions and countries, thereby limiting the capacity of raising capital from across the entire Union. Most of the VC investments are concentrated in a few EU countries, such as Germany and France (approximately € 3.8 billion and € 3 billion, respectively), which altogether received about 46% of VC financing in 2021. The Netherlands and Spain rank third and fourth in terms of absolute amount of VC investments received, with about € 1.8 billion and € 1.3 billion, respectively. The rest of EU countries received a significantly lower proportion of VC financing, pooling together about € 4.1 billion, (approximately 27% of the overall VC resources directed to EU companies)[71]. When considering countries' economic size, VC investments represent only a tiny percentage (<0.5%) of EU Member States' GDP.[72]

VC investments are mainly allocated at the domestic level (i.e. the investor(s) and the target firm(s) are based in the same country), with just a fifth of all transactions involving investors that are all foreign with respect to the target firm, suggesting that the geographical proximity between venture capitalists and VC-backed firms matters.[73] Nevertheless, deals with multiple investors based in different countries are on an upward trend worldwide (50% of total investments). When considering the EU Member States, the level of VC investments coming from foreign investors is higher than that reported in the United States. However,

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[65] Bellucci, A., Gucciardi, G. and Nepelski, D. (2021), *Venture Capital in Europe. Evidence-based insights about Venture Capitalists and venture capital-backed firms*, JRC Working Paper Series, JRC122885.

[66] Testa, G., Compano, R., Correia, A. and Rückert, E. (2022), *In search of EU unicorns -What do we know about them*, EUR 30978 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-47058-8, doi:10.2760/843368, JRC127712.

[67] European Commission (2020), *Impact Assessment accompanying the document. Stepping up Europe's 2030 climate ambition: Investing in a climate-neutral future for the benefit of our people.*

[68] Kraemer-Eis, H., Botsari, A., Gvetadze, S., Lang, F., and W. Torfs (2021), *The importance of Private Equity and Venture Capital financing for Greentech companies in Europe*, SUERF Policy Note, Issue No 258 https://www.suerf.org/docx/f_35ecd9a2456d24cc121af5cf1795c4f6_37513_suerf.pdf

[69] Bellucci, A., Fatica, S., Georgakaki, A., Gucciardi, G., Letout, S. and Pasimeni, F. (2021), *Venture Capital Financing and Green Patenting,* European Commission, JRC Working Paper in Economics and Finance, No. 11/2021, Ispra, JRC127059.

[70] Kraemer-Eis, H., Signore, S., and Prencipe D. (2016), *The European venture capital landscape: an EIF perspective. Volume I: The impact of EIF on the VC ecosystem*, EIF Working Paper 2016/34, EIF Research & Market Analysis.

[71] Data from Invest Europe, 2022.

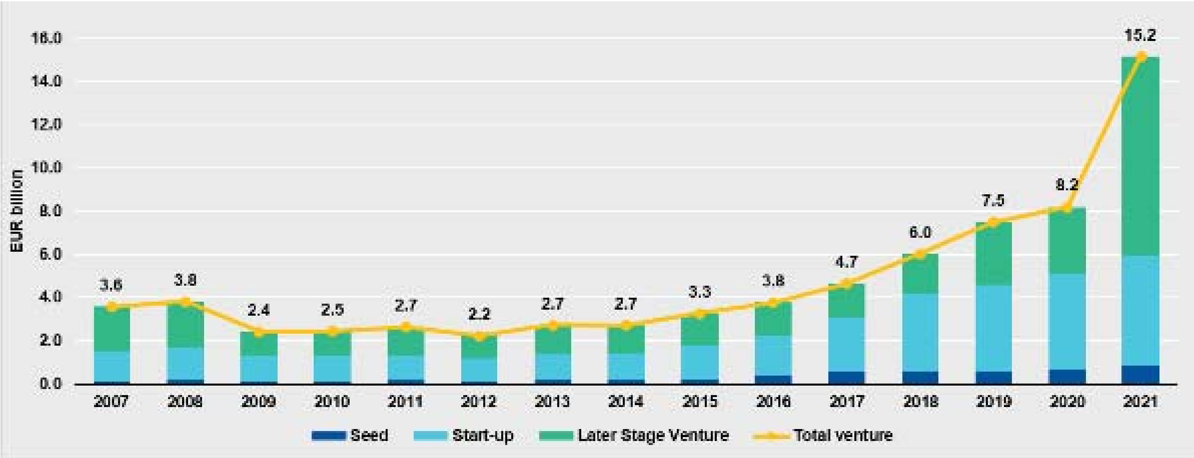
[72] Amaral-Garcia, S., Compano, R., Domnick, C., Fako, P., Gavigan J and Testa, G. (2022), *High Growth Enterprises Demographics & Finance with a focus on venture capital: Factsheet - EU*, European Commission, Joint Research Centre, Sevilla, Spain, JRC128693.

[73] Bellucci, A., Gucciardi, G. and Nepelski, D. (2021), *Venture Capital in Europe. Evidence-based insights about Venture Capitalists and venture capital-backed firms*, JRC Working Paper Series, JRC122885.

40% of EU investments keep occurring domestically, which is a sign of the integration of the EU market. [74]

Overall, VC investments in EU companies increased since 2013 onwards. In 2021, VC investments almost doubled as compared to 2020 and reached about € 15.2 billion. Differences are observed across different development stages. VC capital financing targeting firms at the seed stage[75] slightly increased after having remained more or less stable between 2017 and 2020. Financing allocated to later-stage[76] venture increased considerably, raising from € 2.9 to € 9.2 billion between 2019 and 2021. Investments in start-up stage also recorded a positive performance, increasing from € 4 billion to € 5 billion over the same period (Figure 12).[77]

Figure 12. VC investment in EU portfolio companies by development stage, 2007-2020



Source: Science, Research and Innovation Performance of the EU 2022 based on Invest Europe, 2021. Note: Data are measured following the market statistics approach, an aggregation of the figures according to the country in which the investee company is based, regardless of the location of the private equity fund. At the European level, this relates to investments in European companies regardless of the location of the private equity firm.

In the United States, almost seven times more venture capital funding is raised than in the EU. There is little to suggest that this gap will reduce in the near future. Even though funds raised in the EU have increased since 2013, reaching values above pre-crisis levels (rising from € 2.3 billion in 2013 to € 10.2 billion in 2020), venture funds raised in the United States have also risen from € 15.8 billion in 2013 to about € 70 billion in 2020 (Figure 13). The financing gap between the US and the EU is particularly striking at the scale-up stage, with US companies receiving on average significantly larger funds than EU ones.[78]

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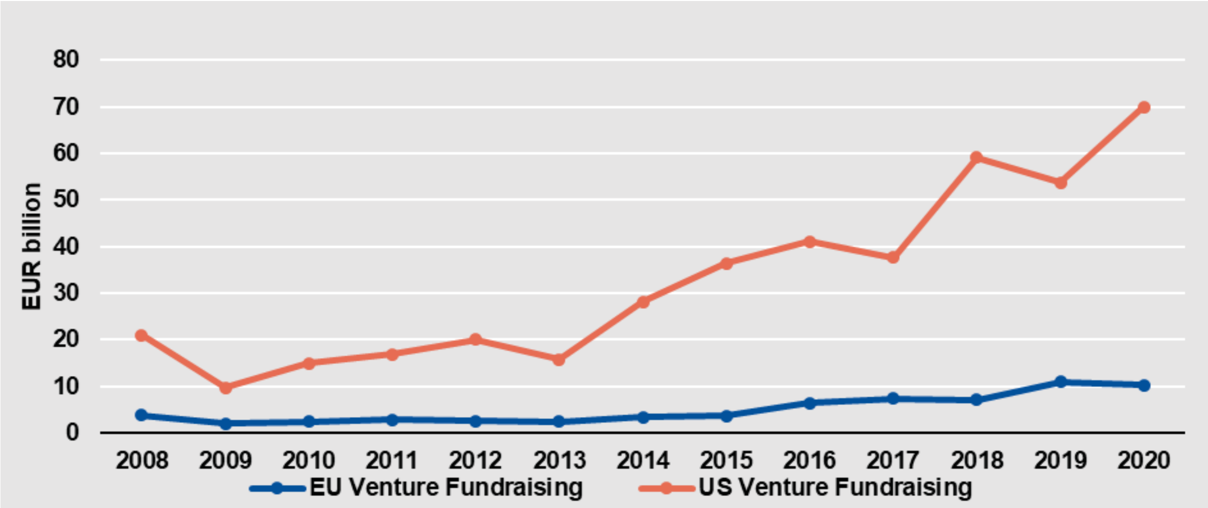
[74] Bellucci, A., Gucciardi, G. and Nepelski, D. (2021), *Venture Capital in Europe. Evidence-based insights about Venture Capitalists and venture capital-backed firms*, JRC Working Paper Series, JRC122885.
[75] Funding provided before the investee company has started mass production/distribution with the aim to complete research, product definition or product design, also including market tests and creating prototypes. This funding will not be used to start mass production/distribution.
[76] Financing provided for an operating company, which may or may not be profitable. Late stage venture tends to be financing into companies already backed by VCs. Typically in C or D rounds.
[77] Data from Invest Europe, 2022
[78] Duruflé, G., Hellmann, T., Wilson, K. (2017), *From Start-up to Scale-up: Examining Public Policies for the Financing of High-Growth Ventures*, Bruegel, Issue 04, 201.

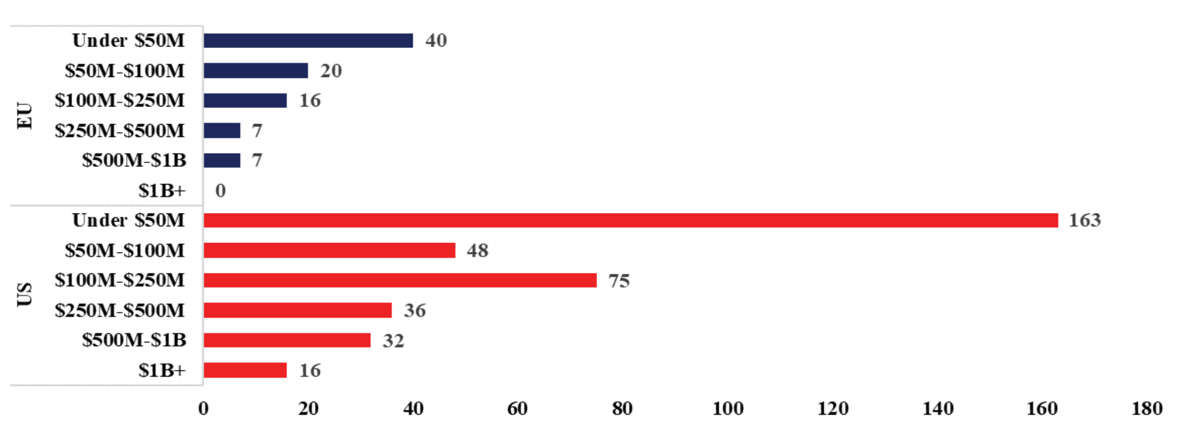
Figure 13. Venture Funds raised in Europe vs US, 2007-2020



Source: Science, Research and Innovation Performance of the EU 2022 based on Invest Europe, 2021.

There exist a significant gap in late stage financing between the EU and US. In 2020, the number of funds above $ 100 million is US was significantly higher than that reported in the EU. The US-EU gap is particularly striking for funds of larger size, namely above $ 250 million, for which the US outperform the UE by a factor of more than five (Figure 14). This signals that despite the increase in late-stage financing experienced by the EU in the last years, a persistent gap still exists as compared to US.

Figure 14. Number of venture capital funds raised by fund size (in USD million) in the EU and US in 2020



Source: Science, Research and Innovation Performance of the EU 2022 based on NVCA/Pitchbook as of 31/03/2021.

There also exists an investment gap in unicorns companies between the EU and its international competitors. US reports the highest amount of investments in unicorns over the period 2008-2021HY, with an average funding per unicorn of € 138 million. China and EU show the same performance, with an average funding reported of € 125 million over the same period.[79] **Furthermore, European unicorns are mostly foreign financed.** Between the

[79] Testa, G., Compano, R., Correia, A. and Rückert, E. (2022), *In search of EU unicorns -What do we know about them*, EUR 30978 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-47058-8, doi:10.2760/843368, JRC127712.

period 2008-2021HY, three of the top 10 venture capital firms investing in European unicorns were located in US.[80]

Exit strategies represent another critical step in scale-up investments. Companies have three financing possibilities to scale-up: they can decide to rely on internal funds, to go public or to be fully or partially acquired.[81] Initial Public Offerings (IPOs) represent the most common exit strategies available to private equity investors. **Nevertheless, EU IPOs play a minor role in the financing of scale-ups as compared to the US.** In the last two decades, the amount of divestment in the US was significantly higher than in the EU (Figure 15). In 2020, only 5% of the total divestment amount took place through IPOs in the EU, against 30% in the US.

Figure 15. Share of IPOs in the total divestment amount (%)

Source: Science, Research and Innovation Performance of the EU 2022 based on Ambrosio et al (2021).

Tackling the scale-up financing gap remains a top priority in the EU. Ensuring that EU companies get access to the necessary amount of financing resources to scale up is critical to the achievement of several EU's policy objectives. Tackling the EU scale-up gap would help the EU to secure its technological sovereignty and strategic autonomy.[82] The innovation landscape is constantly changing, and European firms need funds to remain competitive on the global market. Additionally, leading companies in the emerging technological sectors are likely to play a key role in determining future industry standards.

2.1.2 Tech funding in the (post-)COVID-19 pandemic period

Between 2020 and 2021, the EU funding environment has improved. Deep-tech investments world-wide increased significantly over the period 2016-2020. In 2020, the level of global investments in deep-tech stood at over $ 60 billion (Figure 16). **Private investment in deep-tech from corporate investors is also on the rise.** Between 2016 and 2020, deep-tech private investments coming from corporate investors increased from $ 5.1 billion to $

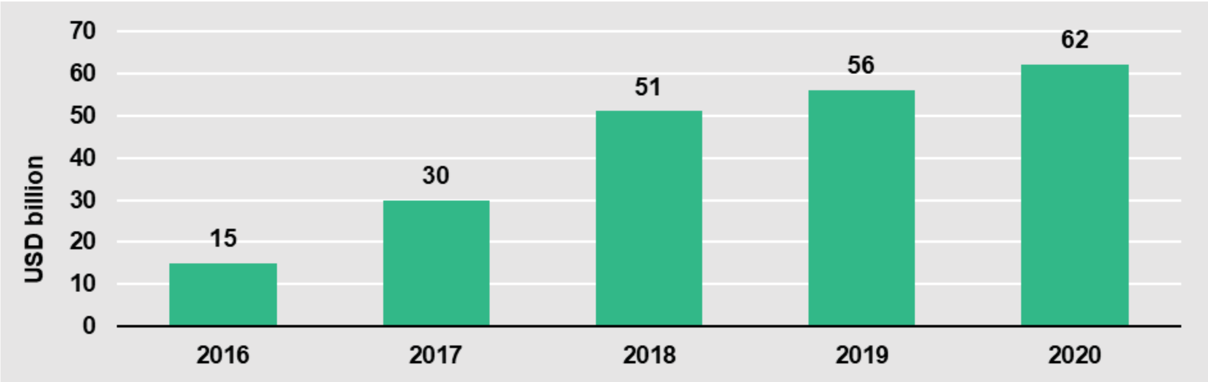
[80] Testa, G., Compano, R., Correia, A. and Rückert, E. (2022), *In search of EU unicorns -What do we know about them*, EUR 30978 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-47058-8, doi:10.2760/843368, JRC127712.

[81] Ambrosio, F., Brasili, A., Niakaros, K. (2021), *European scale-up gap : too few good companies or too few good investors?*, European Commission, Directorate-General for Research and Innovation, https://data.europa.eu/doi/10.2777/886042.

[82] Quas, A., Mason, C., Compano, R., Gavigan, J. and Testa, G. (2021), *Tackling the Scale-up Gap*, EUR 30948 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-46712-0, doi:10.2760/982079, JRC127232.

18.3 billion. Over the period 2015-2018, US and China accounted for over 80% of global private financing in deep-tech companies.[83] Nevertheless, between 2016 and 2020, private investment in Europe has experienced faster growth than China and US, reporting a compound annual growth rate of 49%, against the 34% and 28%, respectively.[84]

Figure 16. Deep-tech investments worldwide, 2016-2020 (USD billion)



Source: Science, Research and Innovation Performance of the EU 2022 based on BCG and Hello Tomorrow (2021). Note: investments include private investments, minority stakes, initial public offerings and M&A.

2021 has been a positive year of the European tech landscape. The EU has gained ground in reducing its scale-up financing gap to the US, and the EU VC market has survived the COVID-19 pandemic without major disruptions, showing a significant degree of resilience. The set of public support measures taken in reaction to the pandemic played a key role in maintaining such a good performance, preventing the EU VC industry from experiencing serious damages.[85] Investment growth in 2021 was largely driven by rounds greater than $ 250 million, which represent 40% of the total capital invested in Europe.[86] Smaller rounds (below $ 5 million) also showed an increased compared to pre-pandemic levels. Nevertheless, keep accounting for a significantly smaller share (about 5%) of overall funding.[87]

Additionally, international investors are becoming progressively more involved in European tech fundraising activities. Although domestic funding remains the predominant source of finance in EU's largest markets (notably, France and Germany), the internationalisation of European tech companies has been increasing in recent years.[88] In 2021, the participation of US and Asian investors to European tech financing has increased considerably, especially in bigger rounds of fundraising. Between 2020 and 2021 the share of rounds above $ 250 million raised in Europe involving either US or Asian investors increased from 73% to 95%.[89] **The increasing presence of foreign investors has important implications for the EU VC market.** VC foreign activities tend to increase the likelihood for foreign VC-backed companies to being acquired by a foreign firm or to exit in a foreign

[83] European Commission (2020), *Science, research and innovation performance of the EU, 2020: a fair, green and digital Europe*, Publications Office.
[84] Boston Consulting Group (BCG) and Hello tomorrow (2021), *The Deep Tech Investment Paradox: a call to redesign the investor model.*
[85] Kraemer-Eis, H., Botsari, A., Gvetadze, S., Lang, F., Torfs, W. (2021), *The European Small Business Finance Outlook 2021*, EIF Working Paper 2021/75, EIF Research & Market Analysis.
[86] Atomico (2021), *State of European Tech 2021.*
[87] Atomico (2021), *State of European Tech 2021.*
[88] Kraemer-Eis, H., Botsari, A., Gvetadze, S., Lang, F. and Torfs, W. (2021), *The European Small Business Finance Outlook 2021*, EIF Working Paper 2021/75, EIF Research & Market Analysis.
[89] Atomico (2021), *State of European Tech 2021.*

market.[90] For instance, over 1 in 3 European companies founded after 2015 choose the US over Europe to list.[91] Furthermore, the share of public EU tech companies valued over $1B that listed in US exchanges increased considerably overtime. For companies founded after 2015, the share is seven times bigger that that reported for companies funded before 2000.[92]

Although still lagging significantly behind the USA, the European scale-up landscape shows considerable potential and proved to be able to quickly react to the challenges posed by the COVID-19 pandemic. Innovative enterprises showed better adaptation capacity to the shock, confirming the role of innovation as key ingredient for economic resilience. Furthermore, since November 2021, the number of European unicorns has increased by more than 40%, asserting that the role of Europe as global tech player is increasing. **The improved EU performance in terms of fast-growing companies is of key relevance in the aftermaths of the COVID-19 pandemic**. High-growth firms have not only the potential to speed-up the recovery, but are also essential to progress in the green and digital transitions. As such, it is of paramount importance to seize the positive momentum, and continue strengthening the EU innovation landscape by improving companies' financing conditions and make them more attractive to private investors.

2.1.3 Funds that could be mobilised through the action on later stage venture capital financing

Pension funds and insurance companies represent an important player in the EU VC landscape, although their involvement in European VC remain still highly underdeveloped[93] as compared to US, where pension funds contribute to around 20% of the money flowing to venture capital funds.[94] Such a difference reflects the higher reliance of retirement income on private savings in the US, leading to assets managed by pension funds considerably higher than in the EU. In 2020, US pension funds accounted for about 65% of the $ 35 trillion of total assets managed by pension funds at global level[95]. On the contrary, EU pension funds and insurance companies have respectively $ 3 trillion[96] and $ 10 trillion[97] assets under management (AUM), very unequally distributed across EU countries. In 2021 capital raised from pension funds and insurance companies accounted only for about 7.9% of the total venture capital funds raised in the EU[98]. On the contrary, VC raised from government agencies in the EU increased significantly between 2019 and 2020. In 2020, capital raised by governments accounted for about 31% of total VC funding in the EU.[99] In 2021, VC capital raised by government agencies still accounted for the largest share of total VC funds raised in the EU.[100]

One of EU's ambition is to convince these institutional investors to adopt a portfolio allocation more similar to the one of their US peers. Private equity, which includes VC, represents a small portion of European pension funds and insurance companies' investments. In the EU in 2020 about 55% of pension funds' AUM are invested in bonds and 20% in

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[90] Braun, R., Weik, S., & Achleitner, A. K. (2019), *Follow the money: how venture capital facilitates emigration of firms and entrepreneurs in Europe,* Available at SSRN 3415370.
[91] Atomico (2021), *State of European Tech 2021.*
[92] Atomico (2021), *State of European Tech 2021.*
[93] Helmut Kraemer-Eis, et.al.(2021)*, The European Small Business Finance Outlook,* EIF working Paper 2021/75.
[94] Dow Jones Private Equity Analyst Sources of Capital survey.
[95] OECD, global pension statistics, 2022.
[96] OECD, global pension statistics, 2022
[97] Insurance Europe, data, 2021.
[98] Data from Invest Europe, 2022.
[99] Data from Invest Europe, 2021.
[100] Data from Invest Europe, 2022.

public equity.[101] In 2020, pension funds yearly investments in European ventures amounted to only about € 700 million, corresponding to less than 0.018% of their total assets in the same year.[102] If pension funds were to channel 50% of their private equity allocations per year to VC, about € 10 billion a year could be raised[103]. In comparison to US figures, a target of 1% of European pension funds' AUM to be allocated to VC by 2025 could mean mobilizing € 30 billion over three years, which would more or less double the EU VC market (in 2020, the total EU28 market was EUR 24 billion). Similarly, EU insurance companies have 9% of their AUM invested in equity, almost exclusively public equity. Private equity is a very small part of their investment portfolios (9% or USD 30 billion in the US)[104]. Given their more risk-averse nature compared to pension funds, a proportionate target of 0.15% of European insurance companies' AUM could be set to be allocated to VC by 2025, arriving at roughly € 15 billion mobilized over three years. Summing up the funds that could be mobilized by European pension funds and insurance companies from 2023 to 2025, a total of € 45 billion could be achieved.

Costs that could be saved through the action on listing

European Commission's internal assessments indicate that reductions in the complexity and length of prospectuses could cut costs by a quarter or more and amendments to the rules on inside information could lead to about 3% lower costs per annum from staying listed. Aggregate issuance costs are estimated to decline by € 67 million and ongoing costs by € 100 million.

2.1.4 A fragmented financial market

Despite these positive recent trends, EU's capital markets remain considerably fragmented, constraining EU companies to mainly rely on domestic markets to meet their financial needs. This results into a heterogeneous degree of access to finance within the Union territory, as well as in different financing costs between EU countries. The EU capacity to attract cross-border/foreign investors is quite heterogeneous across Member States. Germany and France are the two EU countries with the highest capacity to attract investors in innovative firms, with a venture capital attractiveness score of 87.3[105] and 83.6, respectively (Figure 17). The Netherlands, Sweden and Denmark also perform quite well in the EU ranking with a score well above the EU average of 77.3. Southern and Eastern European countries are less good in attracting venture capital investors, with scores below the EU average. Croatia, Latvia, Lithuania and Slovakia are among the Member States with the lowest performance, with a score ranging between 53.1 and 47.5.

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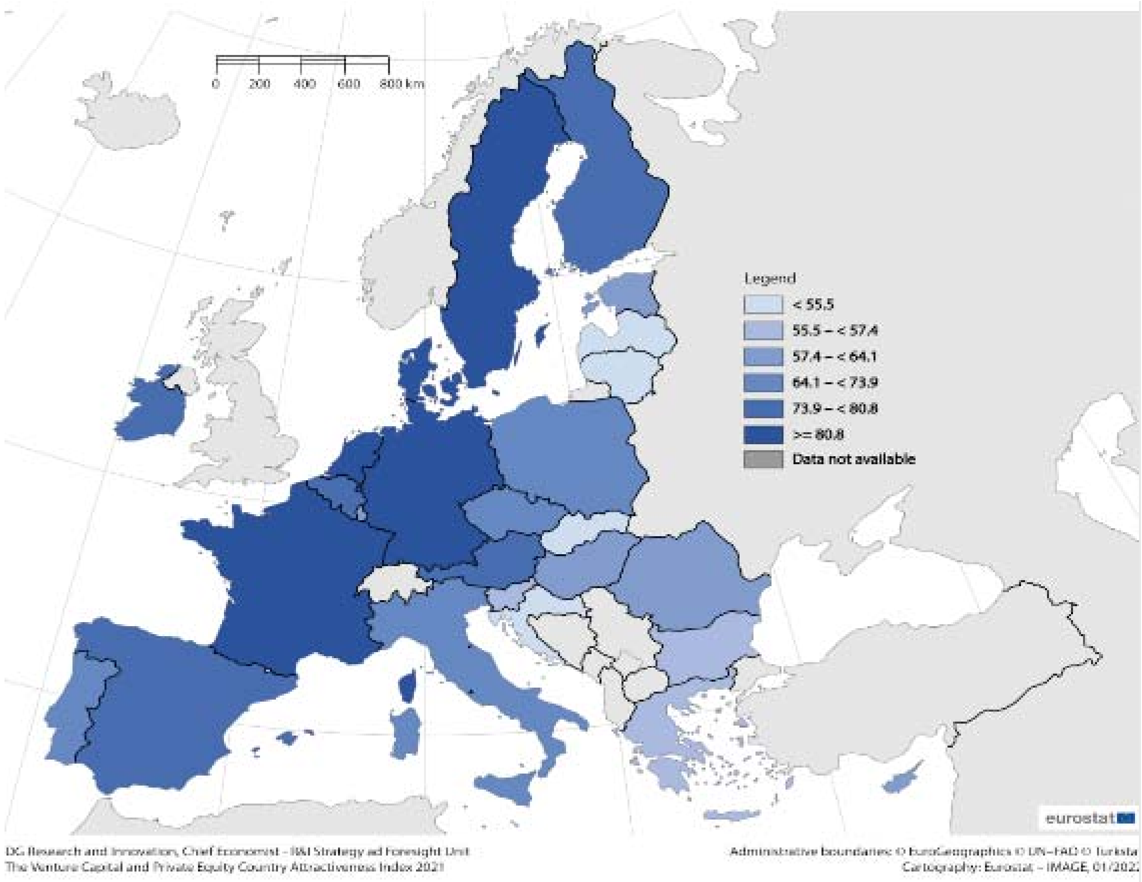
[101] Estimation based on OECD's country data.
[102] Atomico (2021), *State of European Tech 2021.*
[103] Nederlandse Vereniging voor Participatiemaatchappijen (2021), *The untapped potential*.
[104] Centre for capital markets (2019), *The role of insurers in the US economy.*
[105] The index is rescaled to 100 for the most attractive country for VC and PE allocations (here the USA), and it is built considering six key drivers of VC/PE attractiveness (namely, economic Activity, depth of Capital Market, taxation, investor protection and corporate governance, human and social environment, and entrepreneurial culture and deal opportunities. For more details, please refer to Alexander Groh, Heinrich Liechtenstein, Karsten Lieser and Markus Biesinger (2021), *The Venture Capital and Private Equity Country Attractiveness Index 2021*, The Venture Capital & Private Equity Country Attractiveness Index (iese.edu).

Figure 17. The venture capital and private equity country attractiveness index per Member State, 2021



Source: Science, Research and Innovation Performance of the EU 2022 based on the Venture Capital and Private Equity Country Attractiveness Index 2021.

Furthermore, bank loans remain the predominant financing instrument for companies in the EU, while equity capital and market based debt (corporate bonds)[106] still play a minor role compared to other international economies. Traditional bank products, such as loans, credit lines and bank overdrafts continue to represent the most relevant sources of external finance for European enterprises. Alternative external resources such as equity investment keep playing a minor role, although remaining critical to help firms facing specific financial needs and challenges, notably riskier and long duration innovation processes.[107] On average, EU firms make more use of debt finance to finance their innovation activities (9% against 4% using equity finance).[108] Since innovative firms are typically active in intangible-intensive sectors, access to debt financing is challenging, as intangible assets are difficult to be pledged as collateral for bank lending[109]

Internal funding continues to be the primary source of innovation for all European businesses. Given the crucial role of intangible assets in knowledge-based economies,

[106] European Commission (2017), *Analysis of European Corporate Bonds Market. Analytical report supporting the main report from the Commission Expert Group on Corporate Bonds.*
[107] Mazzucato M. (2016), 'Innovation, the State and Patient Capital', *The Political Quarterly*, https://doi.org/10.1111/1467-923X.12235
[108] Community Innovation Survey (CIS).
[109] Demmou, L. and G. Franco (2021), *Mind the financing gap: Enhancing the contribution of intangible assets to productivity*, OECD Economics Department Working Papers, No. 1681, OECD Publishing, Paris, https://doi.org/10.1787/7aefd0d9-en

improving access to finance is essential to fully tap their growth potential. Intangible-intensive sectors have strong productivity potential, but typically face more financial constraints than the rest of the economy. As such, they would be the segments benefitting the most by further financial development[110], e.g. collateralisation. Less financial frictions would improve firms' ability to finance their innovation activities, thereby advancing their productivity performance. **External financing, plays a critical role in enhancing investment opportunities**, but its usage remains limited to larger innovators with collateral, and innovative in-house competencies. **Enhancing access to equity, especially for small innovative firms, is thus key to creating growth opportunities**.

Levelling the playing field for debt versus equity financing and the lack of appropriate tax incentive constitute another important constraint to innovation financing. In many EU corporate tax systems, interest payments on debt financing are tax deductible, while the costs related to equity financing are not. Such asymmetric tax treatment induces a bias in investment decisions, making debt financing more appealing despite the potential negative effects related to increasing companies' debt levels, thereby leading to higher incidence of insolvency and negative spill-over effects for the EU as a whole. In 2019, total indebtedness of non-financial corporations amounted to almost € 14 trillion in 2019 (99.8% of GDP in the EU), and the debt to equity ratio was 53.3%.[111] The COVID-19 pandemic exacerbated corporate financial vulnerabilities, causing considerable revenue losses and further debt accumulation[112]

The tax induced debt-equity bias constitutes an important constraint to the creation of a strong equity market in the EU. This penalises innovative companies (especially start-ups and SMEs) which typically face higher constraints in raising the necessary resources to meet their financing needs. Addressing the higher cost of equity financing is of key relevance to boost EU innovation performance, calling for continuous efforts to minimise unintended distortions in companies' investment decisions and facilitate innovative companies' access to financing resources.

Furthermore, persisting differences in national tax system can create unnecessary burdens for EU companies. Member States have the possibility to introduce measures at national level to mitigate the tax induced debt-equity bias. Country specific rules risk to further enhance the Single Market fragmentation, as multinational enterprises can afford tax-planning and relocate business centres, or companies may be tempted to base their investment decisions on the availability of debt-equity bias mitigating measures, and to create unnecessary compliance costs for businesses, thereby discouraging cross-border investments.[113]

The underrepresentation of women in the European VC landscape represents another major constraint to the development of a strong innovation ecosystem. The gender financing gap in Europe remains persistent. In 2020, only 1.7 % of the capital raised in European VC markets was captured by tech companies with only female founders.[114] The difference between male-led companies and companies with mixed/female founders remains significant both in terms of capital and number of deals. In 2021, male-only firms accounted

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[110] Demmou, L. and G. Franco (2021), *Mind the financing gap: Enhancing the contribution of intangible assets to productivity*, OECD Economics Department Working Papers, No. 1681, OECD Publishing, Paris, https://doi.org/10.1787/7aefd0d9-en

[111] DEBRA Inception impact assessment - Ares(2021)3879996.

[112] COM(2020) 590 final, A Capital Markets Union for people and businesses-new action plan.

[113] COM(2021) 251 final, Business Taxation for the 21st Century.

[114] Atomico (2021), *State of European Tech 2021.*

for respectively about 90 % and 84 % of capital and deals concluded, against 1.1 % and 5.4 % reported for women-led companies, respectively.[115] The gap also remains huge when considering companies with male-female co-founders, which captured only 8.8 % of the capital raised in 2021.[116]

2.1.5 IP protection

Strengthening intellectual property rights (IPR) protection has the potential to open new funding channels for innovative enterprises.[117] **IP protection typically provides companies with a competitive advantage,** especially regarding technologies that can be copied once the product is on the market. IP strategies also **enable start-ups and SMEs to expand their business** by collaborating with partners, through participating in innovation projects, pairing with large companies to provide supplementary services, or licensing their technologies or brands to third parties. As such, **a stronger IPR protection can serve as positive signalling mechanism to investors**.

Additionally, protected, valued and transferable IPR can increase collateral availability, thereby easing innovative firms' access to finance.[118] Young innovative start-ups and SMEs rely considerably on intangible assets, but typically lack tangible assets, which can more easily be pledged as collaterals to access external financing. Although the practice of using IPR to back loans is increasing, large firms appear to benefit more from this opportunity as compared to SMEs. One aspect hindering SMEs' opportunities in exploiting IPR-backed loans relates to the significant capacity constraints SMEs face when applying for patent protection (e.g. payment of specific fees and burdensome administrative procedures, typically better handled by expensive patent consults). In this regard, policy interventions aimed at increasing the use of IPR-backed financing represent an important opportunity to enhance the availability of bank finance for innovative enterprises[119], thereby providing start-ups and SMEs with the same opportunities as larger firms to access a larger pool of financing resources.[120]

2.2 Framework conditions for innovation

In order to ensure well-functioning markets that incentivise competition and innovation, thereby maximising the impact of EU R&I investments, Europe needs a fit-for-purpose, forward-looking and overall innovation-friendly regulatory framework. Regulation can be a powerful instrument to foster innovation in the EU. The emergence of new practices, technologies and business models and the acceleration of innovation call for more flexible and experimental approaches to regulation, such as the implementation of the innovation principle as well as regulatory sandboxes and innovation clauses.

2.2.1 Regulatory environment matters for innovation

Strong institutions help to generate a more innovative environment. Institutional quality is strongly associated with innovation capacity, and this relationship is confirmed for different

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[115] Atomico (2021), *State of European Tech 2021*.
[116] Atomico (2021), *State of European Tech 2021*.
[117] Demmou, L. and G. Franco (2021), *Mind the financing gap: Enhancing the contribution of intangible assets to productivity*, OECD Economics Department Working Papers, No. 1681, OECD Publishing, Paris.
[118] Demmou, L. and G. Franco (2021), *Mind the financing gap: Enhancing the contribution of intangible assets to productivity*, OECD Economics Department Working Papers, No. 1681, OECD Publishing, Paris.
[119] Demmou, L. and G. Franco (2021), *Mind the financing gap: Enhancing the contribution of intangible assets to productivity*, OECD Economics Department Working Papers, No. 1681, OECD Publishing, Paris.
[120] Brassell, M., & King, K. (2013), *"Banking on IP", The role of intellectual property and intangible assets in facilitating business finance*, The Intellectual Property Office.

countries.[121] Respect for the rule of law, in particular independent, quality and efficient justice systems, effective anti-corruption structures, anti-money laundering and anti-fraud frameworks, are important factors of the business environment and of the functioning of the Single Market[122]. In addition to the European Semester, the Commission's Rule of Law Report also covers in one of its pillars the functioning of justice systems. Research shows the positive relationship between the Global Innovation Index[123], GDP per capita, and various measures of institutional quality: rule of law[124], regulatory quality[125] and control of corruption[126]. Regulation matters at all stages of the innovation process, but the relationship between regulation and innovation is complex.

On the one hand, regulation can be a barrier for innovation when it is not properly designed or when it stifles competition. Ineffective regulation raises compliance costs, using entrepreneurs' resources and time. Inflexible regulation or regulation that lags behind innovation cycles can for example prevent the commercialization of an innovative product or its scaling up. Prescriptive regulation may also not generate sufficient incentives for firms to seek improvement of their product or service beyond what is specified in the regulation.

On the other hand, regulation can act as a major driver of innovation: it brings stability and certainty, which matter for investment and planning and enables firms to operate on safe legal grounds, but it can also create strong stimulus for innovation through standard setting[127] or regulatory stringency[128]. Regulation may also have impacts on innovation at the systemic level, when it shifts investment opportunities to different actors. This could occur for example in the context of the twin transition, supported by the European Green Deal and the Digital Decade priorities.

Hence, regulation can be a powerful instrument to foster innovation in the EU. However, several factors can prevent this. The EU is faced with challenges common to other regulatory systems, e.g. how to ensure that regulation is agile enough to adapt rather than react to the pace of innovation; when and how to regulate disruptive innovation, while only limited evidence is available. In addition, EU-specific challenges may also come into play. These include the length of the legislative process, risks of market fragmentation if the same innovation is treated differently across Member States, and problems in national implementation of EU regulation (inadequate transposition or implementation, gold-plating,

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[121] Rodríguez-Pose, A., Di Cataldo, M. (2015), 'Quality of government and innovative performance in the regions of Europe', *Journal of Economic Geography*, 15(4), pp. 673-706; Tebaldi, E., Elmslie, B. (2013), 'Does institutional quality impact innovation? Evidence from cross-country patent grant data', *Applied Economics*, 45(7), pp. 887-900; Hussen, M. S., & Çokgezen, M. (2021), 'The impact of regional institutional quality on firm innovation: evidence from Africa', *Innovation and Development*, 11(1), pp. 69-90.

[122] Annual Sustainable Growth Survey 2022, COM(2021)740 final, p. 8.

[123] The "Global Innovation Index" (World Bank) ranks the innovation ecosystem performance of economies around the globe relying on 81 different indicators, from R&D intensity, education, patenting, ICT, infrastructure to political institutions.

[124] "Rule of law": the key principles of the rule of law are common to all Member States – legality, legal certainty, prohibition of the arbitrary exercise of executive power, effective judicial protection by independent and impartial courts respecting fundamental rights in full, the separation of powers, permanent subjection of all public authorities to established laws and procedures, and equality before the law – are enshrined in national constitutions and translated in legislation (2021 Rule of Law Report, COM(2021)700 final, p. 1).

[125] "Regulatory quality" measures the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development (World Bank).

[126] "Control of corruption" measures extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests (World Bank).

[127] Standard setting may improve the market function as it provides guidance to producers for the design of a new and innovative product, while it increases at the same time trust for the customers in a product that is yet unknown. Setting the standards at ambitious levels can provide strong incentives to businesses to innovate and shift from outdated techniques and procedures to new ones.

[128] Strict environmental regulations can encourage innovations that help improve commercial competitiveness (Porter, M.E., van der Linde, C. (1995), 'Toward a New Conception of the Environment Competitiveness Relationship', *Journal of Economic Perspectives*, 9(4)).

burdens or obstacles in the delivery phase of the legislation). These factors can also discourage investment and limit innovation. At the same time, regulation alone may not be sufficient. Innovation requires public buy-in and trust, with societal uptake of innovation being also a demand-side indicator of emerging regulatory gaps or deficiencies.

When designing and evaluating regulation, the growing role of digitalisation in various sectors of the economy is not always reflected; the same applies to the increasingly data-driven nature of innovation. In some instances, the opportunities offered by digitalisation can facilitate the implementation of and compliance with existing rules, by reducing administrative burdens without affecting intended policy objectives. More importantly, digitalisation also matters for policy design and for identifying policy approaches that grant sufficient adaptability to accommodate innovation and fast technological change, where appropriate. Indeed, while digitalisation and technology are enablers of solutions, they may also be the sources of new risks, which also need to be assessed and understood.

Recent efforts aim at reinforcing consideration of innovation, both in terms of possible impacts of policies on innovation, and the influence that innovation itself can have on the design and implementation of EU policies and legislation. In particular, DG Research and Innovation (DG RTD) is stepping up efforts within the European Commission to implement the **innovation principle** (see Box 1) at all relevant stages of policy-making and create future-proof framework conditions to achieve sustainable development. The innovation principle is an approach ensuring that the processes of preparing, revising and implementing EU legislation take into account emerging innovations that are in line with EU policy objectives, thus facilitating their development and adoption. This simultaneously requires policy to become more agile - able to anticipate, adapt and adjust to changing circumstances - while maintaining or introducing regulatory certainty and relevant legal protection where necessary.

Box 1. The innovation principle

At the EU level, the European Commission recognises the importance of regulation in stimulating innovation to support social, environmental and economic objectives. In this context, it applies an **innovation principle**, when preparing legislative initiatives. The innovation principle helps to ensure that EU legislation is analysed and designed so as to encourage innovation to deliver social, environmental and economic benefits and help protect Europeans. It supports the EU's better regulation approach to help enact smart, future-oriented regulation. The Commission mentions the innovation principle notably in its Communication on a Renewed Agenda for Research & Innovation, in the Single Market Communication and in the Communication on Artificial Intelligence. It also appears in the recitals of the Horizon Europe Regulation proposals. The 2019 Commission Communication on Better Regulation acknowledges the need "to have regulation that fosters and, at the same time, harnesses innovation to the benefit of the environment, the economy and EU citizens.

The implementation of the innovation principle occurs by: using horizon scanning and innovative regulatory approaches to harness future technological advances and steer them in the direction of delivering on European Commission priorities; designing new legislation with innovation in mind, in particular through impact assessments; addressing perceived regulatory obstacles to innovative solutions through innovation deals and ensuring that evaluations consider whether regulations are fit for the future.

In the context of the innovation principle, to clarify how existing regulatory requirements apply to innovative ideas, the Commission has also been piloting **Innovation Deals** to help innovators address perceived EU regulatory obstacles. Early results in pilots on batteries and water reuse suggest the experience can provide useful feedback to improve regulation and promote innovation.

2.2.2 Experimental approaches to regulation

By its very nature and speed, innovation may often call into question traditional approaches to regulation. This raises the broader question of how regulation could be made future-proof and fit for purpose to continue to be effective while meeting the desired policy goals in a fast-moving and increasingly complex environment. Experimental approaches set out in regulations, including the so-called ‘regulatory sandboxes’, are relevant in this context. When testing new solutions and alternative business models, accountability and the involvement of those who are impacted by the tested innovation are essential.

Broadly speaking, a **regulatory sandbox** is a framework that enables the testing of innovations in a controlled real-world environment, under a specific plan developed and supervised by a competent authority. Sandboxes usually entail a temporary loosening of applicable rules, and feature safeguards to preserve overarching regulatory objectives, like safety and consumer protection. They are a relatively new practice in most regulatory systems and experience with implementation of such sandboxes is still limited. At EU level, initiatives paving the way for sandboxes include the Commission proposal for a regulation on Artificial Intelligence and the pilot regime for market infrastructures based on Distributed Ledger Technology (DLT), as well as a regulatory sandbox for blockchain solutions in collaboration with the European Blockchain Partnership and supported under the Digital Europe Programme. At national level, over half of the Member States have set up sandboxes and additional ones are in the pipeline. Applications of sandboxes are mostly in the areas of finance, transport and energy.

Closely connected to sandboxes are **experimentation clauses**: these enable authorities tasked with implementing and enforcing legislation to exercise a degree of flexibility in relation to innovative technologies, products or approaches, even if they do not conform to all existing legal requirements. Experimentation clauses can serve as the legal basis for sandboxes or simply allow for flexibility under certain circumstances.

On 16 November 2020 the Council adopted a set of **conclusions[129] on the role of regulatory sandboxes and experimentation clauses in an innovation-friendly, future-proof, sustainable and resilient EU regulatory framework**. In these conclusions, the Council affirms that regulatory sandboxes can offer **significant opportunities to innovate and grow** for all businesses, especially SMEs, including micro-enterprises as well as start-ups, in industry, services and other sectors. The conclusions also encourage the Commission to continue considering the use of experimentation clauses on a case-by-case basis when drafting and reviewing legislation, as well as to evaluate the use of experimentation clauses in ex-post evaluations and fitness checks on the basis of an exchange of information with member states.

There are other experimentation frameworks without being a fully-fledged sandbox, such as test beds, living labs and digital innovation hubs that enable innovators to test and demonstrate new technologies and solutions. These controlled experimentation activities can also take place in real-world environments, allowing for early engagement with end users and relevant stakeholders, as well as with regulation. Smaller-scale experimentation frameworks

[129] https://data.consilium.europa.eu/doc/document/ST-13026-2020-INIT/en/pdf.

particularly target start-ups and SMEs. These experimentation frameworks can at once support early uptake of existing regulation and provide evidence on new regulatory needs.

- In today's rapid development of science and technology, **test and demonstration facilities** are key to quickly turning research results into innovative products and services. A **test bed** is a set of entities, providing common access to physical facilities, capabilities and services required for the development, testing and upscaling of technology and advanced materials, e.g. in industrial environments. The objective of test beds is to bring technologies and advanced materials within the reach of companies and users in order to advance from validation in a laboratory to prototypes in industrial environments.
- **Living Labs** are collaborative initiatives to co-create knowledge and innovations. There is no commonly agreed definition but the European Network for Living Labs describes them as user-centred, open innovation ecosystems based on systematic user co-creation approach, integrating research and innovation processes in real-world communities and settings. Living Labs embed the notion of the quadruple helix, i.e. involvement of four major actors in the innovation system: science, policy, industry, and society.[130] These actors come together in Living Labs and their interaction fosters collaborative innovation, validation, rapid prototyping and scale up innovations. Through its Living Labs programme[131] the JRC is exploring the potential to extract regulatory insights from testing and demonstration of new technologies in a Living Lab environment. In this context the Commission also supports the creation of a network of 100 living labs experimenting and testing solutions for soil health in rural and urban areas.[132]
- **European Digital Innovation Hubs** (EDIHs) funded by the new Digital Europe Programme provide 'Test before Invest' to SMEs as one of their main objectives. The group of services enabling test before invest may include: awareness raising, digital maturity assessment, demonstration activities, visioning for digital transformation, fostering the integration, adaptation and customisation of various technologies, testing and experimentation with digital technologies (software and hardware), knowledge and technology transfer. Special focus is given on the key technologies promoted in Digital Europe Programme: HPC, AI, and Cybersecurity.[133]
- Furthermore, to embrace the transition towards low-impact green solutions, the industry is looking at R&I for new ways to power its activities and to reengineer its processes. The current speed of this industrial transformation is insufficient and EU policies should play a role in accelerating this transformation. To meet these challenging objectives, the **EU INnovation Centre for Industrial Transformation & Emissions (INCITE)** (see Box 2) will become, after the adoption of the new Industrial Emissions Directive, the first independent centre for identification and evaluation of emerging techniques with high potential for decarbonisation, pollution reduction and/or for increasing circularity in large agro-industrial installations. It will open the possibility to allow more time for operators to test and implement these techniques at full industrial scale

[130] Schütz, F., Heidingsfelder, M.L., Schraudner, M. (2019), 'Co-shaping the Future in Quadruple Helix Innovation Systems: Uncovering Public Preferences toward Participatory Research and Innovation', *She Ji: The Journal of Design, Economics, and Innovation*, 5(2), pp. 128-146.

[131] https://joint-research-centre.ec.europa.eu/pilot-living-labs-jrc_en.

[132] https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/soil-health-and-food_en.

[133] JRC online Catalogue of DIHs and Candidate EDIHs: https://s3platform.jrc.ec.europa.eu/web/guest/digital-innovation-hubs-tool.

Box 2. Instruments to accelerate the industrial uptake of innovation

The **Industrial Emissions Directive** (IED) is the main instrument of the European Union to control the environmental impact of around 52 000 large-scale agro-industrial installations with high-pollution risk in Europe . This is done in an integrated manner, on a sector-by-sector basis[134] and through the application of best available techniques (BAT). BATs are specified in sectoral reference documents, which also list promising emerging techniques that could become "a standard" in the future. In this way, the IED creates a direct link between technological innovation and the establishment of legally binding emission limits for industry.

Experience shows that access to finance is only one element to succeed in innovation deployment. **Another challenge is to pool the results of innovation into tangible and workable solutions that could promote emerging techniques and provide a convincing business case to the industry.**

The **EU Innovation Centre for Industrial Transformation & Emissions** proposed in the revised IED[135] aims at filling this gap. INCITE will scout for emerging techniques worldwide, it will identify and evaluate new processes and techniques by assessing their Technology Readiness Level and environmental performance and, if they are deemed ready for use at an industrial scale within a short timescale, incorporate them in the Best Available Techniques framework.

In addition, plant operators will be allowed up to two years instead of the current nine months to **test emerging techniques** within their own installations. During this time they will be allowed temporary derogations from selected IED permit conditions, subject to monitoring from permitting authorities. Frontrunners will also be allowed an additional 2 years to implement new environmentally better techniques (i.e. a total of 6 years) that INCITE has identified as being close to market deployment. This work is essential for an efficient deployment of breakthrough technologies, thereby minimising the risk of technological lock-ins or stranded technologies.

The information collected and evaluated by INCITE will **provide a sound, evidence-based technical basis for industry to** develop site-specific **Industrial Transformation Plans** as part of their environmental management system. Operators of energy-intensive installations will need to do it by 2030. These Transformation Plans will show how each plant will contribute to achieving the EU's 2050 zero pollution ambition, circular economy and decarbonisation objectives. Transformation Plans will promote transition pathways that create technologies favouring integrated solutions and will build on INCITE findings as decarbonisation and pollution reduction reinforce each other. INCITE will contribute towards putting the EU's industry in the front-foot of industrial transformations, potentially gaining first-mover advantage and exporting the acquired know-how on emerging techniques.

2.3 Innovation ecosystems across the EU

2.3.1 Innovation divide

Regional disparities in R&I performance remain deep across the EU. The Regional Innovation scoreboard 2021 uses 21 indicators at regional level on different aspects (framework conditions, innovative outputs, investments, impacts, etc.) to assess the performance in R&I of EU regions (NUTS 1 and 2 levels) relative to the EU average score.[136] It demonstrates that **there is a clear innovation divide across the EU** as Europe's highest performing regions are up to nine times more innovative than the lowest performing ones (Figure 18).

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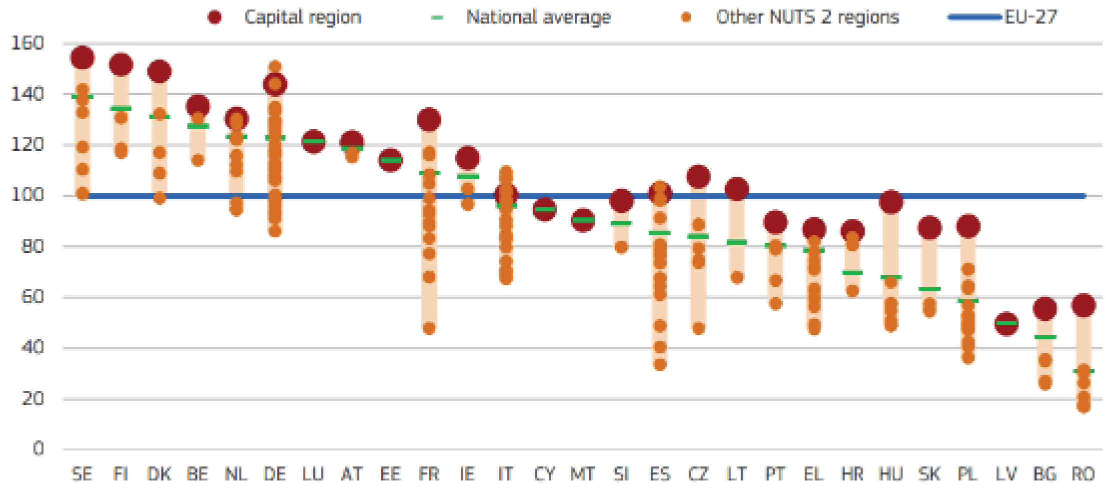
[134] Activities regulated by the IED include e.g. power-plants, refineries, waste treatment and incineration, production of metals, cement, glass, chemicals, pulp and paper, food, and drink, as well as the rearing of pigs and poultry.

[135] COM(2022)156/final 3.

[136] https://ec.europa.eu/info/research-and-innovation/statistics/performance-indicators/regional-innovation-scoreboard_en.

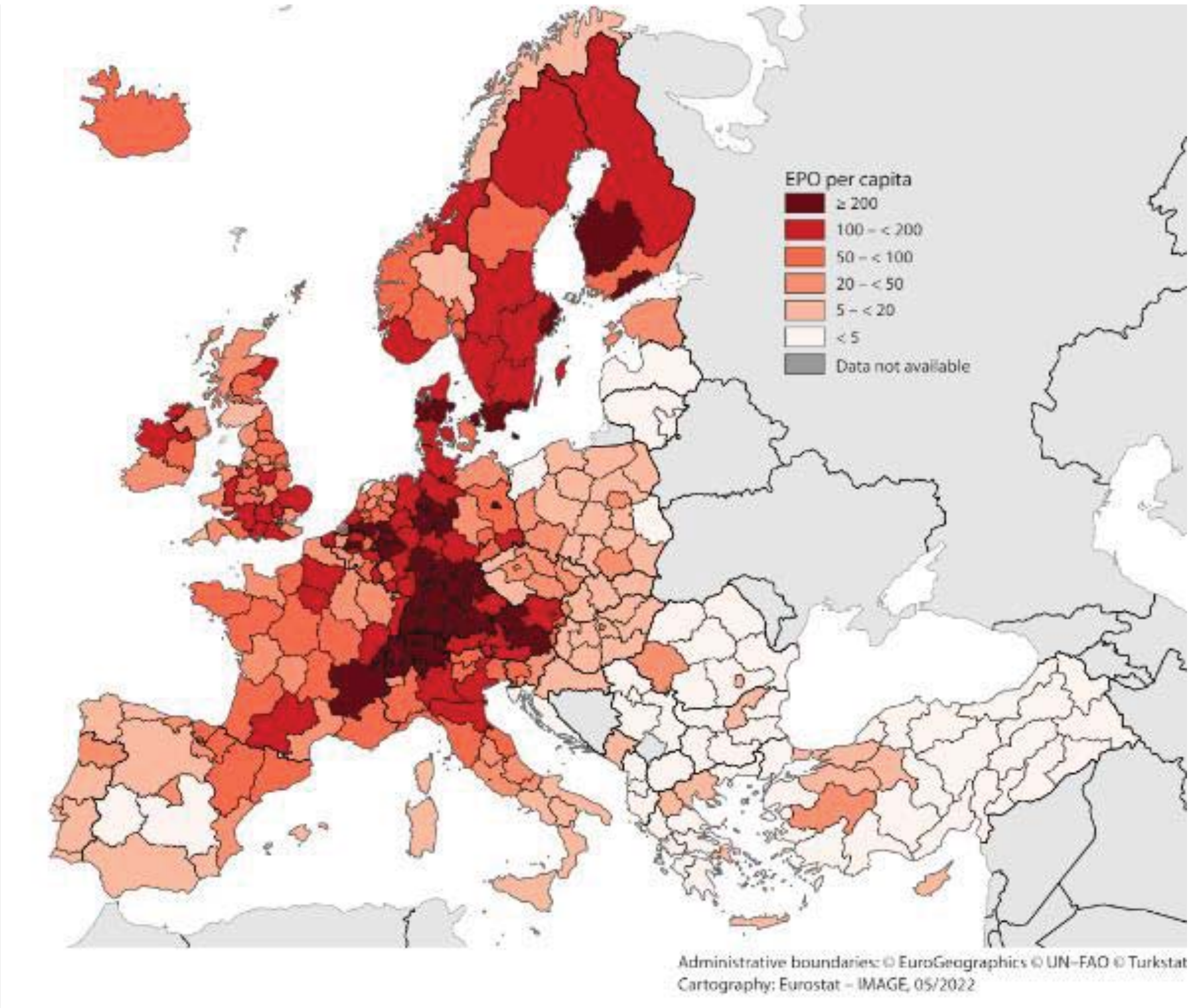
Figure 18. Innovation performance of EU regions, 2021



Source: European Commission, (2022), The Eighth Report on Economic, Social and Territorial Cohesion based on Regional Innovation Scoreboard 2021. DG Regional and urban Policy, Publications Office of the European Union. Luxembourg Note: AT, BE, FR: NUTS 1.

The technological output as measured by patents is concentrated in regions with a high share of manufacturing and with headquarters of large companies. The innovation divide across regions located in Western and Northern Europe and those in Central and Eastern Europe as well as with some Southern countries continues to be pronounced. Some of the least innovative regions in Portugal or Greece have increased the contribution to EU total patents applications over 2010-2018, but the regions that experienced the highest increases in their contribution to EU total patents are in Austria, Belgium and Germany, which are already amongst the top innovative regions.

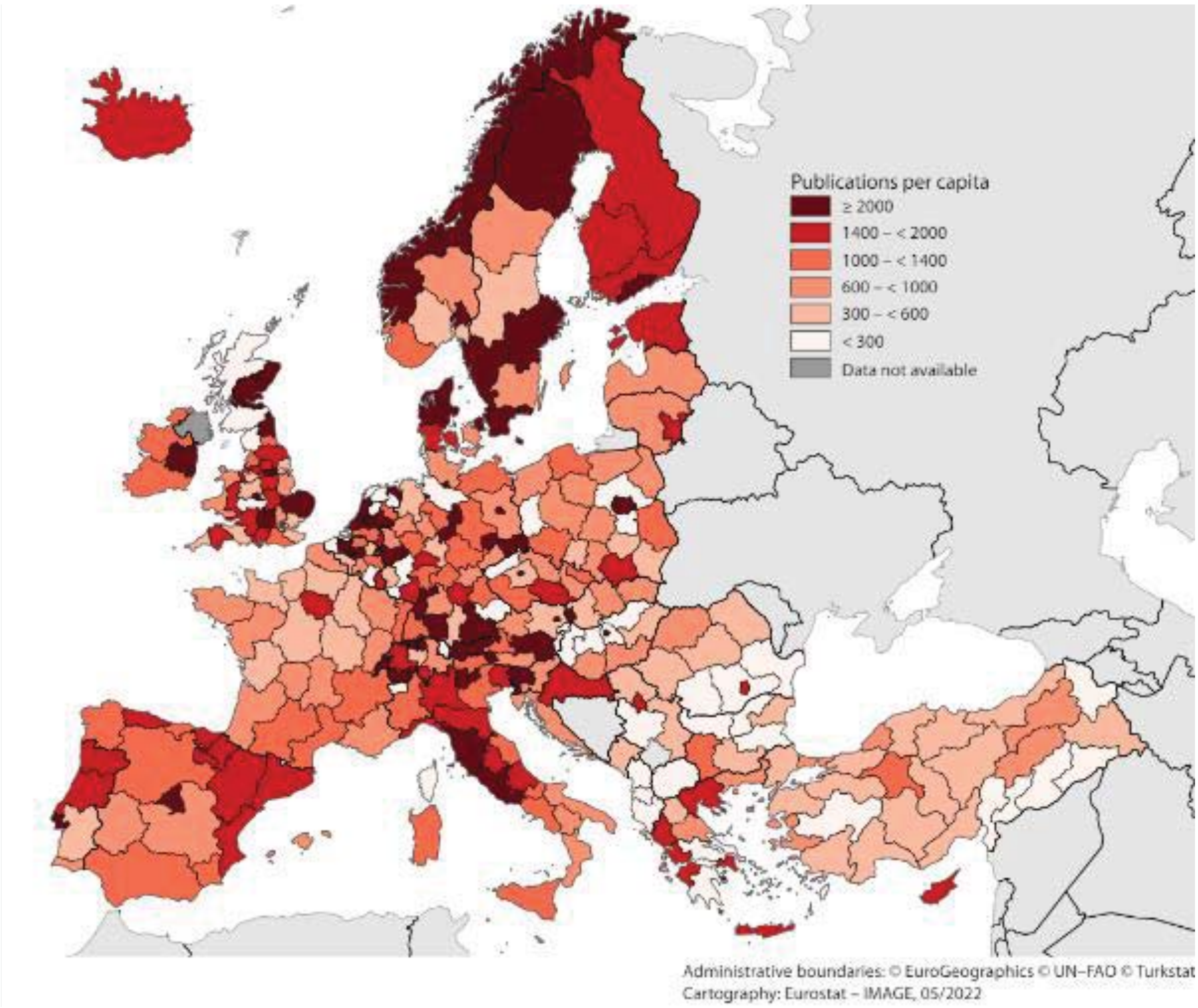
Figure 19. Total EPO applications (fractional count) per million inhabitants at NUTS 2 level, 2018



Source: DG Research and Innovation based on Science Metrix – European Patent Office.

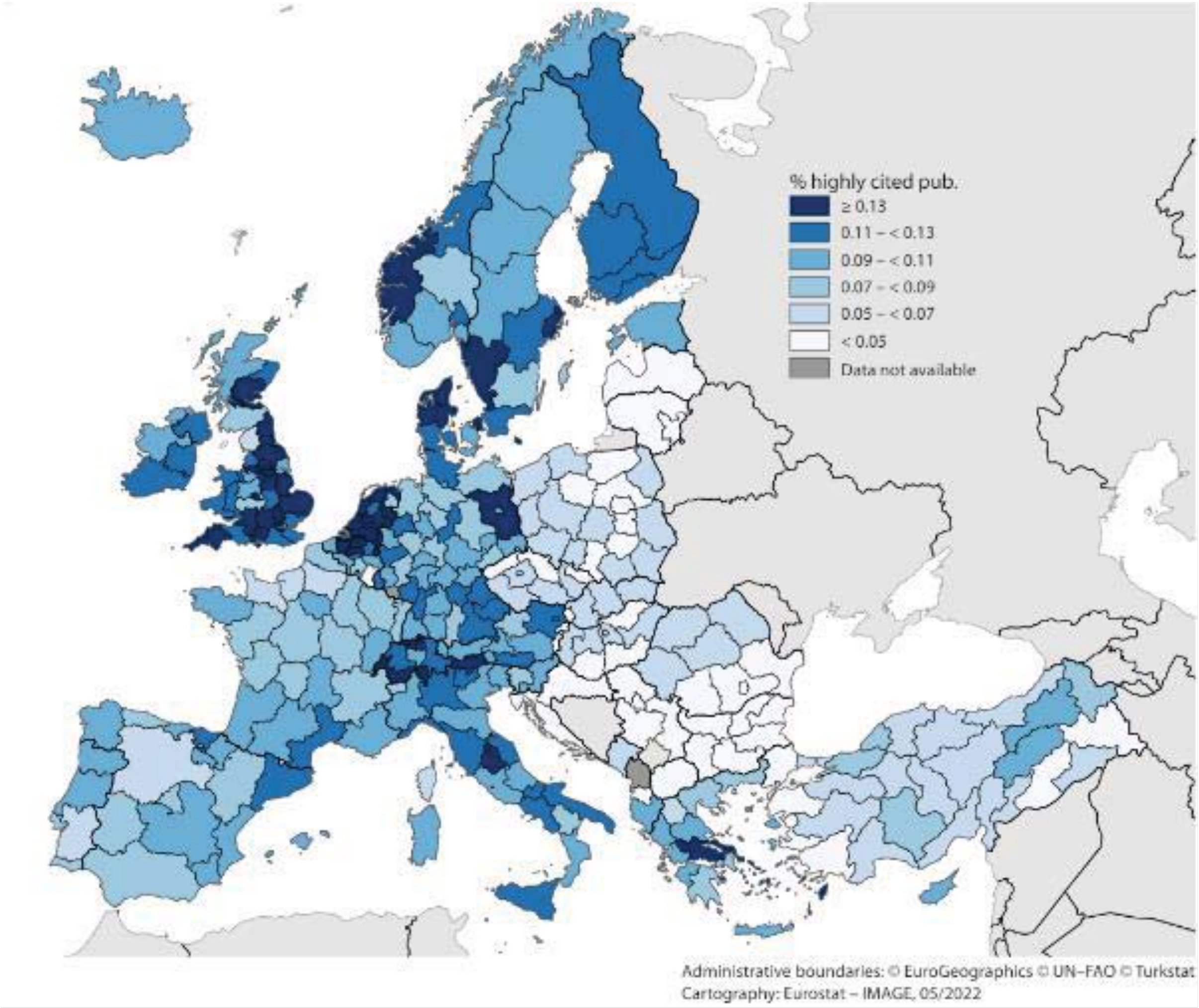
Scientific production measured by scientific publications shows a relatively dispersed pattern across the regions of the EU, although the divide is not as clear as, for example, in terms of overall innovation capacity (Figure 20). Many of the lagging regions, mostly in Eastern and Southern Europe, show an improvement of performance in scientific output over the 2010-2020 period even though the dispersion between European regions has jumped up during 2020, possibly due to the impact of COVID-19 crisis on scientific production. The production of high-quality publications continues to be highly concentrated in a relatively few regions. Hence, the 10% top cited publications are mostly produced in Western Europe, with a dominance of Dutch and Nordic regions (Figure 21).

Figure 20. Scientific publications (fractional count) per 1000 inhabitants at NUTS 2 level, 2020



Source: DG Research and Innovation based on Science Metrix - Scopus.

Figure 21. Percentage of highly-cited publications (top 10%) at NUTS 2 level, 2018



Source: DG Research and Innovation based on Science Metrix - Scopus.

Technology investments also tend to be geographically concentrated, raising the concerns of increasing inequality among regions and how to improve multilevel governance and synergies. Thus, policy interventions aiming at reinforcing and improving the functioning of local innovation ecosystems, particularly in less developed regions, are particularly important for achieving the twin transition, together with the interconnection of regional ecosystems and hubs.

Over the 2015-2018 period, regional disparities in technological innovation have been on an increasing trend. The EU has experienced a convergence process in patenting activity in the beginning of the 2000s, but it has stopped in the middle of the 2010s and, since 2015, the gap between the most and the least innovative regions in terms of patent applications has widened (Table 1). **As far as scientific publications are concerned,** it appears that the convergence process, which was pronounced in the beginning of the 2000s, **is still valid over the 2016-2020 period, but at a much slower pace than it was.** Figure 22 also demonstrates that, over 2016-2021, the share of emerging innovators (the least innovative class) has increased in the less developed regions, meaning that more regions are lagging behind in 2021 compared to 2016. Less developed regions face indeed more difficulties in translating research results into innovation and the returns in terms of patenting on additional R&D

investment tend to be lower than in other regions.[137] Although there is convergence pattern among scientific publications, many disadvantages in less developed regions of Europe prevail and these are less capable of generating innovation from R&D inputs.[138]

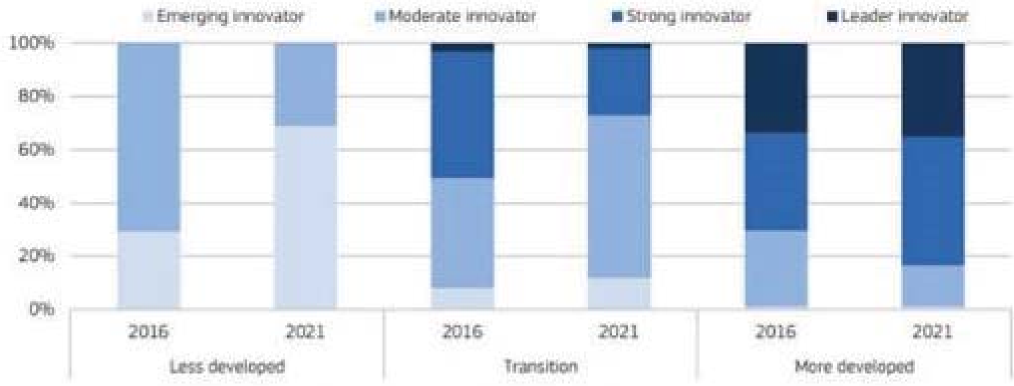
Table 1. Annual growth between 2001 and 2018/2020 for research outputs (patent applications and scientific publications – fractional count) per groups of regions (NUTS 2 level)

	Annual Growth			
Patents per million inhabitants	2001-2005	2006-2010	2011-2014	2015-2018
Most performant regions (1st tercile)	1.1	-0.6	0.3	-3.6
Middle performers (2nd tercile)	4.5	0.6	0.7	-4.7
Least performant regions (3rd tercile)	16.2	1.7	5.3	-11.8
Patents	2001-2005	2006-2010	2011-2014	2015-2018
Most performant regions (1st tercile)	2.4	0.1	-0.1	-2.8
Middle performers (2nd tercile)	5.5	1.6	1.3	-2.4
Least performant regions (3rd tercile)	16.7	1.6	4.1	-12.6
Publications per million inhabitants	2001-2005	2006-2010	2011-2015	2016-2020
Most performant regions (1st tercile)	4.1	2.9	1.4	0.9
Middle performers (2nd tercile)	6	4.3	2.6	1.7
Least performant regions (3rd tercile)	10	9.7	4	2.1
Publications	2001-2005	2006-2010	2011-2015	2016-2020
Most performant regions (1st tercile)	4.6	3.3	2.1	1.2
Middle performers (2nd tercile)	6.5	4.6	2.4	1.3
Least performant regions (3rd tercile)	11.2	9.2	4.1	2.6

Source: DG Research and Innovation based on Science Metrix – Scopus and European Patent Office.

[137] Sterlacchini, A., (2008), 'R&D. higher education and regional growth: Uneven linkages among European regions', *Research Policy*, 37.
[138] Rodríguez-Pose, A, Ketterer, T. (2020), 'Institutional change and the development of lagging regions in Europe', *Regional Studies*, 54(7), pp. 974-986.

Figure 22. Share of EU population by Regional Innovation Scoreboard category and regional level of development, 2021 and 2016



In cases where the RIS score is only available at NUTS 1 level, it is assumed that the same score applies to the latter's constituent NUTS 2 regions. Calculations for both years are based on 2021 population data and level of development classification.
Source: Regional Innovation Scoreboard 2021, DG REGIO calculations.

Rural and urban areas differ in the intensity of innovation as well as in the type of innovation. As illustrated in Table 2, urban regions are much more active in patenting and publications activities than rural or intermediate regions. In Europe, metropolitan regions gather 74% of patent applications in 2018, 84% of scientific publications in 2020, and 87% of highly cited publications. When it comes to the types of innovation, it appears that high-density areas are characterized by a higher degree of unconventionality in innovation, meaning that **research activities and product innovations tend to be concentrated in large cities** or more agglomerated settings, **while process innovations and less technology-intensive activities tend to be more distributed in space.**[139] Besides, while **rural regions** more rarely produce learning related to R&D activities ("learning by searching") they **have a fundamental role in the other dimensions of learning** (by doing; by using; and – in particular – by interacting).

[139] *Eder*, J. (2019), 'Innovation in the Periphery: A Critical Survey and Research Agenda', *International Regional Science Review*, 42(2), pp. 119-146; E. Berkes, R. Gaetani., (2020), The Geography of Inconventional Innovation, *Economic Journal*, 131(636), pp. 1466-1514.

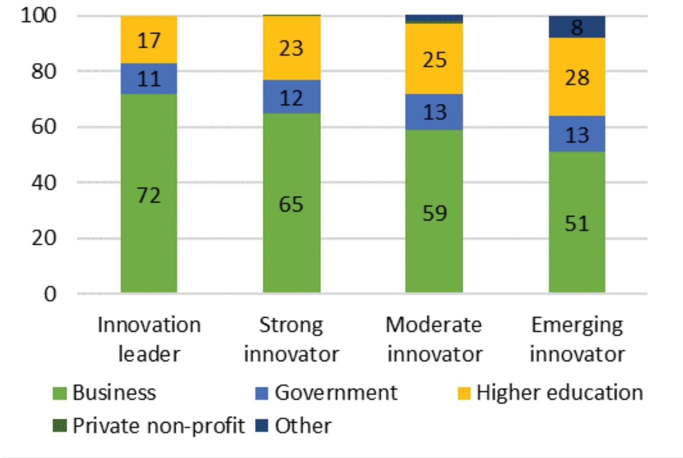
Table 2. Urban-rural innovation divide in Europe

Type of regions	Regions predominantly urban	Regions intermediate. close to a city	Regions intermediate. remote	Regions predominantly rural. close to a city	Regions predominantly rural. remote
Number of regions in Europe	240	464	48	265	150
Publications per million inhabitants 2020 (frac. Count) **% change from 2014 to 2020**	2078.9 + 6.46%	1145.2 +9.3%	400.5 +19.2%	397.7 +14.4%	302.9 +44.5%
Share of publications 2000-2020	63.7%	30.5%	0.6%	4.2%	1.0%
Average of Highly Cited publications (Top 10%) over total publications 2000-2020	0.086%	0.072%	0.063%	0.052%	0.06%
Average of Highly Cited Publications (Top 1%) over total publications 2000-2020	0.008%	0.007%	0.005%	0.004%	0.005%
Patents per million inhabitants 2018 **% change from 2014 to 2018**	132.4 -14.6%	104 -14.5%	31.3 -29.8%	65.8 -4.7%	30.7 -15.2%
Share of patents 2000-2018	52.8%	36.1%	0.8%	8.6%	1.7%
Share of patents cited at least one time over the total patents 2000-2018	17.4%	19.5%	14.8%	20.0%	21.6%

Source: DG Research and Innovation - Common R&I Strategy and Foresight Service - Chief Economist Unit based on Eurostat and Science Metrix – European Patent Office and Scopus.

Regions with lower innovation capacity tend to rely relatively more on government and higher education sectors for R&D investments, whereas strong/leading innovators benefit more from the business enterprise R&D investments. Interestingly, it seems that innovation leaders are also characterized by the highest share of investments in R&D coming from the government, but less from the higher education sector (Figure 23).

Figure 23. Share of 2019 R&D investments per sectors of performance across EU regions classified according to RIS scores



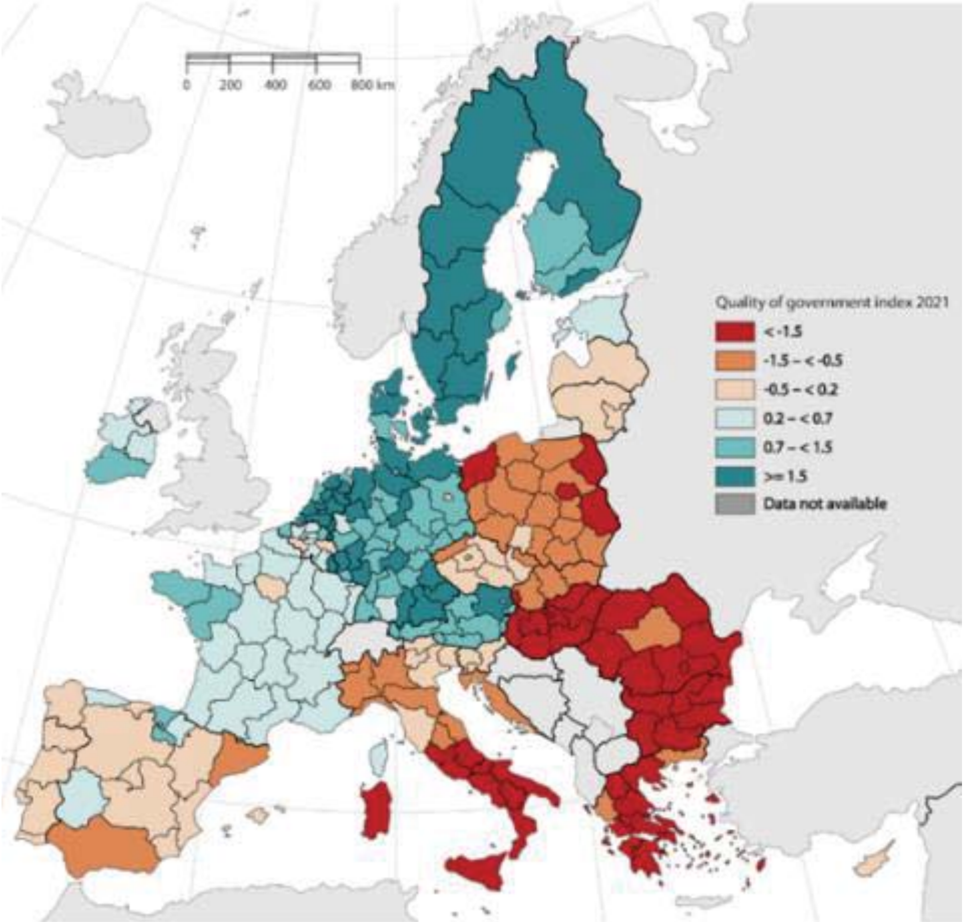
Source: DG Research and Innovation based on Eurostat and the Regional Innovation scoreboard.

Note: no data for BE, FR and NL.

Institutional quality, a key determinant in the innovation capacity of regions, is high in the core of the EU, but with a high degree of regional variation and heterogeneity (Figure 24). Good institutional frameworks improve economic and innovation prospects as they reduce uncertainty on the appropriability of the returns on investment, which is already higher in the context of R&D and innovative activities.[140] Besides, institutional quality ensures the effective and generalised protection of property rights, provides the public infrastructure needed for the diffusion and use of technology, allows for the effective control of corruption, and ensures the efficient delivery of public goods and services, including education at all levels.

[140] Rodríguez-Pose, A., Di Cataldo, M., (2015), 'Quality of government and innovative performance in the regions of Europe', *Journal of Economic Geography*, 15(4), pp. 673-706.

Figure 24. Quality of government across EU regions, 2021



Source: Charron, N., Lapuente, V., Bauhr, M. (2021), Sub-national Quality of Government in EU Member States, University of Gothenburg: The QoG Working Paper Series 2021:4.

The fast pace of innovation dynamics poses new challenges on production systems of many less developed regions, which are often not sufficiently oriented towards knowledge intensive sectors as mirrored in their lower performance of their regional R&I systems (Figure 25). **Many transition regions are characterised by low performance on R&I have also not done well as regards productivity growth**. It has become increasingly clear over recent years that not all regions in the EU with a GDP per capita below the average are catching up.[141] Iammarino et al. (2019)[142] demonstrate that while economic activity and wealth have increasingly accumulated in large urban agglomerations, often capital cities, **many areas have increasingly been caught in 'development traps'**. Since 2000, an increasing number of regions have experienced stagnating economic development in terms of GDP growth, productivity and employment after reaching a level of GDP per capita of 75–100% of the EU average. **Many of these regions are less cost-competitive than less developed regions, characterised by the low cost of capital and labour, and by being less innovative or productive than more developed regions**. Accordingly, their costs tend to be too high to compete with less developed regions and their innovation systems not strong enough to compete with more developed regions.

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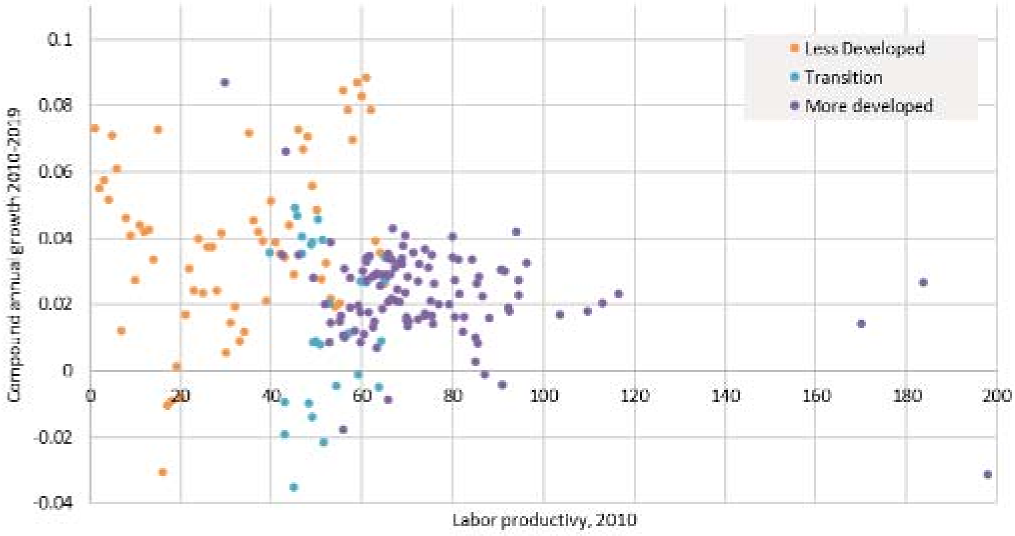
[141] European Commission, (2022), *Cohesion in Europe towards 2050. Eight report on economic, social and territorial development,* Directorate-General for Regional and Urban Policy Luxembourg: Publications Office of the European Union.
[142] Iammarino S., Rodriguez-Pose A., Storper M, (2019), 'Regional inequality in Europe: evidence, theory and policy implications', *Journal of Economic Geography*, 19(2), pp. 273–298

Figure 25. Labour productivity (GDP per person employed), 2010 and annual real growth, 2010-2019, classified by regional development.



Source: DG Research and Innovation based on Eurostat. Note: GDP per worker in current PPS. FR and PL NUTS2 regions not included.

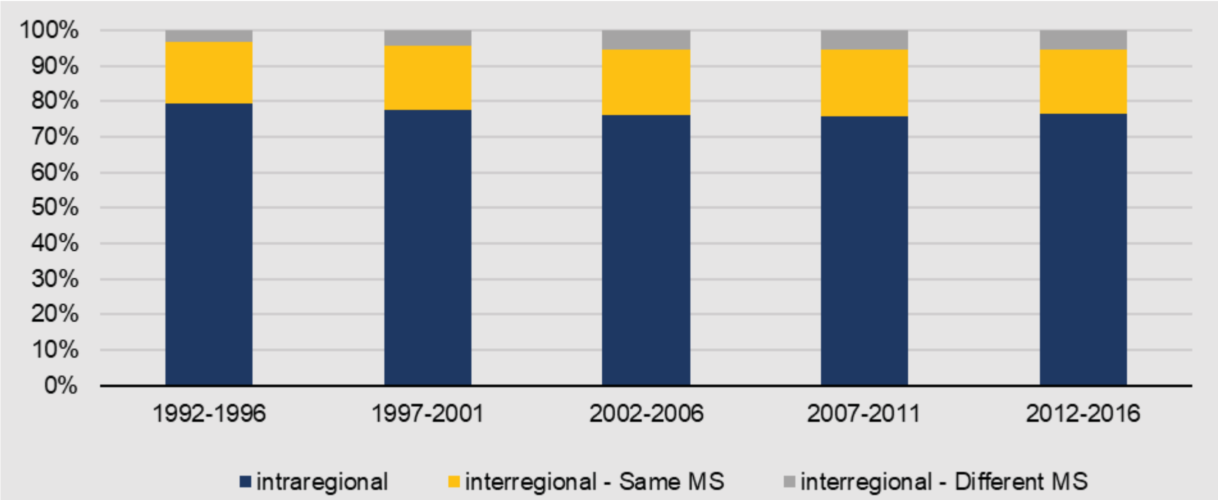
Remaining for long in a development trap is brewing increasing inequalities and geography of EU discontent.[143] Subpar economic performances, lack of employment opportunities, and loss of competitiveness due to low productivity levels are causing social and political resentment towards what is increasingly regarded – justly or unjustly – as a system that does not benefit areas being left behind.[144]

2.3.2 Interregional collaboration across the EU research and innovation ecosystems

Inter-regional co-patenting remains very limited in the EU, even if it has slightly increased from 1992 to 2016. Over 3/4 of collaborations on patents (co-patenting) takes place within the same region, somewhat less than 1/5 is inter-regional with stakeholders in other regions of the same country and only 3-5% is inter-regional across national borders (Figure 26). Still, there are some improvements in terms of inter-regional collaboration beyond national borders – the share from 3.2% over the 1992-1996 period to 5.4% over the 2012-2016 period. **The importance of proximity goes beyond production of research and innovations, as it seems that knowledge diffusion also remains mostly national.** For example, the EIB (2021)[145] used the cross-country citation index, which measures how often countries refer to one another in relative terms, to demonstrate **that most green knowledge stays within national borders or regions.** For both technological innovation and diffusion of knowledge, collaboration and circulation across regions and Member States is as critical to tackle global societal challenges as proximity can be. It ensures that inventions and knowledge benefit from work already done by others. Policy implications include strengthening the ties between regions across national borders, including through R&I policies at European level.

[143] Dijkstra L., Poelman H., Rodriguez-Pose A., (2018)., *The geography of EU discontent,* European Commission, DG Regional and Urban Policy, Luxembourg: Publications Office of the European Union, WP 12/2018.
[144] European Commission, (2020), *Falling into the Middle-Income Trap? A Study on the Risks for EU Regions to be Caught in a Middle-Income Trap*, Final Report, Luxembourg: Publications Office of the European Union.
[145] European Investment Bank (2021), *EIB Investment Report 2020/2021: Building a smart and green Europe in the COVID-19 era.*

Figure 26. Inter- and intra-regional collaboration in patenting (co-patenting) in Europe over 1992-2016



Source: Science, Research and Innovation Performance of the EU Report 2022.

Innovation related to some strategic technologies follows a very specific geography.[146] By mapping links between technologies and the current knowledge structure of EU regional eco-systems, it becomes possible to predict the growth potential of new technologies. Relatedness density maps[147] (Figure 27) indicate which EU regions are in the best position to lead technological change in seven key technologies. Each technology is characterized by a very specific geography. Ile de France, Oberbayern have core technologies related to AI – but when it comes to batteries Rhone-Alpes, Stuttgart, or Trondelag (Norway) are better positioned. mRNA connects most to technologies found in the capital region of Denmark or Languedoc-Roussillon.

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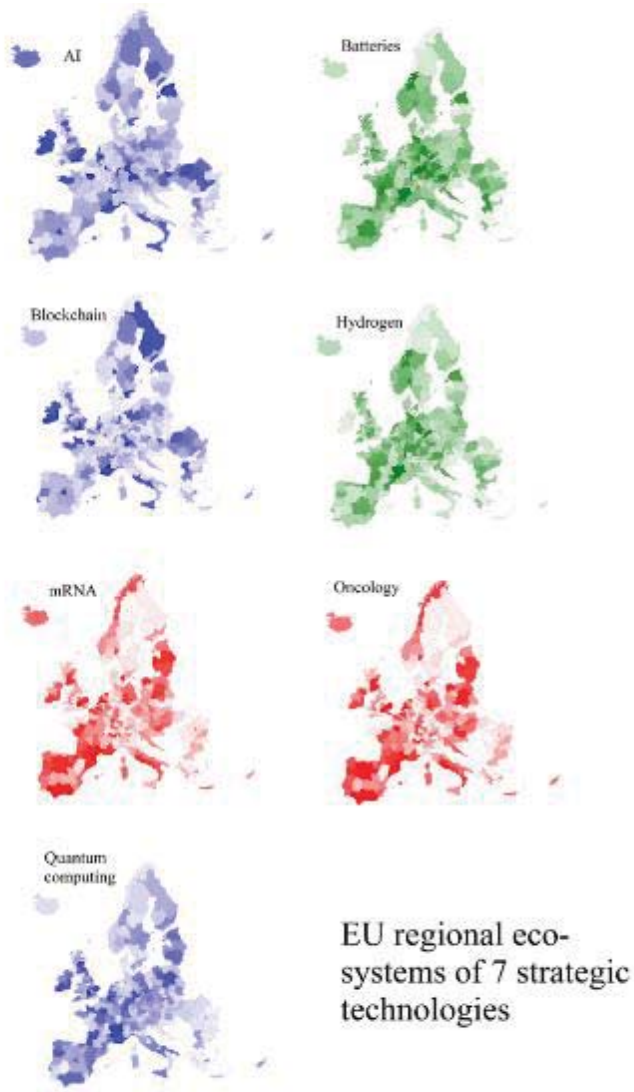
[146] Balland, P.A., (2022), *Innovation policy for a complex world*, In : Science, Research and Innovation Performance of the EU Report 2022, European Commission, DG Research and Innovation, Publications Office of the European Union. Luxembourg.

[147] Relatedness density indicates – for any domain - the shares of related technologies that are present in a region. To illustrate this principle with a simplified example, let's say that 10 technologies are related to AI and 8 of these technologies can be found in Paris, relatedness density between AI and Paris is 8/10 = 80%. Regions with the highest relatedness density are the strongest candidates for prioritizing funding.

Figure 27. Relatedness density maps for seven key technologies in the EU



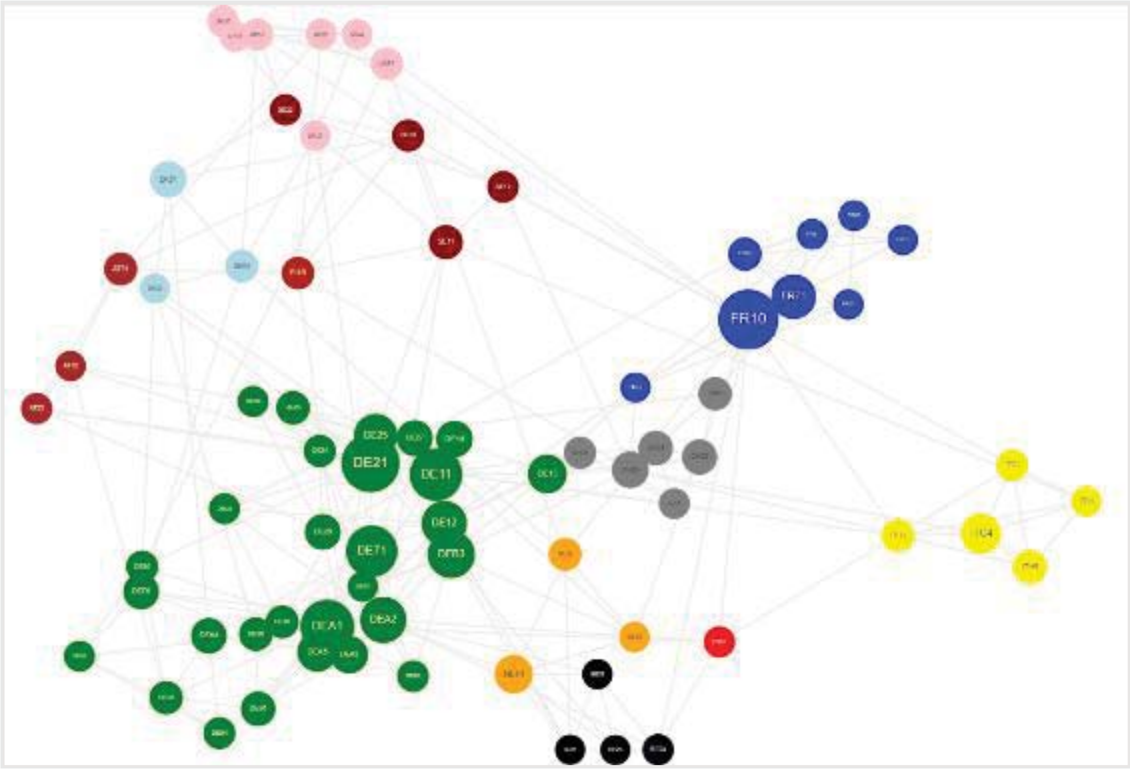
Source: Balland, P.A., (2022), Innovation policy for a complex world, In : Science, Research and Innovation Performance of the EU Report 2022, European Commission, DG Research and Innovation, Publications Office of the European Union. Luxembourg.

A carefully designed research & innovation policy could be technology-specific and empower relevant knowledge eco-systems. It is also important to stimulate inter-regional linkages. Links that are the most impactful for regional leadership and innovation are the ones that build on complementary assets.[148]Another fundamental way to document the spatial distribution of knowledge is not to look at regions in isolation with each other's but to analyse the European inter-regional system of innovation. Figure 28 shows the co-inventor ties between regions[149], for all technologies. **When looking at collaborations, country borders become extremely marked.** The top 10 connections of Ile de France - the EU regions with the most internal collaborations – are all other French regions. The same goes for Upper Bavaria and other EU regions. European regions disproportionally favour same-country collaborations over pan-European ones. **This fact signals system failure in the innovation**

[148] Balland, P. A., Boschma, R. (2021), 'Complementary interregional linkages and Smart Specialisation: an empirical study on European regions', *Regional Studies*, 55(6), pp. 1059-1070.
[149] In the network presented, links between regions (n=74) that have more than 10000 internal links are displayed for purely visualization purpose.

systems that justify higher-policy level intervention to scale-up EU technologies and achieve global leadership in the twin transition.

Figure 28. The EU regional system of innovation – network



Source: Balland, P.A., (2022), Innovation policy for a complex world, In : Science, Research and Innovation Performance of the EU Report 2022, European Commission, DG Research and Innovation, Publications Office of the European Union. Luxembourg.

European regions are hosts to pockets of specialisation in specific sectors of the industry, including the 14 European industrial ecosystems[150]. When considering the industrial specialisation of European regions, over 1100 industry-relevant specialisation nodes across the EU-27 can be identified, accounting for 19.5% of total employment. These pockets of specialisation gather SMEs, large firms, research organisations, related economic actors and institutions, which are located near each other and have reached a sufficient scale to develop specialised expertise, services, resources, suppliers, and skills[151]. Regional industry clusters have a positive impact on regional and industry performance, including job creation, patenting, and new business formation[152], which could explain the high concentration of technological innovation in different sectors across the EU regions. Finally, research and technology infrastructures (e.g., demonstrators, testbeds, incubators and accelerators) are also key in creating and maintaining dynamic R&I ecosystems (see Box 3). For technology infrastructures there is a need to develop a European Strategy for Technology Infrastructures

[150] Communication from the European Commission, 2021, Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery, COM(2021) 350 final.
[151] Cluster Definitions | European Cluster Collaboration Platform.
[152] Glaeser, E.L., W.R. Kerr, 2009, 'Local Industrial Conditions and Entrepreneurship: How Much of the Spatial Distribution Can We Explain?', *Journal of Economics and Management Strategy*, 18 (3), pp. 623–63; Delgado, M., M.E. Porter, and S. Stern (2014), 'Clusters, Convergence, and Economic Performance', *Research Policy*, 43(10), pp. 1785-1799.

to support technology co-creation, scale-up and diffusion across Europe to strengthen its technology sovereignty.[153]

Box 3. The role of Research Infrastructures and Technology Infrastructures in Innovation

The EU benefits from a rich landscape of complementary national, regional and European research infrastructures (RIs) and technology infrastructures (TIs). They are enablers for excellent science, creation of new and fundamental knowledge and have impact beyond research to attract the best talents, researchers, highly qualified engineers, technicians and students; to further develop regional, local, national and EU level innovation ecosystems; and to facilitate the uptake of technologies by regional and local industries notably SMEs and high-tech companies as well as to cooperate at EU level and with global industries.

RIs and TIs are both essential for a functional and efficient European R&I System. Complementing RIs, TIs are used by industry to develop, test and upscale technology to advance from validation in a laboratory up to higher TRLs prior to competitive market entry. Technology infrastructures are a key element in the development of local and regional innovation ecosystems, alongside civil society, universities, RIs, RTOs, industry and SMEs. Beyond the regional and local aspect, pan-European networks of technology infrastructures, offering bundled services for specific technology domains, will help increase innovation cohesion in Europe.

The role of technology infrastructures as accelerators in the "lab' to fab'" process was outlined in the Staff Working Document on technology infrastructures.[154] TIs are, therein, understood as "facilities, equipment, capabilities and support services required to develop, test and upscale technology to advance from validation in a laboratory up to higher TRLs prior to competitive market entry. They can have public, semi-public or private status. Their users are mainly industrial players, including SMEs, which seek support to develop and integrate innovative technologies towards commercialisation of new products, processes and services, whilst ensuring feasibility and regulatory compliance".

At the same time, "research infrastructures" means facilities, resources and related services that are used by the scientific community to conduct research in their respective fields and covers scientific equipment or set of instruments, knowledge-based resources such as collections, archives or structured scientific information, enabling information and communication technology-based infrastructures such as grid, computing, software and communication, or any other entity of a unique nature essential to conduct research. Such infrastructures may be 'single-sited' or 'distributed' (an organised network of resources).

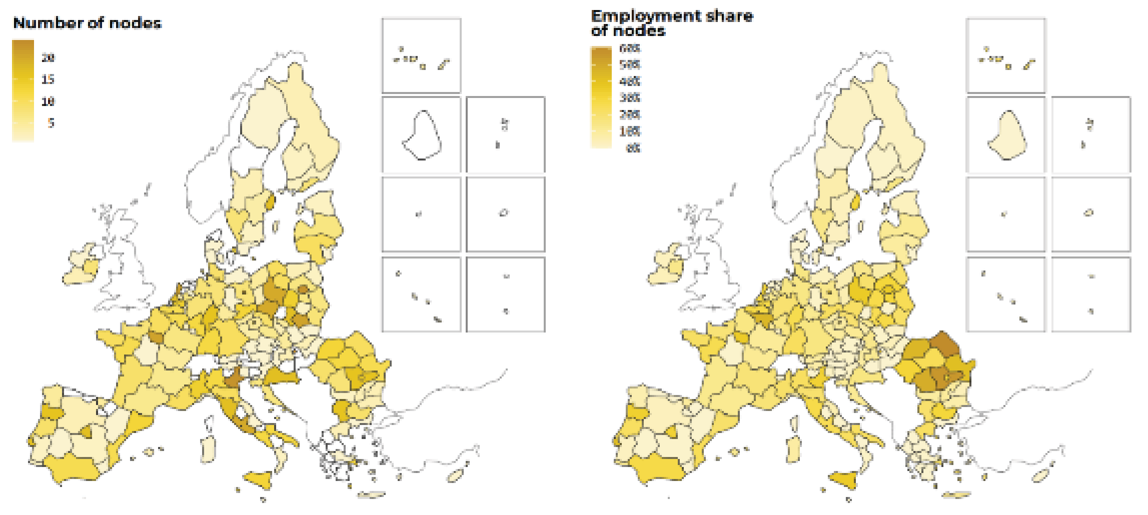
In the broader context of the European research infrastructures landscape, RIs and TIs each have their own specificities and both are important components in a well-functioning R&I system. As underlined in the *JRC Policy Brief*[155], there is a continuum between RIs and TIs, and they often are complementary: RIs create new scientific knowledge, which is often used by TIs to address the future needs of European society and industry. To be able to achieve the ambitious targets of the twin transitions, research actors, industry and SMEs in Europe need access to both, world-class RIs

[153] SWD(2019)158 final, European Commission Staff Working Document on Technology Infrastructures; COM(2020) 628 final, European Commission Communication A new ERA for Research and Innovation; EARTO (2020), *EARTO paper: Setting-up a European Strategy for Technology Infrastructures*; Council conclusions of future ERA Governance 14308/21.
[154] SWD(2019)158 final.
[155] Taucer, F., Grande, S., Kert, K. and Jenet, A. (2021), *Towards the Implementation of an EU Strategy for Technology Infrastructures*, European Commission, Brussels, JRC127798.

and TIs, which are integrated at EU, national and regional levels.

In the *Implementation of an EU Strategy for Technology Infrastructures Report*[156], the analysis shows that TIs are mostly created, managed, maintained and upgraded by Research and Technology Organisations (RTOs) and Technical Universities. Hosting such high-class, well-functioning TI requires dedicated and significant resources from organisations, as well as interdisciplinary and complex technological competences and thirdly, complementary non-technological expertise and highly skilled staff to operate them and to develop their services. TIs are open to a wide range of public and private users such as industry and SMEs collaborating with TIs to jointly develop and integrate innovative technologies into new products, processes, and services.

Figure 29. Industry-relevant specialisation nodes and their share of regional employment



Source: European Cluster Panorama 2021 Leveraging clusters for resilient, green and digital regional economies, December 2021. Note: Industry-relevant specialisation nodes: When the region is specialised in the sector (or industrial ecosystem) (LQ > 1.5) and regional employment in the sector is relevant in the EU context (industry employment share > 1%).

Technologies – especially the most complex ones - are heavily concentrated in a few regional ecosystems. It is essential to take into account this real-world pattern and design an EU-wide place-based[157] innovation policy. Second, the EU regional innovation system does not reflect this geography when it comes to inter-regional collaborations. This gap signals a poor knowledge capability matching and it could be reduced with network-based innovation policy tools. Finally, **resilience at regional level will partly depend on the development of innovation systems and intermediaries that can encourage diffusion and absorption of productivity enhancing technologies, as well as the ability to build on national and regional capabilities to generate new knowledge.**

[156] Viscido, S., Taucer, F., Grande, S. and Jenet, A., (2022), Towards the Implementation of an EU Strategy for Technology Infrastructures, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-46490-7 (online),978-92-76-46502-7 (print), doi:10.2760/4834 (online),10.2760/761184 (print), JRC128007.
[157] Place-based innovation policy is meant in the sense of policy that leverages regional ecosystems to generate EU global leadership.

2.4 Deep tech talents

2.4.1 EU international and intersectoral circulation of talents

Europe faces challenges when it comes to talent circulation. The internationalisation policies of higher education in Europe in terms of the Bologna and Lisbon processes have boosted both the mobility within Europe and migration to Europe, improving European competitiveness in higher education (also due to enhanced attraction of international students).[158] However, there is still space for improvement in terms of EU attractiveness.[159] Furthermore, the decision of the UK to leave the EU might impact on the attractiveness of the European Research Area (ERA) as the UK has been an important part of the EU strategy in attracting international researchers and PhDs.[160]

Overall, eastern and southern European countries experience higher outgoing flows of talents, while western and northern European countries are benefiting from high incoming flows of talents. When calculating the inflow and outflow of researchers in Europe during the last 20 years (Figure 30) to and from the rest of the world (intra and extra EU mobility), there is a brain drain in most eastern and southern European countries like Italy, Greece, Hungary or Poland, with the outflow of researchers outstripping the inflow. These results might be explained by poor career conditions and less attractive research systems that led researchers to look for better conditions in other countries. On the other hands, in the northern and western European countries such as Switzerland, Luxembourg, Norway or United Kingdom, the inflow of researchers outpaces the outflow, thus leading to a brain gain. The results also show that most EU countries show a ratio below 1, which means that more researchers left the country during the period than entered the country. These might be explained by the fact that, not only in most EU countries, the United States are the top destination (data not shown) for European researchers, but also the outflow is higher than the inflow of American researchers to the EU.

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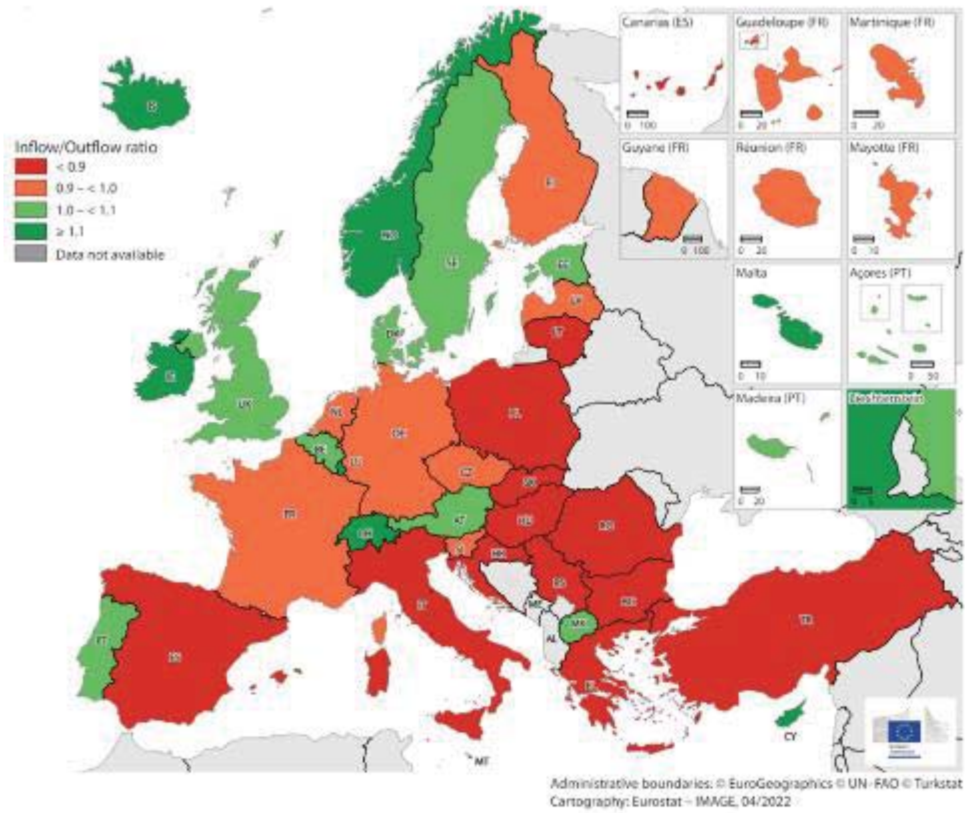
[158] European Commission (2020), *2019 Annual Report on Intra-EU Labour Mobility* (Link); De Wit, H. (2012), *Student mobility between Europe and the rest of the world: Trends, issues and challenges*. In A. Curaj, P. Scott, L. Vlasceanu, & L. Wilson (Eds.), *European higher education at the crossroads* (pp. 431–439). Springer; Teichler, U. (2009), Internationalisation of higher education: European experiences, *Asia Pacific Education Review*, 10(1), 93–106.

[159] Khan, J. (2021), European academic brain drain: A meta-synthesis, *European Journal of Education*, *56*(2), 265-278; PPMI, IDEA Consult and WIFO (2021), *MORE4 study: Support data collection and analysis concerning mobility patterns and career paths of researchers*, European Commission; Grigolo, M., Lietaert, M., & Marimon, R. (2010), 'Shifting from academic "brain drain" to "brain gain" in Europe', *European Political Science*, 9(1), pp.118–130; Ackers, L. (2008), 'Internationalisation, mobility and metrics: A new form of indirect discrimination?' *Minerva*, 46(4), pp. 411–435.

[160] Courtois, A., Veiga, A. (2020), 'Brexit and higher education in Europe: the role of ideas in shaping internationalisation strategies in times of uncertainty', *Higher Education*, 79(3), pp. 811–827.

Figure 30. Map with the ratio between inflow and outflow of researchers during the period 2001-2020 by country



Source: DG Research and Innovation - Common R&I Strategy and Foresight Service - Chief Economist Unit based on data provided by Science-Metrix under a contract with DG Research and Innovation

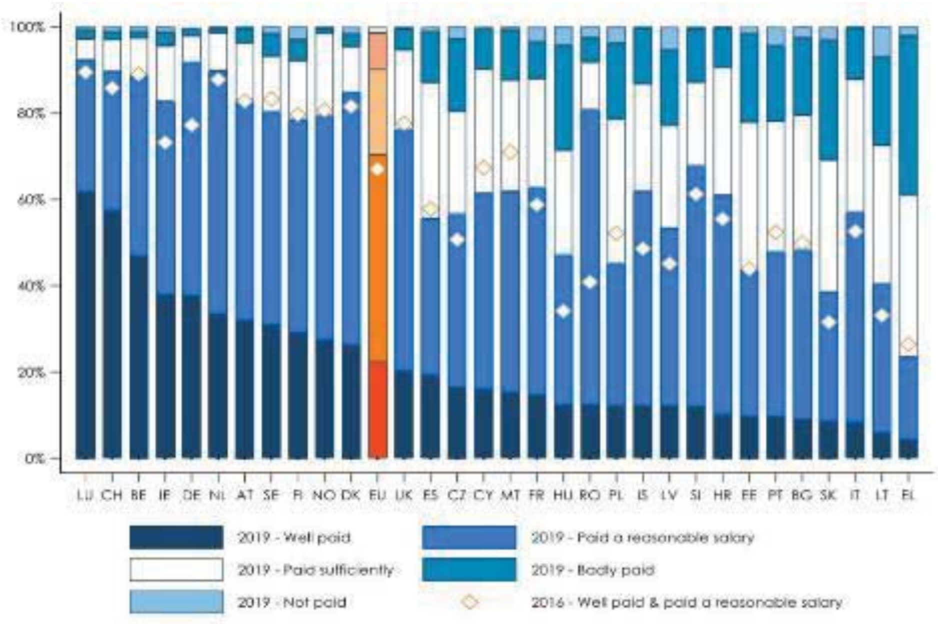
Note: (1) To investigate the mobility of individual researchers, Scopus author IDs (AUIDs) were selected as unique identifiers for individual researchers. AUIDs are generally quite precise and allow for the identification of sets of publications related to unique researchers. One drawback is that it is not as precise for common names, which mostly affects Chinese and Korean researchers, as well as researchers with highly frequent English names. In addition, because an AUID relies partially on institutional affiliations, mobility may cause a rupture in the portfolio of publications of researchers, resulting again in a split of the output between the original AUID and a new distinct AUID assigned after moving, again impacting the measurement of mobility. Therefore, the indicator will tend to underestimate mobility because of the aforementioned issues. (2)RO: period corresponds to 2001-2019.

The main elements found to pull talents outside of the EU are lower salaries if compared to US and Japan and the lack of fair recruitment processes, particularly in southern European countries.[161] In the last study provided by PPMI, IDEA Consult and WIFO (2021)[162], it is

[161] Mendoza, C., Staniscia, B., & Ortiz, A. (2020), '"Knowledge migrants" or "economic migrants"? Patterns of academic mobility and migration from southern Europe to Mexico', *Population, Space and Place*, 26(2), pp. 1–11; Ackers, L. (2008), 'Internationalisation, mobility and metrics: A new form of indirect discrimination?' *Minerva*, 46(4), pp. 411–435; Musselin, C. (2004), 'Towards a European academic labour market? Some lessons drawn from empirical studies on academic mobility', *Higher Education*, 48(1), pp. 55–78; Morano-Foadi, S. (2006), 'Key issues and causes of the Italian brain drain', *Innovation: The European Journal of Social Science Research*, 19(2), pp. 209–223; Grigolo, M., Lietaert, M., & Marimon, R. (2010), 'Shifting from academic "brain drain" to "brain gain" in Europe', *European Political Science*, 9(1), pp.118–130.

found that “international networking”, “working with leading scientists”, “quality of education and training”, “research autonomy”, “availability of appropriate funding” and “suitable positions” are the more important determinant of PhD mobility. On the other hand, the EU is found as attractive for its social security and retirement systems.

Figure 31. Perceptions of remuneration by country



Source: MORE4 EU HE survey (2019)

University-industry collaboration is a crucial channel for the production and diffusion of knowledge between universities and firms. It most commonly takes place in close geographical proximity.[163] Firms’ decision to collaborate with universities, research performing organisations and research and technology organisations is driven by the strategic decision of the firm to develop its innovation process. Furthermore, firm characteristics such as R&D intensity, firm size and human capital determine the propensity of firms to collaborate with universities and other research performing organisations.[164] Within the EU R&I Framework Programme projects, 70% of innovations with high potential are co-developed with universities.[165] In this context, collaboration between universities and SMEs seems to be particularly fruitful: considering that universities often report that what they most need in order to bring their innovation to the market is "partnership with other companies",

[162] PPMI, IDEA Consult and WIFO (2021) MORE4 study: Support data collection and analysis concerning mobility patterns and career paths of researchers, European Commission (Link).

[163] Acs, Z.J., Audretsch, D.B., Feldman, M.P. (1994), ‘R&D spillovers and recipient firm size’, *Rev. Econ. Stat.*, pp. 336-340; Piergiovanni, R., Santarelli, E., (2001), ‘Patents and the geographic localization of R&D spillovers in French manufacturing’, *Reg. Stud.*, 35 (8), pp. 697-702; Zucker, L.G., Darby, M.R., Furner, J., Liu, C., Ma, H. (2007), ‘Minerva unbound: knowledge stocks, knowledge flows and new knowledge production’, *Research Policy*, 36(6), pp. 850-863.

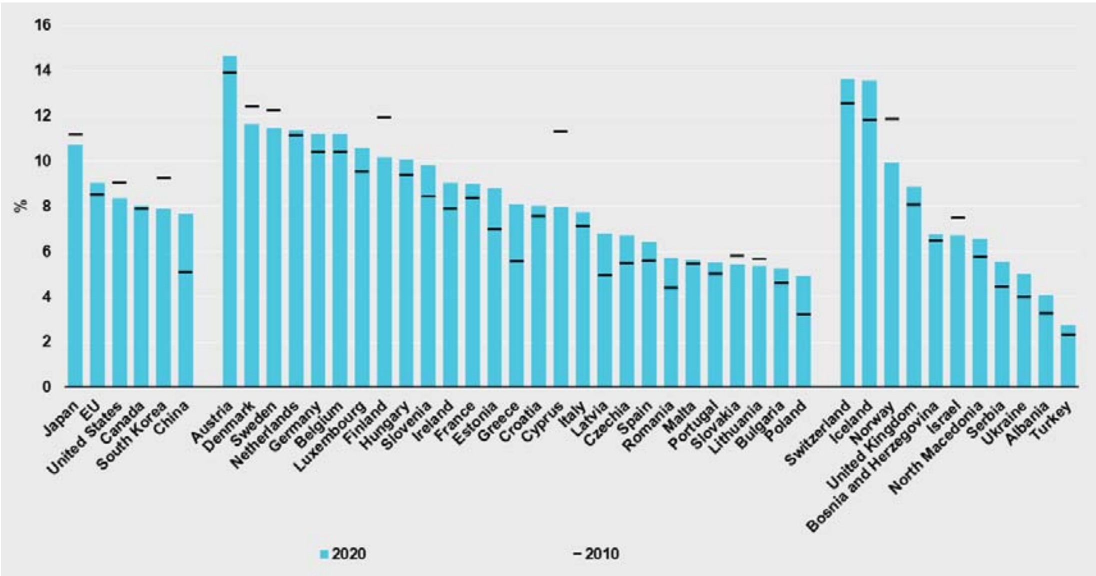
[164] Fitjar, R.D., Rodríguez-Pose, A. (2017), ‘Nothing is in the air’, *Growth Change*, 48 (1), pp. 22-39; Atta-Owusu, K., Fitjar, R. D., & Rodríguez-Pose, A. (2021), ‘What drives university-industry collaboration? Research excellence or firm collaboration strategy?’. *Technological Forecasting and Social Change*, 173, 121084; Garcia-Quevedo, J., Mas-Verdú, F., & Polo-Otero, J. (2012), ‘Which firms want PhDs? An analysis of the determinants of the demand’, *Higher Education*, *63*(5), 607–620; Maietta, O.W. (2015), ‘Determinants of university–firm R&D collaboration and its impact on innovation: a perspective from a low-tech industry’, *Research Policy*, 44 (7), pp. 1341-1359.

[165] JRC. Pesole, A., Nepelski D. (2016), *Universities and Collaborative Innovation in EC-funded Research Projects: An Analysis based on Innovation Radar Data*, JRC104870.

one can conclude that universities are seeking complementary capabilities, to help them commercialise their technologies. These capabilities can be brought in by private organisations, often SMEs participating to the EU Framework Programme projects.

Between 2010 and 2020, the share of public-private co-authored scientific publications increased from 8.5% to 9.1% in the EU. Within the EU, there are significant differences across the Member States. On one side, Austria, with a share of 14.7%, is the top performer, not only within the EU, but also among all countries selected. On the other side, Poland, with a share of 4.9%, is the least performing country in the EU. Countries with higher business R&D expenditure tend to have a higher share of public-private co-publications, since, in many cases, enterprises contract public research performing organisation and research and no-profit technology organisations to perform research, leading to more scientific publications. This research is then applied by the enterprises to develop new products or processes.

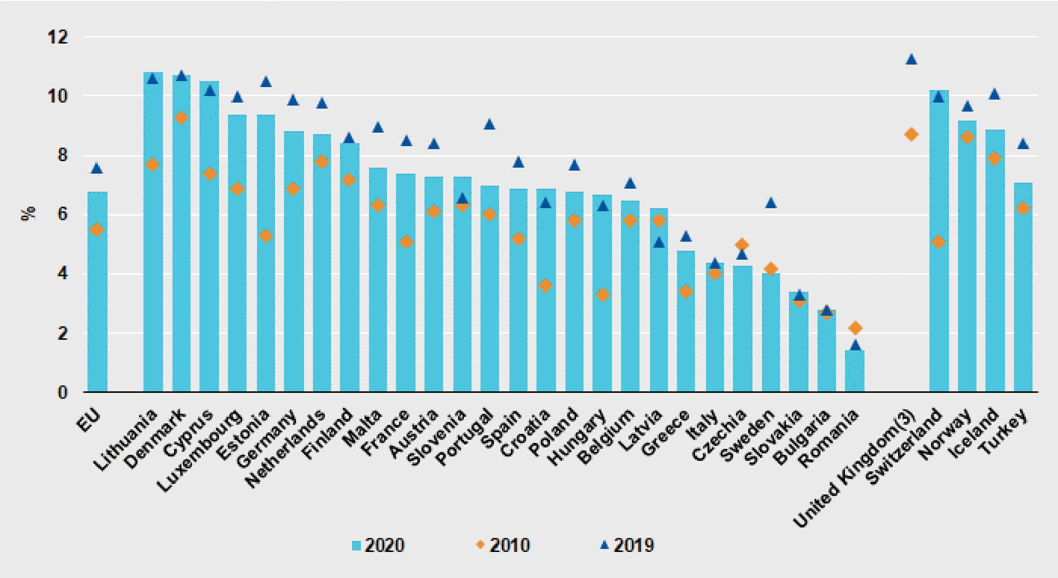
Figure 32. Share of public-private co-authored scientific publications in total scientific publications, 2010 and 2020



Source: Science, Research and Innovation Performance of the EU 2022. *Data from Science-Metrix*

At EU level, the share of job-to-job mobility has increased from around 6% to 7% between 2010 and 2020. Within the EU, there are significant differences in the mobility patterns of human resources in science and technology, as can be seen in Figure 33. With the exception of Czechia, Sweden and Romania, all other Member States had an increase in job-to-job mobility in the last ten years. Mobility increased the most in Estonia, Croatia and Hungary. Despite the increase in the ten-year period, there was a decline between 2019 and 2020 for the majority of the Member States and other European countries, in particular Sweden and Portugal. This drop can also be explained by the Covid-19 pandemic that led to people preferring to remain in their current jobs, rather than moving; and to less job openings.

Figure 33. Job-to-job mobility[(1)] of human resources in science and technology (HRST)(2) as % of total HRST, 2010, 2019 and 2020



Source: Science, Research and Innovation Performance of the EU 2022. Data: Eurostat (online data code: hrst_fl_mobsex). Notes: (1) 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. (2)HRST: Persons with tertiary education and / or employed in science and technology. (3)No data available for UK in 2020. (4)Figures for Ireland are not available.

University licensing, patenting and start-up creation is rising in many countries in Europe and Asia, as well as in the USA, Australia, Canada and Israel.[166] These commercialization activities are called '**academic entrepreneurship**'. However, universities face still today different issues in commercialising their research.[167] As an example, technologies developed in university labs are typically more embryonic than their industrial lab counterparts, making them harder to commercialise, and requiring venture capital/business angels.[168] Universities are now required to become more entrepreneurial in their organisational outlook and in their offerings, as well as to facilitate economic development and societal impact, including at territorial level, often inspired by regional smart specialisation strategies[169]. Scientific teams with exposure to peers who have experience in commercialising science can substantially increase the propensity of engaging in entrepreneurship due to awareness, demonstration effects, professional legitimization, and experience with commercialisation.[170] Research team composition and social networks can affect entrepreneurial opportunity and commercialization outcomes.[171]

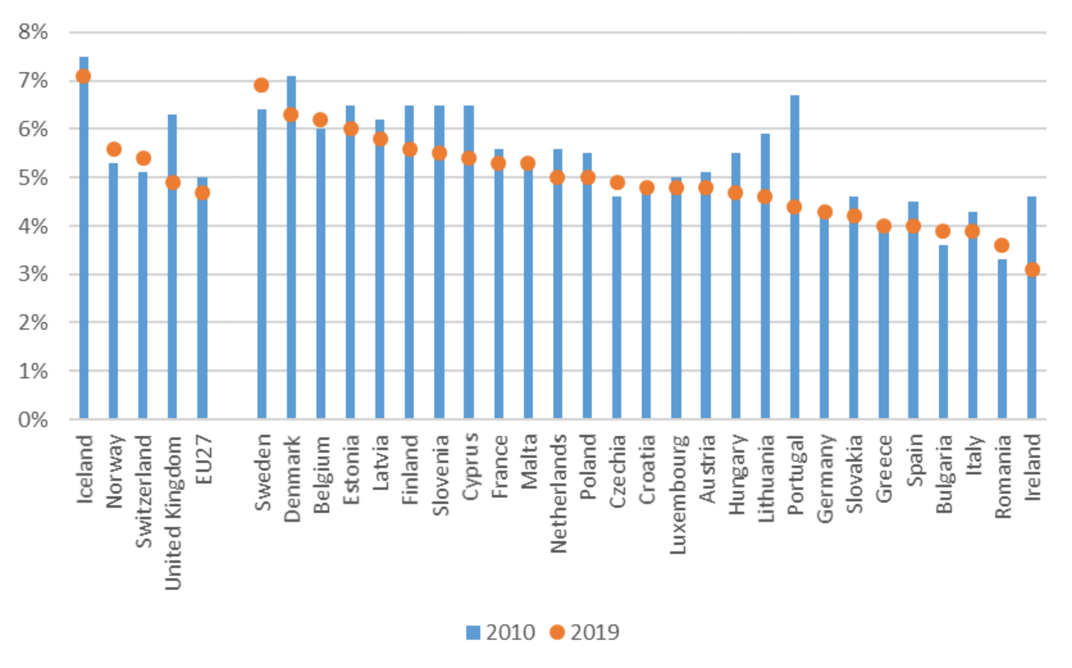
[166] Grimaldi, R., M. Kenney, D. S. Siegel and M. Wright (2011), '30 years after Bayh–Dole: reassessing academic entrepreneurship', *Research Policy*, 40, pp. 1045–1057.
[167] Siegel, D. S. and M. Wright (2015), 'University technology transfer offices, licensing, and start-ups'. In A. N. Link, D. S. Siegel and M. Wright (eds), *Chicago Handbook of University Technology Transfer and Academic Entrepreneurship*, pp. 1–40. Chicago, IL: University of Chicago Press; Siegel, D. S., & Wright, M. (2015), Academic entrepreneurship: time for a rethink?. *British journal of management*, *26*(4), 582-595.
[168] Jensen, R., & Thursby, M. (2001), 'Proofs and prototypes for sale: The licensing of university inventions', *American Economic Review*, 91(1), 240-259.
[169] European Commission, Joint Research Centre (2021), *Higher Education for Smart Specialisation, A Handbook*.
[170] Stuart, T. E., Ding, W. W. (2006), 'When do scientists become entrepreneurs? The social structural antecedents of commercial activity in the academic life sciences', *American journal of sociology*, 112(1), pp. 97-144.
[171] Baron, R.A. (2006), 'Opportunity recognition as pattern recognition: How entrepreneurs "connect the dots" to identify new business opportunities', *Academy of management perspectives*, 20(1), pp. 104-119.

At the same time, there is a need for research results to circulate more rapidly and widely within society. This has become clear during the COVID-19 pandemic. On this front, the Commission encourages (and requires under Horizon Europe) the use of open licenses for all scientific research publications about research findings that do not require IPR protection and are peer-reviewed. In addition, university staff are increasingly required to be acquainted with open licenses and understand the benefits of open research, open data and open education for human capital and skills development, and societal innovation.[172]

2.4.2 EU investment in talent and EU labour market trends

General government expenditure on education (% of GDP) has slightly decreased from 2010 to 2019. Sweden, Denmark and Belgium have the highest spending figures in the EU, while Ireland, Romania and Italy spend the least. On average, governments spend about 5% of GDP on education in the EU. Sweden, Belgium, Norway, Czechia, Bulgaria and Romania have increased their spending on education

Figure 34. General government expenditure in education (% of GDP)



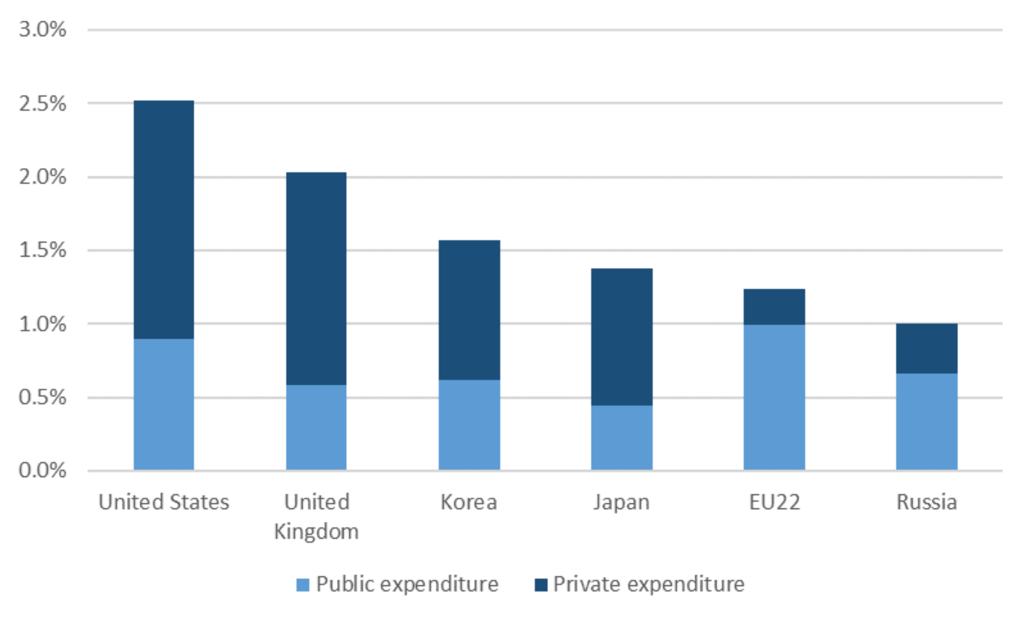
Source: Science, Research and Innovation Performance of the EU 2022. *Eurostat. Online data code: GOV_10A_EXP*

Private expenditures on education are relatively low in most EU countries, especially as regards tertiary education. Most of the expenditure on education in the EU comes from the public sector, while other countries (particularly the US and UK) have a more significant private contribution. The EU22 is the entity with the higher public expenditure (% GDP) on tertiary education. However, overall, the United States is the country with the highest total expenditure (% GDP) on tertiary education, followed by the United Kingdom (see Figure 35). In the US, UK, Japan and South Korea private contributions account for the majority of tertiary education spending. The US public expenditure on tertiary education accounts for

[172] Related factsheets: http://openaire.eu/ec-policies-and-mandates; Inamorato dos Santos, A. (2019), *Practical Guidelines on Open Education for Academics: modernising higher education via open educational practices*, European Commission, Joint Research Centre; COMM (2013) Opening up Education: Innovative Teaching and Learning for All through New technologies and Open Educational Resources.

0.9% of its GDP, while in the EU it accounts for 1%. At the same time, the US private expenditure on tertiary education accounts for 1.6% of its GDP, while in the EU it is only 0.2%.

Figure 35. Expenditure in tertiary education (% GDP)

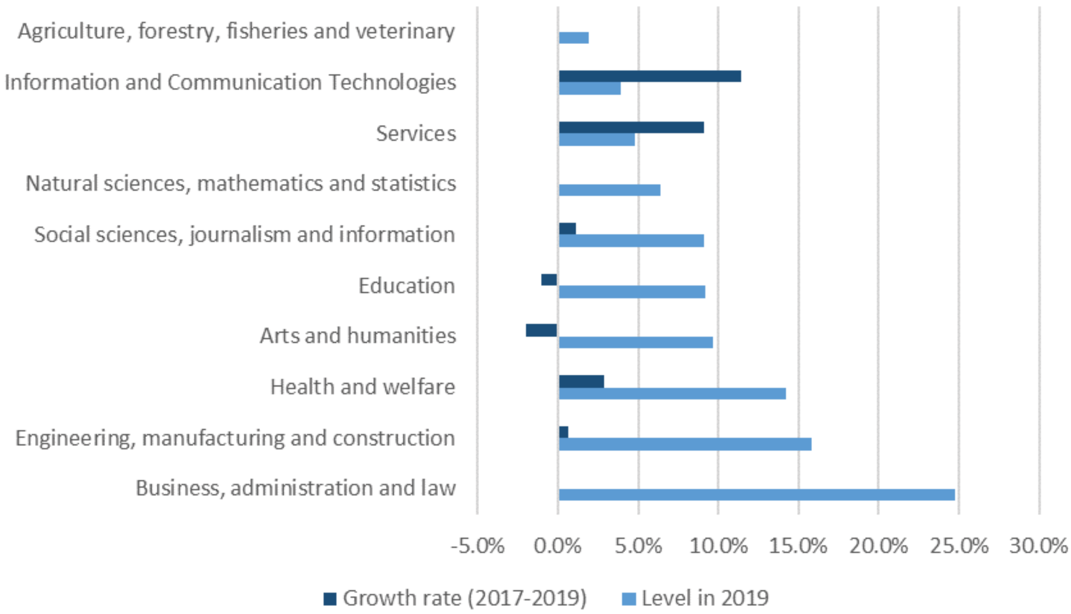


Source: Science, Research and Innovation Performance of the EU 2022. Education at Glance 2021, OECD Indicators. Note: For the US figures are for net student loans rather than gross, thereby underestimating public transfers. Data refers to 2018. EU22 includes Austria, Belgium, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain and Sweden.

The influence of the digital transition is clearly observable in the tertiary graduates' trend, with degrees in ICT being the ones showing the highest growth from 2017 to 2019 (Figure 36). The share of ICT graduates has grown from 2017 to 2019 by 11.4%. This is likely related with job market demands. Indeed, ICT is the second most requested competence in the job market, with 25% of job postings mentioning ICT among the desired competences. Despite such remarkable increase, the current growth in number of ICT specialists is far from enough to reach the target of 20 million by 2030[173]. The shortage of ICT experts leads to delays in developing new products and services, hampering innovation and growth in all industrial ecosystems, far beyond the ICT sector. In level, "business, administration and law" stays the most common degree, with a share of 24%. "Business, administration and law" is also the first most requested competence in the job market. "Engineering, manufacturing and construction" is the third most common degree, with a share of 15%. The share of tertiary graduates in "arts and humanities" and "education" degrees have been declining.

[173] SWD(2021) 247 final.

Figure 36. Share of tertiary graduates by field of study (EU)



Source: Science, Research and Innovation Performance of the EU 2022. DG Research and Innovation based on Eurostat. Online data code: EDUC_UOE_GRAD03. Note: Percentage of tertiary education graduates by field of study. Growth rate from 2017 to 2019 of the percentage of graduates of a field out of the total graduates. As an example, ICT graduates increased from 3.5% to 3.9%, implying a growth rate of 11.4% from 2017 to 2019.

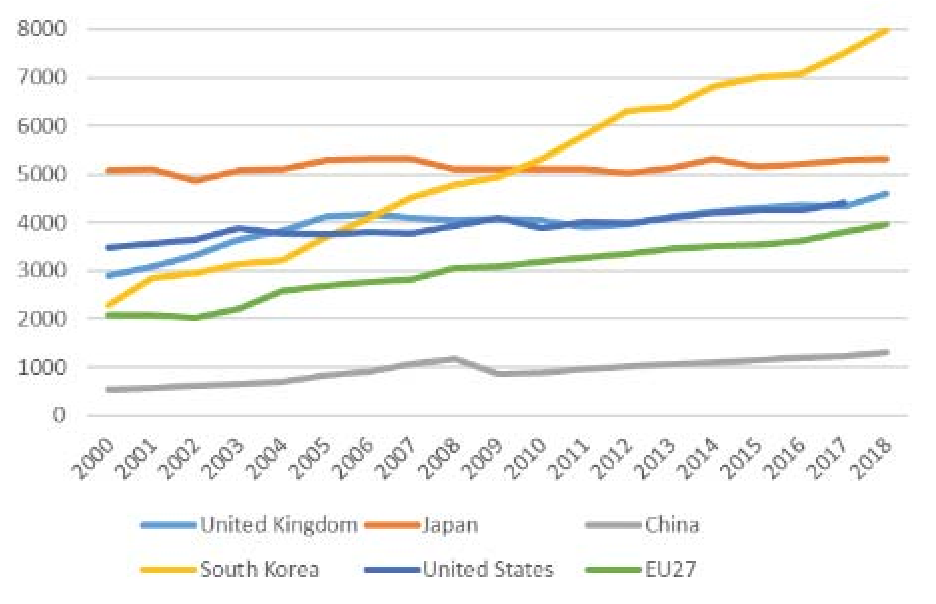
PhDs and doctoral students are newest form of resource in a world driven by knowledge-based economies.[174] The recruitment of doctoral graduates leads to collective knowledge, skills, networking, and prestige benefits to the firms that decide to make doctoral graduates an asset of their organisation.[175] Doctorate holders have a determinant role in building relationships between universities and businesses that enable knowledge sharing, and more innovative firms tend to recruit more PhDs.[176] Based on Eurostat data, the number of researchers in the EU increased nearly by one-quarter (22.6 %) between 2008 and 2018, from 1.27 to 1.79 million. More than half (54.9 %) of researchers in the EU worked in business enterprises, 33 % in higher education and 11.3 % in government sector in 2018, with increasing trend (Figure 37).

[174] Neumann, R., Tan, K.K. (2011), 'From PhD to initial employment: The doctorate in a knowledge economy', *Studies in Higher Education*, 36(5), pp. 601–614; Temple, P. (2012), *Universities in the knowledge economy: Higher education organisation and global change*, London: Routledge; Bryan, B., Guccione, K. (2018), 'Was it worth it? A qualitative exploration into graduate perceptions of doctoral value', *Higher Education Research & Development*, 37(6), pp. 1124-1140.

[175] Diamond, A., Ball, C., Vorley, T., Hughes, T., Moreton, R., Howe, P.,& Nathwani, T. (2014), *The impact of doctoral careers*, Leicester: CFE Research.

[176] Garcia-Quevedo, J., Mas-Verdú, F., Polo-Otero, J. (2012), 'Which firms want PhDs? An analysis of the determinants of the demand', *Higher Education*, 63(5), pp. 607–620.

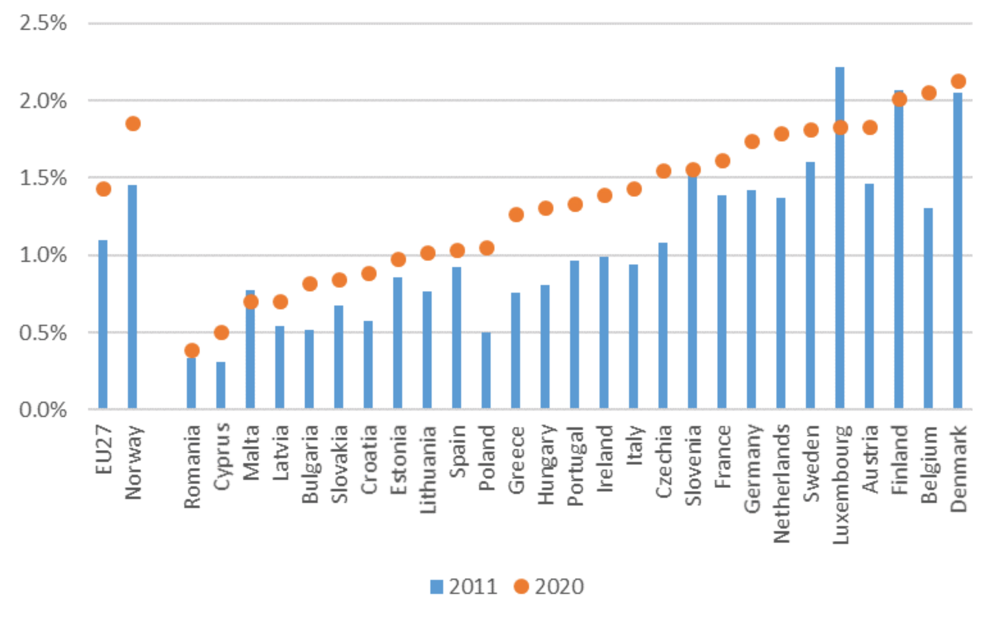
Figure 37. Researchers per million inhabitants (FTE)



Source: Science, Research and Innovation Performance of the EU 2022. UNESCO data. Note: Units refer to full time equivalent. EU average is computed (as unweighted average between researchers per million inhabitants across all available member states) by DG Research and Innovation.

The share of researchers in the workforce is increasing in the EU, though there is a strong variation across EU countries. The share of R&D personnel and researchers increased from 1.1% to 1.4% of the labour force in the EU (see Figure 38). In 2020, countries with the highest share of researchers are Denmark, Belgium, Finland and Norway, while nations with the lowest share are Romania, Cyprus, Malta and Latvia. In the EU, the majority of researchers and R&D personnel works for businesses, followed by the higher education sector, the government and the private non-profit sector. The business sector accounts for more than double the number of researchers and R&D personnel of the higher education sector, and more than four times the numbers of the government sector. Furthermore, in the last 10 years, the private sector is the one that increased the most its number of researchers and R&D personnel, growing from about 1.3 million employees (in full time equivalents) in 2013 to almost 1,8 million in 2020.

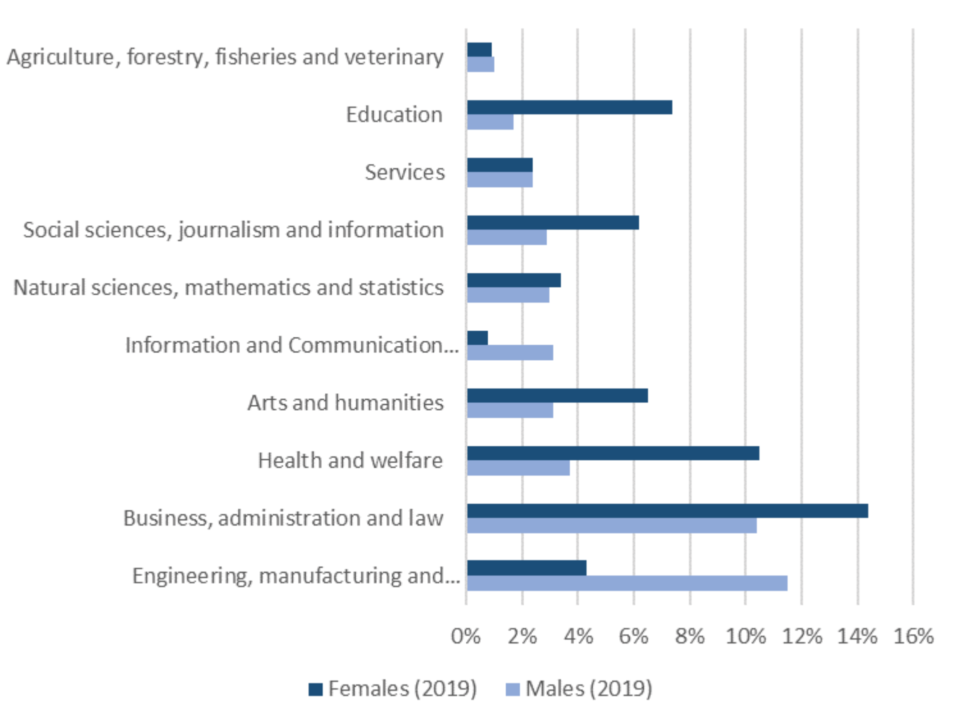
Figure 38. Share of R&D personnel and researchers in the labour force



Source: Science, Research and Innovation Performance of the EU 2022. Eurostat. Online data code: RD_P_PERSLF. Note: Share of R&D personnel and researchers (full time equivalent) is measured respect to the labour force, across all sectors.

Despite the fact that in the EU more than half of tertiary graduates are women, there are still strong gender differences in study fields chosen. Degrees in engineering, manufacturing and construction and in ICT are predominantly chosen by males, while female students are overrepresented in art and humanities, health and welfare, as well as education degrees (see Figure 39). Male graduates in ICT are around three times more numerous than females, and the same holds for graduates in engineering, manufacturing and construction. Female graduates in arts and humanities are double the male graduates, while women graduates in education are more than three times the male graduates in the field.

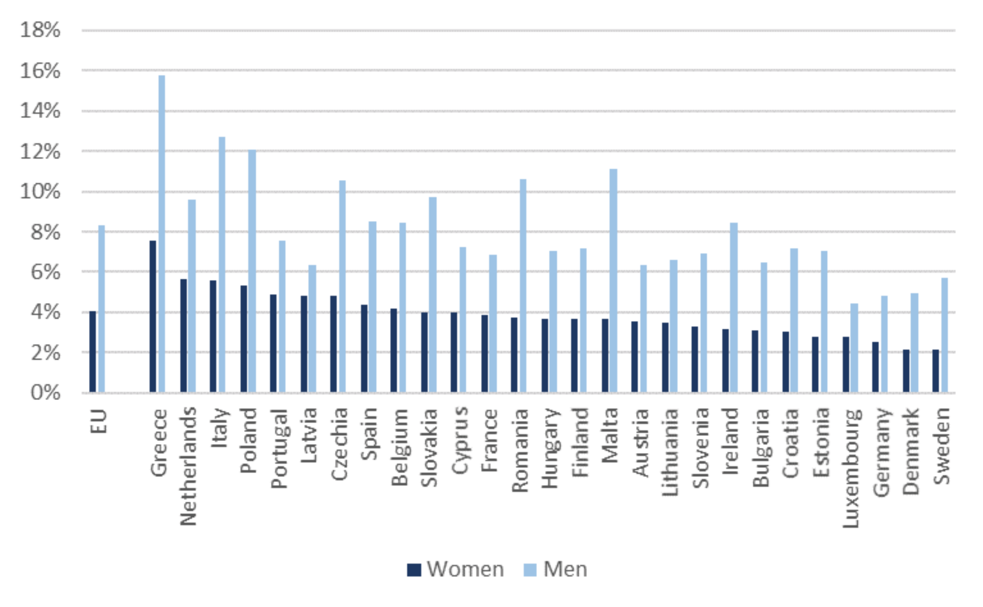
Figure 39. Tertiary graduates by field of study and gender (EU)



Source: Science, Research and Innovation Performance of the EU 2022. Eurostat. Online data code: EDUC_UOE_GRAD03. Note: Percentage of tertiary education graduates by field of study and gender in 2019.

Even though the share of women starting a business has been increasing in the last decades, the rate of entrepreneurship is still higher for men than for women. In the EU the women entrepreneurship rate is half of the men one (Figure 40). Despite wide heterogeneity on the rate of self-employment across EU countries, such inequality is consistently present in all member states.

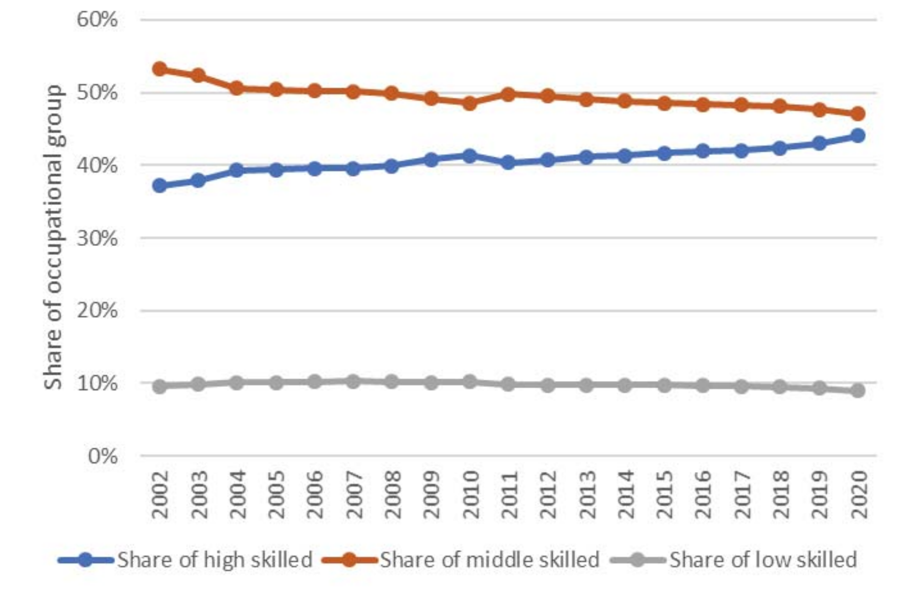
Figure 40. Female entrepreneurship rate across EU Member States, 2020



Source: Science, Research and Innovation Performance of the EU 2022. Eurostat. The entrepreneurship rate is measured as number of self-employed women as proportion of total active population aged 15 to 64.

In the European Union the proportion of high-skilled occupations increased, the proportion of middle-skilled occupations decreased, and the proportion of low-skilled occupations remained steady over the last two decades (Figure 41). In the EU, the share of high-skilled occupations (out of total employment) increased by 7 percentage points between 2002 and 2020, growing from 37% to 44%, especially in market services. The share of low-skilled occupations remained steady at around 10%. On the contrary, the share of middle-skilled occupations plummeted by around 6 percentage points, from 53% in 2002 to 47% in 2020.

Figure 41. Structural changes in skills requirements (EU)



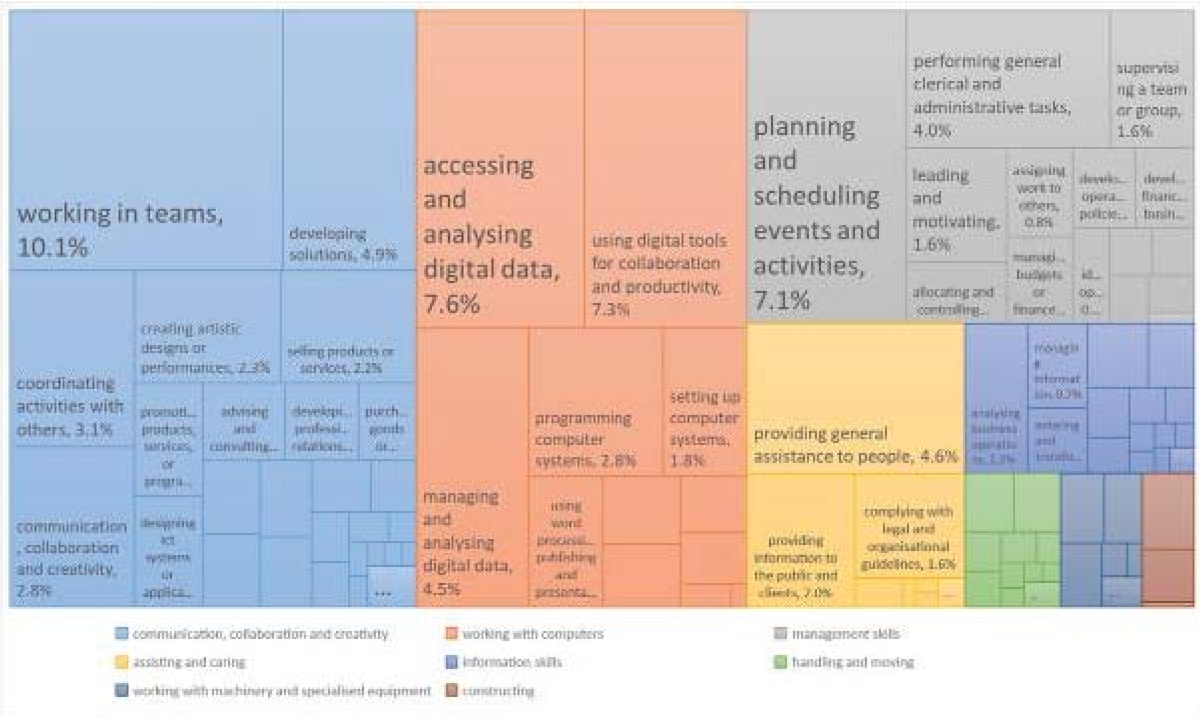
Source: Science, Research and Innovation Performance of the EU 2022 based on Eurostat data. Online data code: LFSA_EGISED. Note: Following the ILO (2007) methodology, high-skilled occupations include jobs classified under the ISCO-08 1-digit codes 1, 2, and 3. Middle-skilled occupations include jobs classified under the major groups 4, 5, 6, 7, 8. Low-skilled occupations include jobs classified under the groups 9. Data refer to the EU.

Analysis by Cedefop of online job vacancies suggests that social and digital skills, combined with managerial and analytical competences are among the most frequently requested in the EU. Cedefop collected millions of online job advertisements[177] in 27 European countries from thousands of sources, including private job portals, public employment service portals, recruitment agencies, online newspapers and corporate websites over the period 2020Q3-2021Q2.

The more requested skills are on one side the ability to communicate, working in teams, collaborating and being creative, and on the other side the capacity to effectively work with computers. Around 34% of online jobs posted in the EU (from 2020 to 2021) mention communication, collaboration and creativity skills, 28% mention computer skills and 20% mention management skills (Figure 42). Such trends are in line with our above-mentioned findings on structural changes in skills requirements triggered by the digital transformation: the diffusion of digital and automation technologies increases demand not only for digital skills but also for complementary abstract thinking and social skills. The least requested skills are constructing (0.98%), working with machinery (1.55%) and handling and moving (1.8%).

[177] Online job advertisements tend to relatively over-represent white-collar (mostly professional) occupations and their attendant skills, compared to manual ones, in terms of the occupational structure.

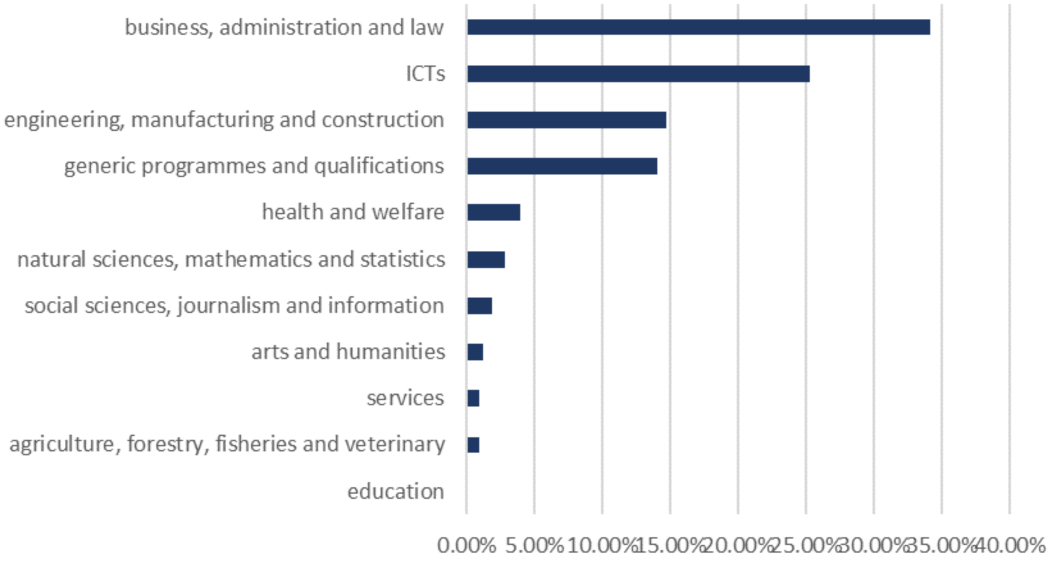
Figure 42. Percentage of skills type total mention (EU)



Source: Science, Research and Innovation Performance of the EU 2022. Cedefop, Skills-OVATE. The image represents the share of total mentions of skills (skills ranking) in millions of online job advertisements (OJAs) in 27 European countries, collected from thousands of sources, including private job portals, public employment service portals, recruitment agencies, online newspapers and corporate websites. Period: Q3 2020 – Q2 2021.

The more requested knowledge domains are business, law and ICT, closely followed by engineering. Around 34% of online job posted in the EU from 2020 to 2021 mention business, administration and law, 25% mention ICT competences and 15% mention engineering, manufacturing and construction knowledge (see Figure 43). A relatively high proportion of vacancies (14%) includes only generic qualification requirements. The high demand for ICT-related knowledge suggests that ICT skills are not being required exclusively in the science and technology sector, but across the entire economy.

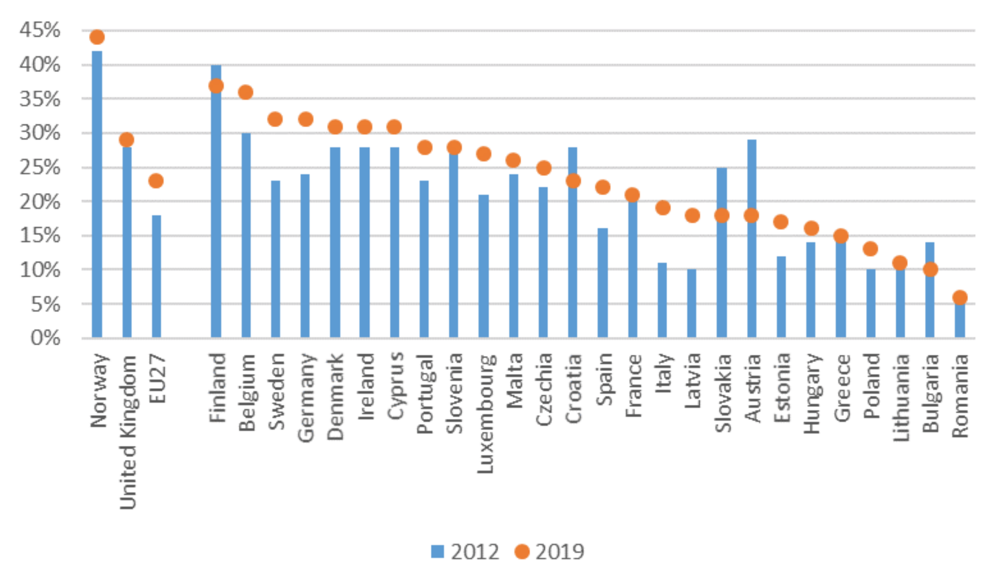
Figure 43. Percentage of knowledge type total mention (EU)



Source: Science, Research and Innovation Performance of the EU 2022. Cedefop, Skills-OVATE. The image represents the share of total mentions of knowledge (knowledge ranking) in millions of online job advertisements (OJAs) in 27 European countries, collected from thousands of sources, including private job portals, public employment service portals, recruitment agencies, online newspapers and corporate websites. Period: Q3 2020 – Q2 2021.

Given the rising importance of digital skills in the work environment, more and more firms are training their personnel in ICT skills. Between 2012 and 2019 the percentage of EU firms that provided ICT training to their employees has increased by 5 percentages points, growing from 18% to 23%, equivalent to a growth rate of 28% (Figure 44). The country that has trained its workers the most is Norway, with around 44% of enterprises that provided ICT training, followed by Finland, Belgium, Austria and the UK. The country that engaged the least in such training provision is Romania with only 6% of enterprises upgrading workers' ICT skills. Adequate investments should be made in education and skills for adults. The lengthening of working lives in today's knowledge economy requires a paradigm shift where individuals dedicate themselves to long-life learning.

Figure 44. Enterprises that provided training to upgrade ICT skills of their personnel



Source: Science, Research and Innovation Performance of the EU 2022. Eurostat. Enterprises that provided training to develop/upgrade ICT skills of their personnel. Online data code: ISOC_SKE_ITTN2. Percentage of enterprises.

2.5 Data Informed Policy and Policy Support

2.5.1 Data and monitoring for innovation policy

Several tools are currently being used at the EU level to monitor innovation activities in Europe and support innovation policy design and policymaking. The main tools include most notably the European Innovation Scoreboard, the Regional Innovation Scoreboard and the Innovation Output Indicator. The Community Innovation Survey, published by Eurostat, is the reference survey on innovation in enterprises and provides statistics on innovation in Europe, based on the methodology defined in the Oslo Manual. The European Eco-innovation scoreboard also provides a comparative analysis of the performance in the environmental innovation in EU countries

The **European Innovation Scoreboard (EIS)** provides a comparative analysis of innovation performance in EU countries, other European countries, and regional neighbours. Based on a composite indicator, the Summary Innovation Index, Member States fall into four performance groups: innovation leaders, strong innovators, moderate innovators and emerging innovators (see also Box 4). The scoreboard helps the Member States to assess areas in which they need to strengthen their efforts to improve performance. The European Innovation Scoreboard is used as a reference to check the eligibility of applicants under the Regional Innovation Scheme (RIS) of the European Institute of Innovation and Technology (EIT) and its KICs. This scheme aims indeed to reinforce the innovation capacity of applicants from countries that have an emerging or moderate innovation performance according to the EIS and, furthermore, acts as an entry point to the EIT's ecosystem by widening participation in the KICs' activities.

Box 4. The European Innovation Scoreboard

The first edition of the EIS was published in 2001, and since then it is published annually. Over time the measurement framework has been revised several times, with the latest major revision in 2021, which addressed methodological issues and ensured that increasingly important phenomena, such as digitalisation and environmental sustainability, are adequately reflected.

The EIS 2021 measurement framework distinguishes between four main types of activities (Framework conditions, Investments, Innovation activities and Impacts), capturing 12 innovation dimensions and in total 32 different indicators, of which 10 new and 3 revised. Additional indicators were introduced for the set of contextual indicators, which are used to help in the interpretation of the performance differences between the innovation indicators of the main measurement framework.

Based on their average performance scores as calculated by a composite indicator, the Summary Innovation Index, Member States fall into four different performance groups:

- Innovation Leaders: all Member States where performance is above 125% of the EU
- Strong Innovators: all Member States with a performance between 100% and 125% of the EU
- Moderate Innovators: all Member States where performance is between 70% and 100% of the EU
- Emerging Innovators: all Member States where performance is below 70% of the EU

Figure 45. EIS 2021 measurement framework

FRAMEWORK CONDITIONS

- Human resources
  - 1.1.1 New doctorate graduates (in STEM)
  - 1.1.2 Population aged 25-34 with tertiary education
  - 1.1.3 Lifelong learning
- Attractive research systems
  - 1.2.1 International scientific co-publications
  - 1.2.2 Top 10% most cited publications
  - 1.2.3 Foreign doctorate students
- Digitalisation
  - 1.3.1 Broadband penetration
  - 1.3.2 Individuals who have above basic overall digital skills

INVESTMENTS

- Finance and support
  - 2.1.1 R&D expenditure in the public sector
  - 2.1.2 Venture capital expenditures
  - 2.1.3 Direct government funding and government tax support for business R&D
- Firm investments
  - 2.2.1 R&D expenditure in the business sector
  - 2.2.2 Non-R&D innovation expenditures
  - 2.2.3 Innovation expenditures per person employed in innovation-active enterprises
- Use of information technologies
  - 2.3.1 Enterprises providing training to develop or upgrade ICT skills of their personnel
  - 2.3.2 Employed ICT specialists

INNOVATION ACTIVITIES

- Innovators
  - 3.1.1 SMEs with product innovations
  - 3.1.2 SMEs with business process innovations
- Linkages
  - 3.2.1 Innovative SMEs collaborating with others
  - 3.2.2 Public-private co-publications
  - 3.2.3 Job-to-job mobility of Human Resources in Science & Technology
- Intellectual assets
  - 3.3.1 PCT patent applications
  - 3.3.2 Trademark applications
  - 3.3.3 Design applications

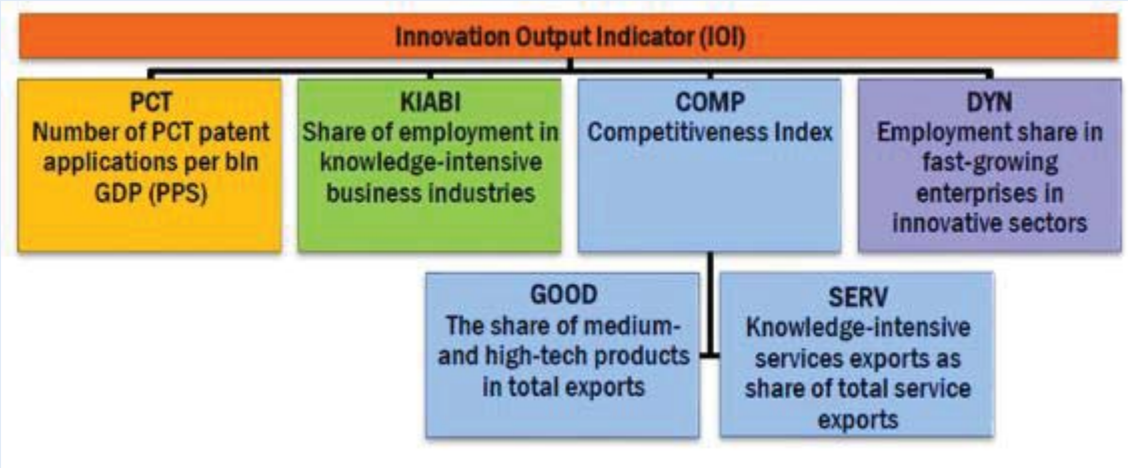
IMPACTS

- Employment impacts
  - 4.1.1 Employment in knowledge-intensive activities
  - 4.1.2 Employment in innovative enterprises
- Sales impacts
  - 4.2.1 Medium and high-tech product exports
  - 4.2.2 Knowledge-intensive services exports
  - 4.2.3 Sales of product innovations
- Environmental sustainability
  - 4.3.1 Resource productivity
  - 4.3.2 Air emissions by fine particulates PM2.5 in Industry
  - 4.3.3 Development of environment-related technologies

The **Regional Innovation Scoreboard (RIS)** accompanies the EIS every two years and provides a comparative assessment of performance of innovation systems across 240 regions of 22 EU Member States, Norway, Serbia, Switzerland, and the United Kingdom. In addition, Cyprus, Estonia, Latvia, Luxembourg, and Malta are included at the country level, as in these countries NUTS 1 and NUTS 2 levels are identical to the country territory. The RIS 2021 followed the revised methodology of the EIS 2021 and used data for the 21 of the 32 EIS indicators, for which data at regional level was available.

The **Innovation Output Indicator** (IOI) (see Box 5) aims to support policymakers by offering an output-oriented measure of innovation performance at the country and EU levels, which is directed at capturing countries' capacity to derive economic benefits from innovation and the dynamism of innovative entrepreneurial activities. It complements other benchmarking tools, such as the R&D spending targets and the European Innovation Scoreboard. The IOI was introduced in the 2013 Communication and Staff Working Document[178] and refined in 2014, 2016 and 2017 Methodology Reports[179]. The Commission is currently in the process of further revising and updating the methodological development of the index to improve its statistical properties, capture the latest developments in countries' economic systems and innovation processes and align it with the new priorities set by the organisation.

Box 5. The Innovation Output Indicator framework



The 2021 edition of the IOI includes four components. The first component, referred to as 'PCT', is given by the number of patent applications per billion GDP falling under the legal framework of the Patent Cooperation Treaty (PCT). The second component, 'KIABI', measures the number of persons employed in knowledge-intensive business industries within total employment. It aims to capture the structural orientation of the business economy towards knowledge-intensive activities. The third component, 'COMP', aims to capture the competitiveness of knowledge-intensive goods and services in the export markets. It is built by integrating in equal weights the share of high-tech and medium-tech product exports to the total product exports (GOOD) and knowledge-intensive service exports as a share of the total services exports of a country (SERV). Finally, the last component, referred to as 'DYN', measures the employment dynamism in fast-growing[180] enterprises in innovative sectors.

An important source of information and data concerning innovation is the Community Innovation Survey (CIS), published every two years by Eurostat and carried out by EU Member States, EFTA countries and candidate countries. In short, the CIS is a survey about innovation activities in enterprises, and it is designed to capture the information on different types of innovation, to enable analysis of innovation drivers or to assess the innovation outcomes. The CIS provides various innovation indicators by three main breakdown variables: type of innovator, economic activity and size class of enterprises. For each survey round, Eurostat together with the countries develops a standard core questionnaire –

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[178] COM(2013)624 and SWD(2013)325, Measuring innovation output in Europe: towards a new indicator.
[179] See Vértesy, D. and Tarantola, S. (2014), *The Innovation Output Indicator 2014. Methodology Report*, JRC Technical Reports, EUR 26936, Luxembourg: Publications Office of the European Union; Vértesy, D. Deiss, R. (2016), *The Innovation Output Indicator 2016. Methodology Update*, JRC Technical Reports, EUR 27880, Luxembourg: Publications Office of the European Union; Vértesy, D. (2017), *The Innovation Output Indicator 2017. Methodology Update*, JRC Technical Reports, EUR 28876, Luxembourg: Publications Office of the European Union.
[180] High-growth is defined by annual average employment growth of 10% over three years.

Harmonised Data Collection (HDC) listing the mandatory and rotational questions to be provided within a given round. The standard mandatory questions refer to number of innovative enterprises, product and goods new to the market and new to the firm, innovation cooperation, objectives of innovation, sources of information for innovation, hampering factors for innovation activities, innovation developer, turnover from innovation and expenditure on innovation. In the latest edition, a set of new questions were included: customization and co-creation, patents and IRPs, buying technical services, innovative purchases, using information channels, organising work and expectations from innovation. The target enterprise population of the survey is enterprises in the NACE categories with at least 10 employees. An enterprise is considered innovative if during the reference period it introduced successfully a product or process innovation, had ongoing innovation activities, abandoned innovation activities, completed but yet introduced the innovation or was engaged in in-house R&D or R&D contracted out. On the other hand, a non-innovative enterprise had no innovation activity mentioned above whatsoever during the reference period.

The Community Innovation Survey is based on the methodology laid down in the Oslo Manual.[181] The Oslo Manual, under its 4th Edition of 2018, is a joint publication of the OECD and Eurostat and intends to provide guidelines for collecting and interpreting data on innovation, to facilitate international comparability and to provide a platform for research and experimentation on innovation measurement. In more detail, the Oslo Manual intends to support national statistical offices and other producers of innovation data in designing, collecting, and publishing measures of innovation to meet a range of research and policy needs. As defined in the Manual, an innovation is a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process).

The performance of EU Member States on environmental innovations is also measured by the Eco-innovation scoreboard and the Eco-innovation index.[182] The Eco-innovation Index, a composite indicator building on the scoreboard, allows to present Member States according to four performance groups: eco-innovation leaders, average eco-innovation performers, countries catching up with eco-innovation (see Box 6).

Box 6. The European Eco-innovation scoreboard

The **European Eco-innovation scoreboard** (ECO-IS) provides a comparative analysis of the performance in the environmental innovation in EU countries. The scoreboard helps the Member States to assess areas in which they need to strengthen their efforts to improve performance. The European Eco-innovation index helps assessing progress towards greening industry in the single market and on how green innovation can boost the green transition.

Published for the first time in 2014, the scoreboard is published annually, and few revisions took place in view of improving the methodology and the relevance of the data source.

The scoreboard aims at capturing the different aspects of eco-innovation by applying 16 indicators grouped into five thematic areas: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, resource efficiency and socio-economic outcomes.

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181 OECD/Eurostat (2018), *Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation*, 4th Edition, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris/Eurostat, Luxembourg.
182 https://ec.europa.eu/environment/ecoap/indicators/index_en.

It thereby shows how well individual Member States perform in different dimensions of eco-innovation compared to the EU average and presents their strengths and weaknesses. The Eco-IS complements other measurement approaches of innovativeness of EU countries and aims to promote a holistic view on economic, environmental and social performance.

Based on their average performance scores as calculated by a composite indicator, the Eco-Innovation Index, Member States fall into three different performance groups:

- Eco-Innovation Leaders: all Member States where performance is above 120% of the EU;
- Average Eco-Innovation performers: all Member States with a performance between 80% and 120% of the EU;
- Countries catching up with Eco-innovation: all Member States where performance is above 80% of the EU.

Other platforms and tools provide information and data on applicants and beneficiaries from several innovation-related funding instruments of the Commission, at micro level. For example, the Innovation Radar[183] initiative identifies high potential innovations and innovators in EU-funded research and innovation projects. The European Innovation Council and Small and Medium-sized Enterprises Executive Agency (EISMEA) has developed datahubs[184] that provide similar data on several funding instruments.

Despite the above-mentioned initiatives, there is a growing need for better data collection and analysis with regards to start-ups, scale-ups and their ecosystems. Several stakeholder consultation groups and other European institutional actors have expressed this need in recent reports and recommendations.[185] Currently, there are some existing initiatives by both public and private organisations tracking the development of Europe's start-up scene more broadly. However, due to the use of diverging data and definitions, and a number of different methodologies, they are often incompatible and unable to provide a clear picture on the European start-up landscape. This is one of the reasons the EIS currently does not include any indicator on the start-ups and/or scale-ups despite their important role in the overall innovation ecosystem.

Table 3. Examples of definitions from several sources

Indicator	Definition	Source
Start-up	Businesses that are looking to grow in terms of market access, revenues, and number of employees, but are still in search of a repeatable and scalable business model.	European Investment Bank
	The company must be younger than ten years. It must have an innovative product or business model. The start-up must aim to scale up (intention to grow the number of employees and/or markets operate in).	European Startup Monitor
	A business entity (up to and including 10 years of operational history) belonging to a company headquarter in EU, which is starting activity with the purpose of developing and launching an innovative business model or technological component with high global growth potential,	Start-up Estonia based on European Startup

[183] https://www.innoradar.eu/.
[184] https://eismea.ec.europa.eu/eismea-datahubs_en.
[185] For example, proposals on 'defining key terms Data taxonomy' and 'data collection measures' from the "Action Plan to Make Europe the new Global Powerhouse for Start-ups", as well as the proposal for a 'tracking platform to make sure female-founded companies are being supported' from the "Invest in Women NOW" petition.

	that is innovative and has the potential to significantly contribute to the development of the EU business environment.	Network
Scale-up	High growth start-ups - start-ups that reported an average turnover growth of greater than 60 per cent over the last three years. A start-up that has raised investments of at least 1 million euros has at least ten registered employees and has an annual growth in employees and turnover of at least 20% within three years.	European Investment Bank Start-up Estonia based on European Startup Network
	Development-stage business, specific to high-technology markets, that is looking to grow in terms of market access, revenues, and number of employees, adding value by identifying and realizing win-win opportunities for collaboration with established companies.	Startup Europe Partnership
	High-growth enterprises - enterprises with at least 10 employees in the beginning of their growth and having average annualised growth in number of employees greater than 10% per annum, over a three-year period.	Eurostat
	Gazelles - high-growth enterprises that are up to five years old with average annualised growth (turnover or employment) greater than 10% per annum, over a three-year period are available.	Eurostat
	High-growth enterprises - rate of high growth enterprises (20% or higher growth based on employment): number of high growth enterprises as a percentage of the population of active enterprises with at least 10 employees.	OECD
Deep-tech	Deep-Tech start-up - the product or service is based on scientific advancement and development or meaningful engineering innovation; the product or service development is based on or results in commercialise intellectual property and therefore it is not easily replicable.	Start-up Estonia
	Deep tech – examples: artificial intelligence, robotics, autonomous driving & delivery, space flight, aviation, computer vision, speech recognition, AR/VR.	Dealroom

2.5.2 *Design, implementation and governance*

Policy experimentation can help to make innovation policy more impactful. The idea behind policy experiments is to start on a small scale, test different policy designs systematically, learn lessons to increase impact and scale it up. Policy experimentation stimulates the emergence of such new solutions for policy by de-risking the process of exploring new policy ideas and changes (see Box 7). Policy experimentation is intended as a way of testing something new or evaluating "what works", in order to improve policy design or implementation. It provides a controlled environment for testing and devising novel, innovative public policy approaches to the challenges ahead before adoption and implementation[186]. Hence, policy experiments can be used for example for evaluating a programme, improving an existing programme by testing small or large tweaks in the implementation process or examining the underlying causes of a problem.[187] Horizon

[186] European Commission, Directorate-General for Research and Innovation, (2020), *A new ERA for research and innovation : staff working document*, EU Publications Office.
[187] https://www.consilium.europa.eu/media/41259/eurogroup-presentation-november-7th-discussion-note.pdf.

Europe's Strategic Plan 2021-2024[188] encourages developing innovations in policy, as well as institutional and governance frameworks by building on strong empirical evidence and experimentation practices that can prepare for policy designs adaptation to the arising challenges and design future pathways.

However, evidence about the breadth to which policy experimentation is used innovation policymaking in the EU is not fully available. There does not exist a consistent body of accessible information about policy experimentation actions and their features (stakeholders involved, resources invested, geographical coverage and so on), their strengths and weaknesses. This knowledge gap is particularly topical regarding how to ensure that policy implementation and goals delivery fully benefit from citizens' engagement.

Box 7. Some examples of experimental innovation policies and their impact

Exposure to innovation when young: A natural experiment in the US has investigated how the chances to become an inventor or file a patent depend on socio-economic circumstances.[189] It is typically only the top student from a high-income family that will become a future inventor. The researchers also find that growing up in an area with many inventors is a strong predictor of becoming an inventor. Lack of such exposure when young could therefore lead to a generation of "lost Einsteins", which is both detrimental to growth and contributes to income inequality.

Innovation vouchers: In the Netherlands an experiment with innovation vouchers was undertaken in 2004 and 2005. The aim was to stimulate the interaction between SMEs and public knowledge institutes, to try and improve knowledge diffusion. These innovation vouchers were allocated randomly by means of a lottery among applicant firms, thus allowing to investigate the causal impact of the innovation instrument. The long-run impact of this scheme has recently been investigated[190], with interesting results. It is found that 12 years after the experiment, firms in the treatment group (those that have received a voucher) have a higher survival rate, more often use R&D tax credit schemes, invest more in R&D and employ more workers. These effects are structural, but already become visible in the short-term (within two years after the lottery).

Online entrepreneurship courses: An experimental study in Denmark looked into the impacts of randomly offering online entrepreneurship courses to secondary school students.[191] The researcher finds that students who took the online course were more open to pursue a career in entrepreneurship, had higher self-efficacy, and had more positive entrepreneurial attitudes. One year after the experiment, the differences between the treatment group and the control group who did not take the online course were smaller, but still present.

Innovation contests: One way to make innovation more inclusive is through innovation contests, enticing people to participate who may not naturally consider themselves innovators or creative. An experiment in the Netherlands has shown that this indeed could pay off.[192] This experiment has shown that with nudging or small financial incentives, people can be encouraged to submit ideas into innovation contests, without a decrease in the quality of these ideas. Simply relying on self-volunteered contributors thus comes with a cost as we are missing out valuable ideas.

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[188] Horizon Europe Strategic Plan (2021 – 2024) European Commission, 2021.

[189] Bell, A., R. Chetty, X. Jaravel, N. Petkova, Van Reenen, J. (2019), 'Who Becomes an Inventor in America? The Importance of Exposure to Innovation', *Quarterly Journal of Economics*, 134 (2), pp. 647–713.

[190] Roelandt, T., van der Wiel, H. (2020), *The long-term impact of Dutch innovation vouchers: Back to the future with randomised controlled trials*, Innovation Growth Lab.

[191] Moberg, S. (2021), 'Online-based entrepreneurship education-its role and effects: A randomised controlled trial about the effects of an online entrepreneurship programme based on role models", *Journal of Entrepreneurship Education*, 24(2).

[192] Weitzel, U., C. Rigtering, Fenneman, A. (2019), 'Increasing Quantity without Compromising Quality: How Managerial Framing Affects Intrapreneurship", *Journal of Business Venturing*, 34 (2), pp. 224–241.

A transformative[193] **and forward-looking innovation policy also emphasises the necessity for novel forms of governance**, which are aimed at ensuring end-users and citizens engagement, thus allowing for co-creation and co-evolution of society and innovation policies, and be prepared for the challenges ahead. The ESIR high-level expert group[194] provides evidence-based policy advice to the Commission on how to develop a forward-looking and transformative research and innovation policy. Such a framework calls for an **effective framework for coordination**, aligning innovation policy and other sectoral policies at all levels of governance (i.e. EU, national and regional) through a **"whole of government" approach** that encompasses the coordination of policy instruments, an alignment of policy objectives and the synchronisation of investments. In order to be transformative, innovation policy should go beyond a narrow sectoral, business and growth perspective, but should be horizontal, inclusive and aim for strategic policy mix for system innovation and transformative change.[195] This means innovation policy, together with environmental policy, cannot be effective with respect to environmental and climate targets if economic policies promote fossil fuels, resource inefficiency or unsustainable production and consumption. Similarly, innovation policy need to go hand in hand with education and employment policies, building capacities and skills for students and labour force to support the transitions[196]. Furthermore, the size of the challenges that need to be addressed call for collective action and critical mass, hence coordination of efforts and results from national innovation systems.

Several EU instruments support Member States and regions in designing and implementing better innovation policies. Reforms of national systems are encouraged notably through the European Semester of economy policy coordination. The Semester constitutes the basis for an in-depth policy dialogue with national authorities and stakeholders based on factual evidence and cross-country benchmarking: the analysis of the capabilities and performance of the different components of each national innovation system and of the interlinkages between enables to identify the key bottlenecks impeding the full contribution of innovation to growth and national competitiveness. During its 2022 cycle, the European Semester resumes its broad economic and employment policy coordination, while further adapting in line with the implementation requirements of the Recovery and Resilience Facility. This approach leads to targeted Country-Specific Recommendations, which can trigger a request for assistance by Member States through instruments that support national reforms such as the **Horizon Policy Support Facility (PSF)** or the **Technical Support instrument (TSI)**. The PSF gives Member States and countries associated to Horizon Europe practical support to design, implement and evaluate reforms that enhance the quality of their research and innovation investments, policies and systems. The TSI can be used by Member States to request technical support for implementing national reforms on various areas, including those aiming at improving R&I policies and systems. **Technical Assistance under**

[193] A transformative innovation policy approach simultaneously supports directionality, coherence and alignment, societal engagement, experimentation and foresight. It can help to fill in the current gap between policy ambitions and the lack of structured knowledge on the effectiveness of policy and governance interventions to achieve these ambitions. It can provide an evidence base and methodological approach to design and implement innovation policies and programmes – such as Horizon Europe planning and programming of the work programme for 2023-2024 and the Strategic Plan for 2025-2027 - that aim to accelerate the twin transitions. See also: European Commission, Directorate-General for Research and Innovation, Biggeri, M., Ferrannini, A., (2020), *Framing R&I for transformative change towards sustainable development in the European Union*, Publications Office; European Commission, Directorate-General for Research and Innovation, Borunsky, L., Correia, A., Delauré, S., Martino, R., Rakic, R., Ravet, J. (2020), *Making R&I transformative : evidence in support of the new European Research Area Communication*, Publications Office.

[194] https://ec.europa.eu/info/research-and-innovation/strategy/support-policy-making/shaping-eu-research-and-innovation-policy/esir_en.

[195] Lundin, N., Schwaag Serger, S. (2018), *Agenda 2030 and A Transformative Innovation Policy – Conceptualizing and experimenting with transformative changes towards sustainability*, Transformative Innovation Policy Consortium WP 2018-01.

[196] Biggeri, M. and Ferrannini, A. (2020), *Framing R&I for transformative change towards sustainable development in the European Union*, R&I paper series, working paper 2020/11, Publication Office of the European Union, Luxembourg.

the Technical Assistance for regional policy is also available to help stakeholders set up and ensure the organisational conditions which would allow the smooth implementation of the European Structural and Investment Funds interventions, which includes interventions to boost research and innovation capacity.

2.5.3 Innovation procurement

The potential of public procurement to bring innovative solutions to the market is not fully exploited in Europe. Public buyers in the EU spend around 17% of GDP on public procurement every year, amounting for more than €2.3 trillion per year.[197] Procurement represents a key source of demand for firms in sectors such as construction, health care, space and defence systems, energy and transport. The public sector can employ innovation procurement as a powerful demand-side instrument for tackling societal challenges[198], and this use of public demand as an engine for the development, uptake and diffusion of innovation has attracted interest both at EU and national levels. In 2004, France, Germany and the UK issued a position paper[199] to the European Council calling for the use of public procurement across Europe to spur innovation, which was continued by various calls of the Council of the European Union[200]. In 2015, the European Research Area and Innovation Committee (ERAC) in the Council adopted a position with 5 concrete recommendations to mainstream innovation procurement across Europe[201]: creating national strategies and action plans, financial incentives, national competence centers, EU wide knowledge sharing and an EU wide monitoring system for innovation procurement with an indicator in the EU Innovation Scoreboard.

In order to address these challenges, several actions have already been taken at national and EU level. At national level, 10 Member States have meanwhile setup **national action plans or strategies for innovation procurement**, 12 have national competence centres, 13 provide national financial incentives and 9 setup national monitoring. 11 Member States have already implemented policies that encourage public buyers to leave IPR ownership in public procurements as much as possible with contractors in line with the recommendation of the EU IPR action plan. At EU level, the European Commission has gradually reinforced since 2013 **EU financial incentives for innovation procurement**. Grants in EU funding programmes such as Horizon 2020, Horizon Europe, COSME, Innovation Fund, CEF, Digital Europe Program and the European Structural Funds have already co-financed hundreds of innovation procurements and the new Recovery and Resilience Facility will fund many more to come. The EIB has also provided loans to Member States for innovation procurement programs. The Commission also funded the creation of a **European network of national competence**

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[197] 2018 figures. This spending consists of €1 765 billion (13% of GDP) of public procurement performed by public authorities, €436 billion (3.5% GDP) by public procurers in the energy, transport, postal, water and waste management sector and €75 billion (0.5% GDP) by defence procurers. Source: European Commission, Directorate-General for Communications Networks, Content and Technology (2021), *The strategic use of public procurement for innovation in the digital economy: executive summary in English, French and German*, Publications Office.

[198] Lember V., Kattel R., Kalvet T. (2014), How Governments Support Innovation Through Public Procurement: Comparing Evidence from 11 Countries, in: Lember V., Kattel R., Kalvet T. (eds), Public Procurement, Innovation and Policy, Springer, Berlin, Heidelberg.

[199] French, German, UK Governments, 2004. Towards and innovative Europe. A Paper by the French, German and UK Governments. 20 February 2004

[200] See in particular: COMP Council Conclusions (30 May 2008, 26 May 2010, 21 Feb 2014, 27 May 2016), EU Council Conclusions (4 Feb 2011, 26 April 2012 and 25 October 2013) and EP resolution on PCP (3 Feb 2009)

[201] ERAC opinion on innovation procurement, 23 June 2015 (https://data.consilium.europa.eu/doc/document/ST-1209-2015-INIT/en/pdf).

centres on innovation procurement[202] and a **European Assistance For Innovation Procurement**[203]**.** In 2021, the Commission also published the first **EU-wide benchmarking on national policy framework and investments on innovation procurement**[176] and is preparing to launch the second one to take stock of progress made meanwhile.[176] and is preparing to launch the second one to take stock of progress made meanwhile.

Evidence has also been building up on the positive impacts of innovation procurement both for public buyers and participating companies and researchers. Literature suggests that innovation procurement has a positive impact on private spending on research and innovation activities and innovation commercialisation success[204], and it also appears that innovative public procurement may be more effective than R&D grants in stimulating private expenditure on innovation.[205] EU funded pre-commercial procurements have proven to decrease costs of innovative solutions with 20% for public buyers, increase interoperability of solutions with 50%, open up 20 times more cross-border sales opportunities for companies, almost triple the amount of contracting from SMEs and more than double their commercialisation success rate[206]. Similar effects have been observed in such procurements across Europe[207]. A Eurobarometer survey also showed that companies that participated in a public procurement of innovative solutions, were 4 times more likely to win additional procurement contracts later[208]. Recent studies show a solid and robust relationship between the share of public procurement for innovation (PPI) in public procurement and GDP per capita for 30 European countries.[209]

Despite the efforts, public buyers across Europe are still not widely implementing innovation procurement (Figure 46). Benchmarking across 30 European countries[210] demonstrated that in 2018 these countries devoted 9.6% of their total public procurement expenditure (10.6% when including defence) to the purchase of innovative solutions, an equivalent of €265 billion excluding defence and €305 billion including defence. This consisted of €16.6 billion of R&D procurement (€10.2 billion excluding defence) and €288 billion of procurement of innovative solutions (€255 billion excluding defence). This means that R&D procurement investments were still only at 0.6% instead of 3% of total public procurement expenditure, while investments in public procurement of innovative solutions were at 9.3% instead of 17% of total public procurement. While overall a doubling of overall innovation procurement investments is needed to reach 20% of public procurement expenditure, the biggest increase (with a factor 5) is needed for R&D procurements.

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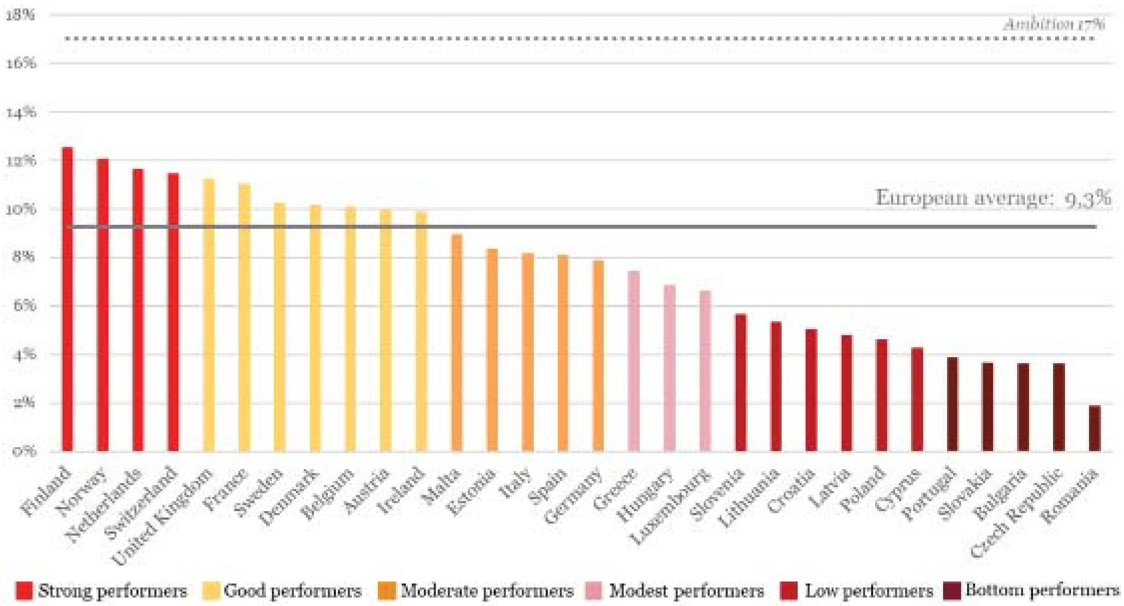
[202] https://procure2innovate.eu/home/.
[203] www.eafip.eu provides local innovation procurement assistance to public buyers across EU Member States.
[204] Edquist C., Zabala-Iturriagagoitia J-K. (2012), 'Public Procurement for Innovation as mission-oriented innovation policy', *Research Policy*, 41(10), pp. 1757–1769.
[205] Guerzoni M., Raiteri.E. (2015), 'Demand-side vs. supply-side technology policies: Hidden treatment and new empirical evidence on the policy mix', *Research Policy*, 44(3), pp. 726–747.
[206] Impacts of EU funded Pre-Commercial Procurements, published on EU webpages.
[207] Comparison of impacts of national and EU level pre-commercial procurements, published on EU webpages.
[208] Flash Eurobarometer 394. The role of public support in the commercialisation of innovations, 2004.
[209] Bento, N., Sousa, C., Trindade, P., Paes Mamede, R., Fontes, M., Alves, T. (2022), 'Robust relation between public procurement for innovation and economic development', *Economics Letters*, 211, 110241.
[210] European Commission, Directorate-General for Communications Networks, Content and Technology (2021), *The strategic use of public procurement for innovation in the digital economy: executive summary in English, French and German*, Publications Office.

Figure 46. Benchmarking of national procurement for innovative solutions out of total public procurement expenditure (including defence), 2018



Source: European Commission. The strategic use of public procurement for innovation in the digital economy: executive summary in English, French and German, Publications Office, 2021.

The underlying factors explaining underinvestment are linked to the status of development of national policy frameworks for innovation procurement. On average, the 30 countries around Europe have so far only deployed one quarter (26.6%) of the potential measures to stimulate innovation procurement. However, countries with stronger national policy frameworks that have deployed a more comprehensive set of policy measures also achieve higher national investments in innovation procurement, and as a result faster public sector modernisation and faster industrial growth. The benchmarking therefore concluded that additional EU and national efforts are needed to substantially reinforce both policy frameworks and investments in innovation procurement.