CHAPTER 4

EU R&I ECOSYSTEMS

CHAPTER 4.1

THE EU R&I DIVIDE

Key questions

- What are the main characteristics and latest trends of the EU regional R&I ecosystems?
- How has the R&I divide evolved across EU Member States and regions?
- How concentrated are R&I activities, specifically those addressing societal challenges and increasing strategic autonomy?

Highlights

- Between 2000 and 2022, there was a clear innovation divide among European countries, with innovation leaders and strong innovators primarily located in northern and western Europe, and moderate and emerging innovators more common in southern and eastern Europe.
- Between 2014 and 2023, some European regions improved their R&I performance, while others were left further behind, creating a pattern of regional differences.
- There is evidence of regional gaps in R&I collaborations, spending, and employment over the last decade.
- Small and medium-sized enterprises (SMEs) in less advanced regions tend to have improved their R&I performance, while those in strong regions have declined in several R&I indicators.
- The industrial structure of European regions and asymmetric developments in productive specialisation across countries and regions have underpinned the emergence of spatial disparities in R&I.
- Smaller and diverse social innovation clusters focusing on local or regional areas have emerged in the EU.

Policy insights

- Overall, European funding has a strong potential to narrow the divide, as low R&I performers rely more on EU funding to support their R&I systems than top performers.

- However, the European Framework Programme for R&I funding is quite concentrated, raising the risk of widening the R&I gap.

- Actions under the Framework Programme (FP) and European Structural and Investment Funds (ESIF) to support territories' development, to enhance institutional capacity and to improve public administration, are therefore critical for promoting cohesion, counterbalancing potential closed-club effects and enhance the overall competitiveness of the EU.

- The Recovery and Resilience Facility (RRF) funding dedicated to R&I is also expected to play a role in reducing the R&I gap, as it represents a significant support in countries with weaker innovation performance.

Europe's economic landscape is marked by considerable territorial disparities (Rodríguez-Pose, 2002; Pike et al., 2017; Diemer et al., 2022), and Research and Innovation (R&I) activities are no exception (Crescenzi et al. 2017). Since the 2000s, regional convergence was observed in the European Union, but it has been challenged over recent years (European Commission, 2022a; European Commission, 2022b). This chapter brings insights on the latest trends and characteristics of the R&I spatial divide, investigating recent changes and long-term trends, linking these to the European industrial structure and the economic divide.

Since the Single European Act, the aim of the EU R&I policy has been to strengthen the scientific and technological basis of EU industry and to make it more competitive at international level (Article 179 of the Treaty of the Functioning of the European Union (TFEU)). The TFEU also provides that the EU shall aim at "reducing disparities between the levels of development of the various regions and the backwardness of the least favoured regions or islands" (Article 174). This chapter, in its second part, by examining the spatial allocation of European funding across the EU, offers an overview of the significance and role of European policies, encompassing R&I, Cohesion, and Recovery instruments, in EU territories based on their level of development and their R&I performance.

1. Territorial disparities in research and innovation

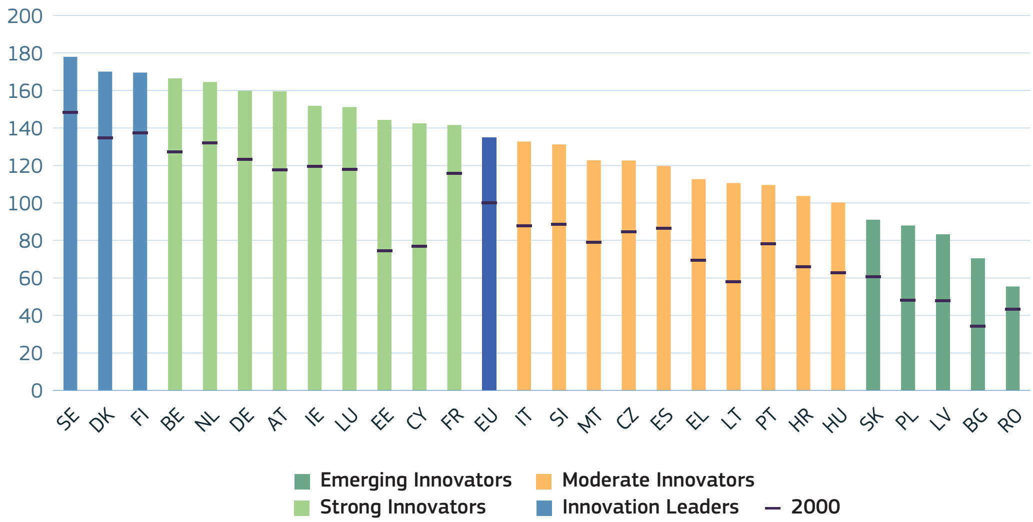
Europe's economic landscape is marked by disparities (Rodríguez-Pose, 2002; Pike et al., 2017; Diemer et al., 2022) **in R&I activities** (Crescenzi et al., 2017). Since the 2000s, the European Union has been observing regional convergence, but this convergence has been challenged over recent years (European Commission, 2022a; European Commission, 2022b).

All Member States have progressed in innovation performance over the last two decades despite persistent disparities. The long-term series of the European innovation scoreboard (EIS) measures the innovation performance of countries from 2000 to 2022, based on 32 indicators. The composite index is calculated using indicators grouped into four main dimensions – framework conditions, investments, innovation activities, and impacts – covering multiple aspects of R&I beyond investment in R&D.[1]

There is a clear innovation divide, with innovation leaders and strong innovators primarily located in northern and western Europe, and moderate and emerging innovators more common in southern and eastern Europe (Figure 4.1-1). In 2022, the Nordic countries – Sweden, Denmark and Finland – led the ranking, performing at levels above 125% of the EU average for that year. Estonia and Cyprus stand out among the strong innovators, showing significant progress over two decades, despite not being part of the EU-14. Conversely, some EU-14 countries, like Italy and Spain, are performing below the EU-27 average. This geographical divide has remained persistent over the 20-year period, with a few notable exceptions, such as Cyprus.

1 More information on the measurement framework of the EIS: European Commission Directorate-General for Research and Innovation (DG Research and Innovation), EIS 2023, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/119961.

Figure 4.1-1 Performance of EU Member States innovation systems in 2000 and 2022



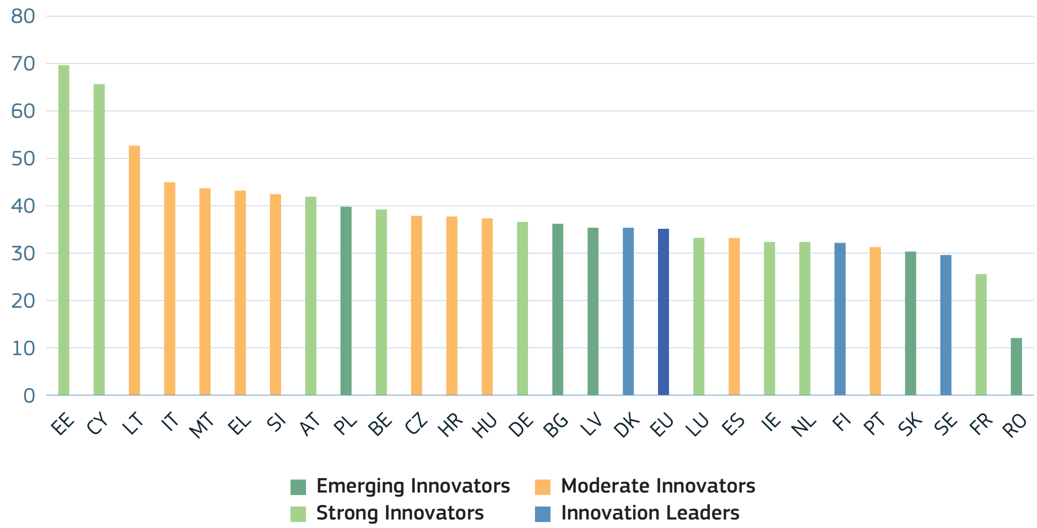
Science, research and innovation performance of the EU 2024

Source: DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on the EIS long-term series.

Note: Performance groups are defined as follows: innovation leaders are Member States where performance is above 125% of the EU average. Strong innovators include Member States with a performance of between 100% and 125% of the EU average. Moderate innovators are those with performance of between 70% and 100%. Emerging innovators have a performance level below 70% of the EU average. The innovation performance groups are based on the year 2022. The scores are expressed relative to the EU average in 2000, with the EU average for 2000 set at 100.

Between 2000 and 2022, innovation performance increased in all EU Member States. Overall, the EU progressed by 35 percentage points during this period. In 17 Member States, progress rates exceeded that of the EU. Interestingly, these faster-paced countries belong to different performance groups. When examining the performance change over time, no clear pattern emerges, either among the Member States that have joined since 2004 or along the north-west/ south-east divide (Figure 4.1-2).

Figure 4.1-2 Performance change between 2000 and 2022 in percentage points

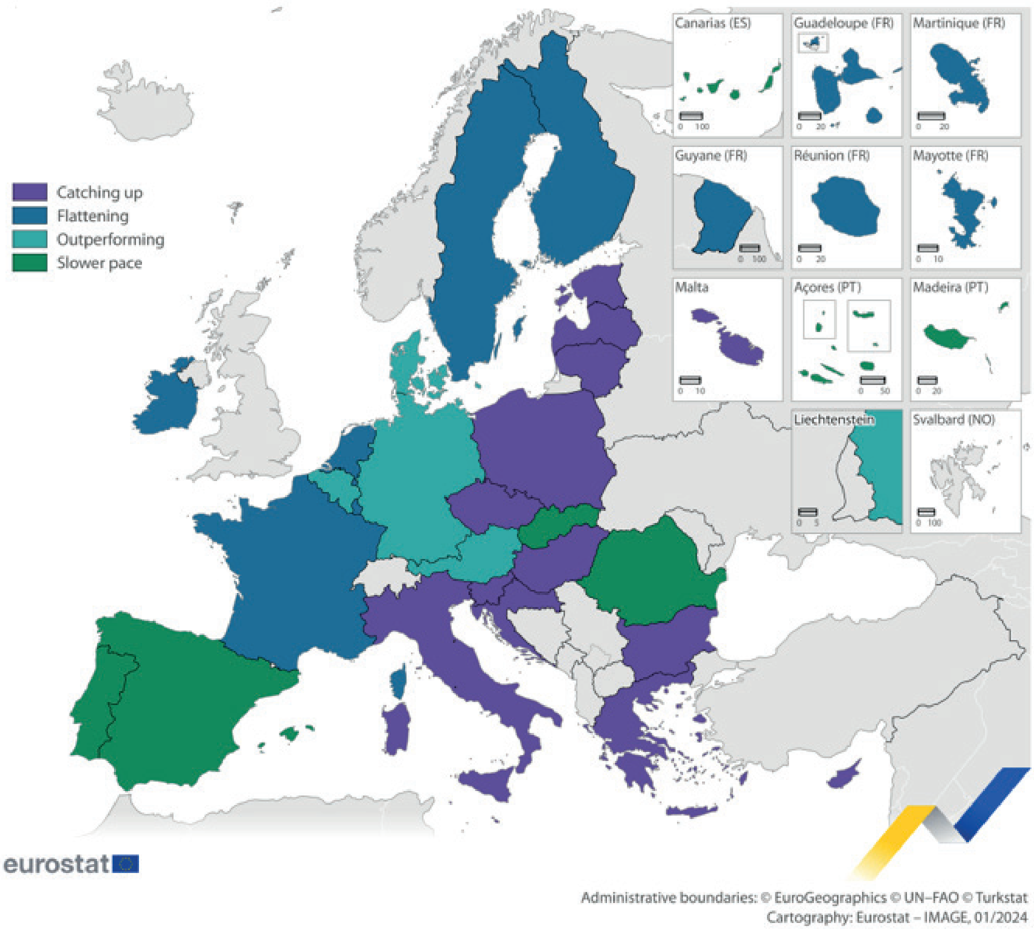


Science, research and innovation performance of the EU 2024
Source: DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on the EIS long-term series.
Note: Performance change is measured as the percentage point difference between the 2000 and 2022 scores.

There is some evidence of overall convergence in innovation performance in terms of catching up. The concept of convergence is typically associated with economic growth models. One way to define the process of convergence is to measure whether countries with initially lower performance scores tend to progress faster than those with initially higher performance scores. This process is known as beta convergence (See for instance Barro, 2015).

In Europe, some countries are following a process of convergence in innovation performance (Figure 4.1-3). Thirteen countries in the southern, eastern and Baltic regions are catching up, with scores lower than the EU average in 2000 but higher progress rates than the EU average ('catching-up' category). Finland, Sweden, the Netherlands, Ireland, France and Luxembourg are experiencing a flattening trend, with lower progress rates than the EU average, starting from a higher position ('flattening' category). Germany, Austria, Belgium and Denmark are outperforming the EU average, having started from a higher than average position ('outperforming' category). Finally, Romania, Portugal, Spain and Slovakia have evolved at a slower pace than the EU average, starting from performance levels lower than the EU average in 2000 ('slower pace' category).

Figure 4.1-3 Patterns of convergence on the EIS, 2000-2022

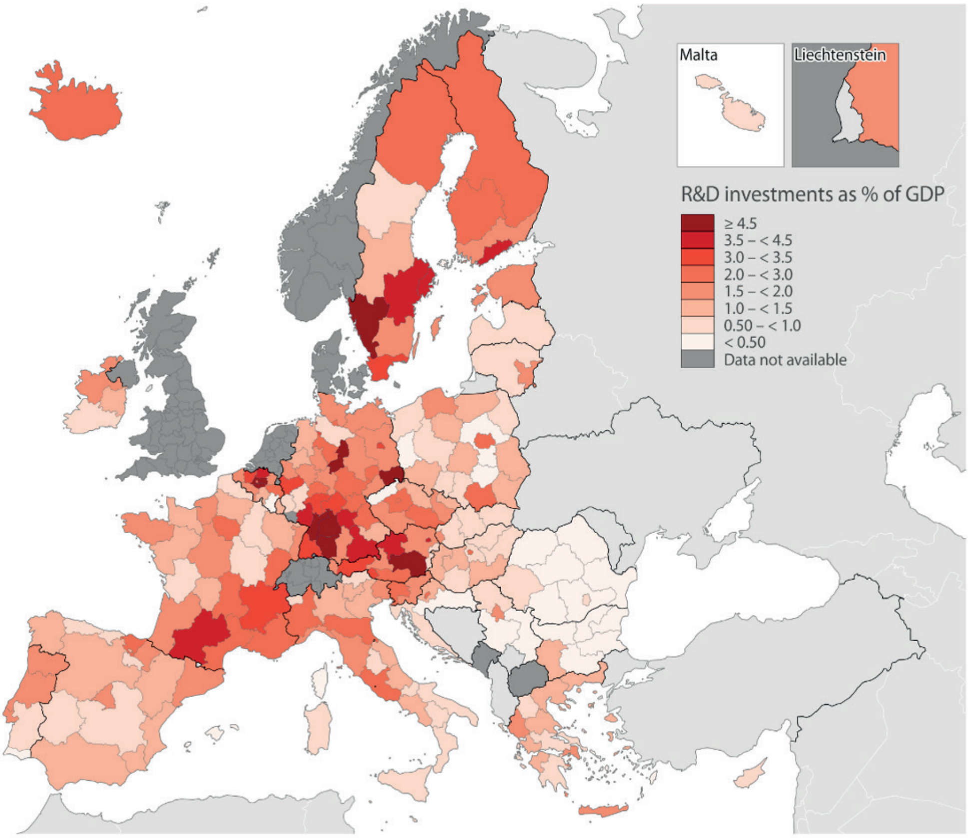


Science, research and innovation performance of the EU 2024

Source: : DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on EIS long-term series.

The regional innovation divide in the EU is pronounced, both in terms of R&I inputs, such as R&D investment, and outputs, such as patenting activity. There is a pronounced regional concentration of R&D investment in the EU (Figure 4.1-4). In particular, R&D intensity is high in western and northern Europe, although well-performing regions can be found in other parts of Europe, too. The regional pattern of technological production is also driven by the existing innovation divide.

Figure 4.1-4 R&D intensity (R&D investments as percentage of gross domestic product (GDP)) per NUTS 2 region in Europe, 2021



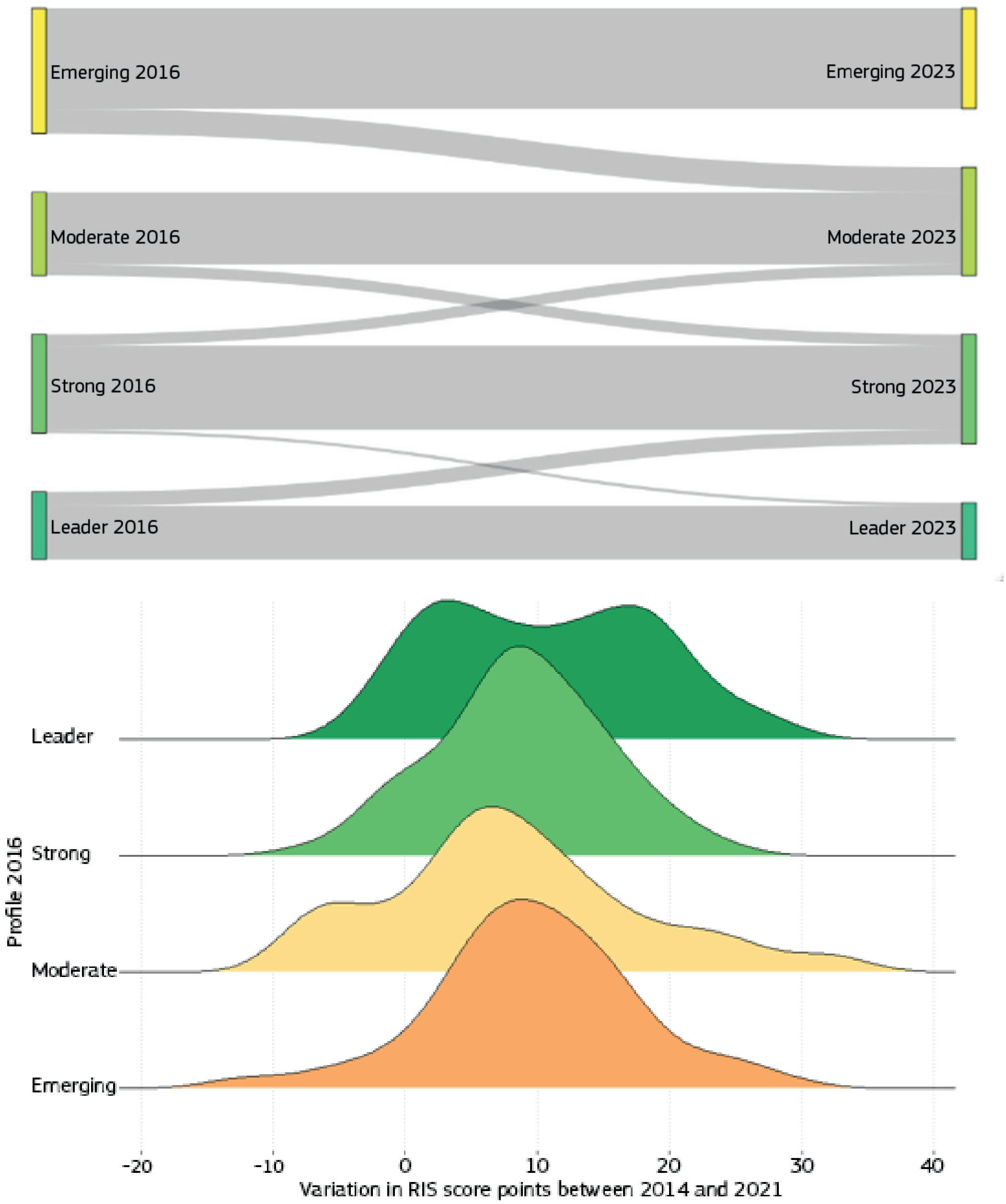
Science, research and innovation performance of the EU 2024
Source: DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on Eurostat.

Between 2014 and 2021, some European regions made remarkable progress in their regional performance indexes, while the majority improved slowly, and others underwent a decline, leading to a particular pattern of regional divergence.[2] There is a significant divide between the regions labelled as innovation leaders and those labelled as moderate innovators (Figure 4.1-5). Within the two categories, one group of regions made significant advances in their regional performance indexes (increases of 15-35 points during 2014-2021 for some 2014 leaders and of 20-40 points for some who were moderate innovators in 2014), while another group experienced a decline, or even a severe decline in the case of moderate innovators (nine 2014 leaders with indexes of over 43 regressed to become strong innovators by 2021 and some moderate innovators saw declines of 10-15 points in their indexes).

As for the emerging and strong innovators in 2016, a more homogeneous evolution can be noted, with only a small fraction witnessing small negative changes over time (Figure 4.1-5). However, this progress was slower compared to the improvements achieved by the top-performing moderate and strong innovators, as well as the leaders, reducing the possibility of achieving regional convergence in the 2014-2023 period. Similar trends of regional divergence in R&I are corroborated by Iammarino and McCann, 2018, OECD, 2021, Crescenzi et al., 2021, and European Commission, 2023a.

2 The European Regional Innovation scores used are for 2016 and 2023, but there is a 2-year lag on the data.

Figure 4.1-5 Distribution of EU NUTS 2 regions according to the change in their R&I performance indexes by regional innovation scoreboard (RIS) profile between 2014 and 2021[3]



Science, research and innovation performance of the EU 2024

Source: : DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on the RIS 2023 data.

Note: Data and profiles in the RIS 2023 are based on data and indicators that usually have a two-year lag. Therefore, the RIS score for 2023 mainly captures data from 2021. More information can be found in the methodology report.

3 RIS profiles of 2016 and 2023 are based on 2014 and 2021 data for most indicators.

A closer look at the performance of the European Union regions across key R&I indicators between 2014 and 2020 reveals a mixed picture (Figure 4.1-6). In terms of R&I collaborations (international or public-private), R&I expenditures (business and public R&D investments) and employment (employed ICT specialists), there are signs of divergence; regions that were stronger performers in 2014 experienced relatively larger increases than those that were initially performing worse.

Achieving marginal gains in quantity and quality of R&I outputs becomes increasingly challenging for regions that are already among the top players, which explains the divide between the highest- and lowest-performing regions. This is certainly the case for some indicators of quality and quantity of research outputs, such as the top 10% of scientific publications in terms of citations received, patents and designs. The regions with the lowest performance levels in 2014 have shown the most significant improvement, while the top performers from 2014 have experienced a decline. Interestingly, variation in trademarks is positive for all groups of regions and with little variation from one performance group to another. This could be explained by the regional structure of the economy, as trademarks are used more often in industries such as textiles, education and training, or transportation[4], which are not the most R&D intensive.

SMEs located in emerging and moderately performing regions seem to have improved their R&I performance, while SMEs in strong and leading regions tend to have witnessed declines in terms of the R&I performance indicators examined in the community innovation survey. There are several factors that could explain such a divide. Since the financial crisis, SMEs have faced severe difficulties in accessing funding (European Central Bank, 2020), and this has led to different reactions. Firstly, exit rates have skyrocketed (OECD, 2009) and in areas that were the most affected, SMEs which survived might very well be the most innovative (Edwards et al., 2008; Ioanid et al., 2018). Secondly, SMEs located in higher-performing regions may face fiercer international and national competition, notably over skilled workers (Prasanna et al., 2019), which could affect their R&I capacity. Thirdly, some national and regional governments have developed support programmes for innovative SMEs and start-ups, and European funding has also been successful in supporting those located in less-developed regions and regions in transition (Romero-Martinez et al., 2010; Radicic et al., 2016; Henriques et al., 2022; Ferraro et al., 2023). Finally, the structure of the community innovation survey is such that coverage of groups of regions is sometimes only partial.

4 Dyvik, E., (2022), Percentage of trademark applications, by industry sector 2022. Statista.

Table 4.1-1 Variation in RIS indicators across EU regions between 2014 and 2021 or latest year available

RIS indicator	Group of regions based on their performance for each RIS indicator at the beginning of the period									
	Bottom 10%	2nd decile	3rd decile	4th decile	5th decile	6th decile	7th decile	8th decile	9th decile	Top 10%
Variation in number of public-private co-publications per million inhabitants (2015-2022)	19.637	41.517	55.843	73.140	83.219	88.607	121.174	138.052	158.888	196.416
Variation in number of international scientific co-publications per million inhabitants (2015-2022)	161.749	158.612	276.491	341.016	402.859	463.502	532.624	627.881	834.108	1098.979
Variation in R&D expenditure in the business sector as percentage of GDP (2013-2020)	0.074	0.187	0.189	0.134	0.193	0.164	0.041	0.178	0.017	0.257
Variation in R&D expenditure in the public sector as percentage of GDP (2013-2020)	0.029	0.023	0.047	0.042	0.062	-0.020	0.044	0.045	0.126	0.150
Variation in percentage of employed ICT specialists over total employment (2014-2021)	0.000	0.202	0.477	0.499	0.618	0.837	0.985	1.227	1.411	2.524
Variation in percentage of scientific publications among the top 10 % most cited (2013-2020)	3.992	1.230	1.586	1.282	0.448	-0.096	-0.175	-0.636	-1.712	-2.338
Variation in number of individual design applications per billion GDP (in Purchasing Power standards - PPS) (2015-2022)	0.456	0.365	0.743	0.465	-0.124	-0.974	-0.682	-0.100	-2.402	-6.286
Variation in number of patent applications per billion GDP (in Purchasing Power standards) (2014-2021)	0.063	-0.003	-0.086	-0.075	-0.163	-0.352	-0.504	-0.560	-0.947	-2.467
Variation in number of trademark applications per billion GDP (in Purchasing Power standards) (2014-2021)	1.276	1.780	1.151	1.534	1.092	1.626	1.341	1.492	0.855	1.938
Variation in innovation expenditures per person employed in innovative SMEs (2014-2020)	-0.007	0.037	0.059	0.023	0.029	0.043	0.046	0.041	0.070	0.090
Variation in non-R&D innovation expenditure as a percentage of total turnover (2014-2020)	0.027	0.039	0.043	-0.016	-0.024	-0.020	-0.056	-0.059	-0.117	-0.269
Variation in employed persons in innovative SMEs as a percentage of total employment (2016-2020)	0.077	0.133	0.085	0.089	0.093	0.131	0.044	-0.019	0.005	0.042
Variation in percentage of turnover of sales of new-to-market and new-to-firm innovations (2014-2020)	0.241	0.183	0.104	0.182	0.111	0.064	0.020	0.174	0.097	0.012
Variation in the percentage of SMEs introducing process innovations over total SMEs (2014-2020)	0.136	0.113	0.199	0.228	0.260	0.260	0.211	0.220	0.189	0.082
Variation in the percentage of SMEs introducing product innovations over total SMEs (2014-2020)	0.119	0.129	0.169	0.224	0.292	0.175	0.104	-0.001	-0.080	-0.041

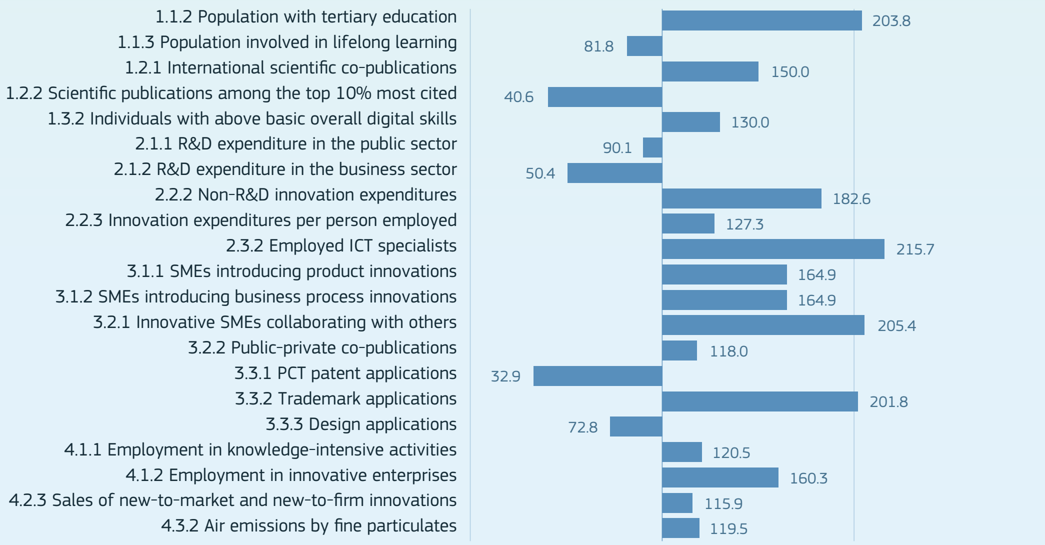
Source: DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on the RIS 2023 data.
Note: See the methodology report of the RIS 2023 for details on each indicator.

Box 4.1-1: Regional case study using quantitative RIS 2023 data and a qualitative approach: the case of the Vilnius region

The RIS provides detailed information on each region's R&I assets. It makes it possible to perform case analysis to determine the key aspects of R&I systems and offer policy recommendations. Considering the Vilnius Capital Region, this box introduces an example of a combination of quantitative and qualitative analysis using RIS 2023 data.

On the RIS, the Capital Region is in the 'strong innovator' category. It ranks 96th out of 241 regions in the EU, and 1st in Lithuania. The region's innovation index rapidly increased from 70 % of the EU average in 2014 to 103 % in 2021, meaning that its performance is now slightly above the EU average (see Figure 4.1-6).

Figure 4.1-6 Capital Region RIS performance (2021 data relative to EU 2014)



Source: Regional case study from the Regional Innovation Scoreboard.

Using both quantitative data from the RIS and qualitative data in the form of interviews with policymakers and experts, the following key aspects driving innovation in the Capital Region have been identified.

- **A progressive regulatory policy** aimed at creating favourable conditions for high-tech and innovative companies, e.g., by significantly shortening the time needed to issue licenses, reducing the initial capital requirement or offering unique European license types.

- **A cluster effect of increasing innovation**. Since 2014, innovation has been increasing very rapidly; for example, the regional average for SMEs introducing business process innovations increased more than threefold (49% to 165%), and the share of innovative SMEs collaborating with other similar companies increased twofold (101% to 205%) compared with the EU average, establishing the Capital Region as a strong innovator in this field.

- **A well-developed infrastructure** for high-tech manufacturing companies (e.g., lasers, biotech) in the Capital Region, which it is oriented towards innovative business practices (e.g. fintech). There are multiple innovation clusters that facilitate cooperation between innovative companies from the same sector.[5] The situation regarding the research system and publications gradually improved during the 2014-2021 period, especially regarding international scientific co-publications and to a lesser degree the number of scientific publications in the top 10% in terms of citations.

- **A high number of foreign direct investment** (FDI). Around three quarters of FDI in Lithuania is in the Capital Region.

On the other hand, there are sizeable barriers to innovation in the region.

- **Limited cooperation between the public and private sectors in the field of innovation or insufficient public financial support for innovation projects.** Although there has been a clear improvement for most of the expenditure indicators – for example, innovation expenditure per person employed increased from 96% to 127% – R&D expenditure in the public sector has decreased (from 139% to 90%).

- **The level of cooperation between educational institutions and businesses, which is relatively low** in Lithuania. In addition, research and education infrastructure in Lithuania is fragmented, which leads to weak knowledge- and technology-transfer processes from educational institutions to businesses.

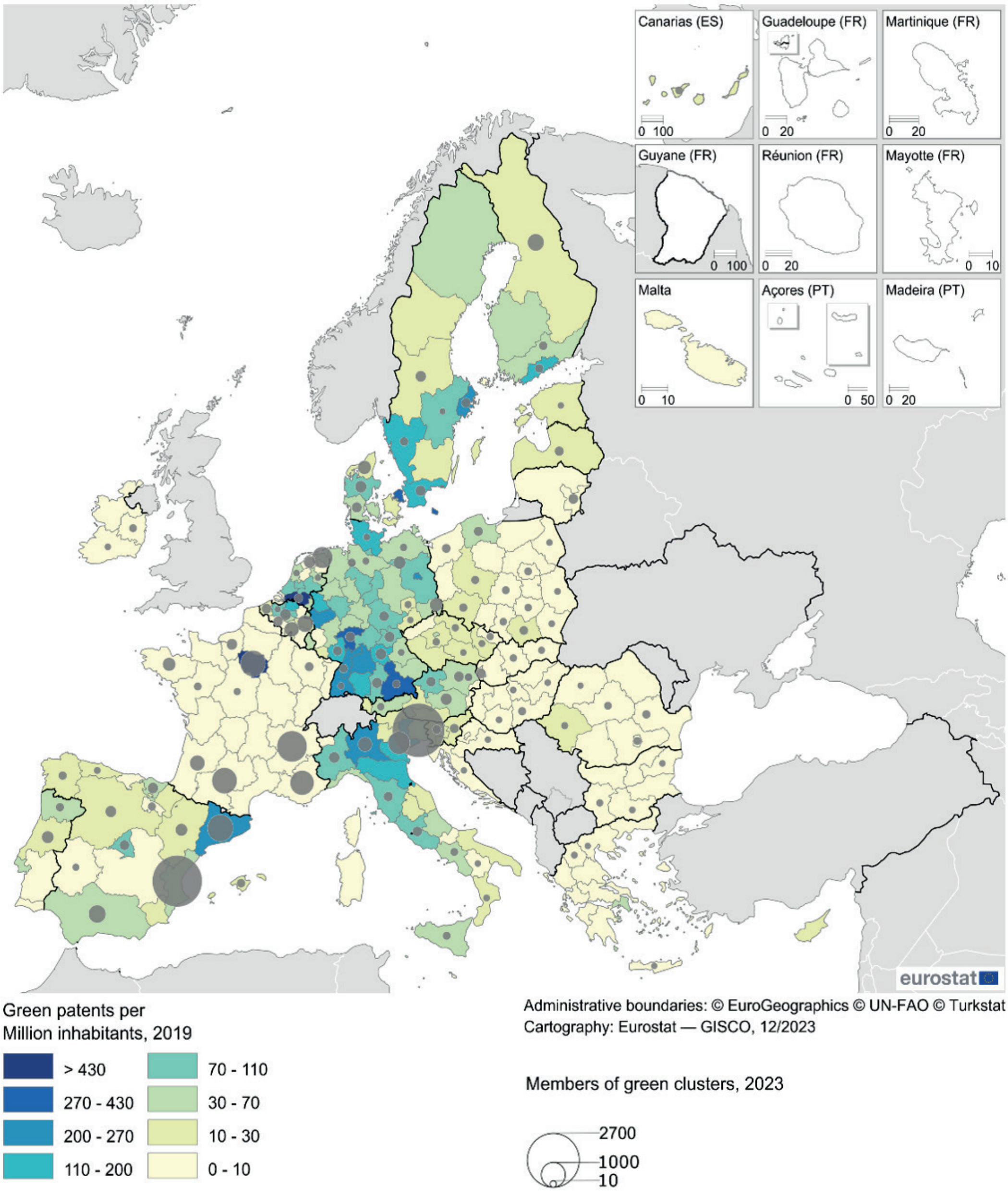
5 For example, Inovacijų Slėnys. More information is available at https://inovatoriuslenis.lt/

The industrial structure of European regions and asymmetric developments in productive specialisation across countries and regions are the most frequently quoted explanations for the existence of spatial disparities in R&I (Bracalente and Perugini, 2010; Mongelli et al., 2016; López-Villuendas and del Campo, 2023; Capello and Cerisola, 2023). Industrial clustering is a phenomenon which leads to SMEs, large firms and research organisations with sector-specific expertise basing themselves close to each other, creating pockets of specialisation across the EU to benefit from economies of scale (Krugman, 1991; Ottaviano and Puga, 1998; Fujita et al., 2001; Iammarino and McCann, 2006; Moretti, 2018). These industrial clusters have positive impacts on regional and industrial performance, including job creation and new business formation (Delgado et al., 2014), while playing a vital role in explaining the high concentration of technological innovation in various sectors across EU regions (Figure 4.1-7 for the green and digital sectors).

Over the last century, while industrial clustering has mainly been driven by production activities, location choices are now determined more by shared skill requirements, especially in service sectors (Diodato et al., 2018). This has resulted in stronger industrial clustering in cities in western Europe and an even spread across regions in central and eastern Europe, especially since the financial crisis (Odendahl et al., 2019). Finally, innovative clusters are becoming more specialised in related innovation activities, leading to a reinforcement of overall geographical concentration and a tendency toward regional divergence (O'Sullivan and Strange, 2018; Iammarino and McCann, 2018).

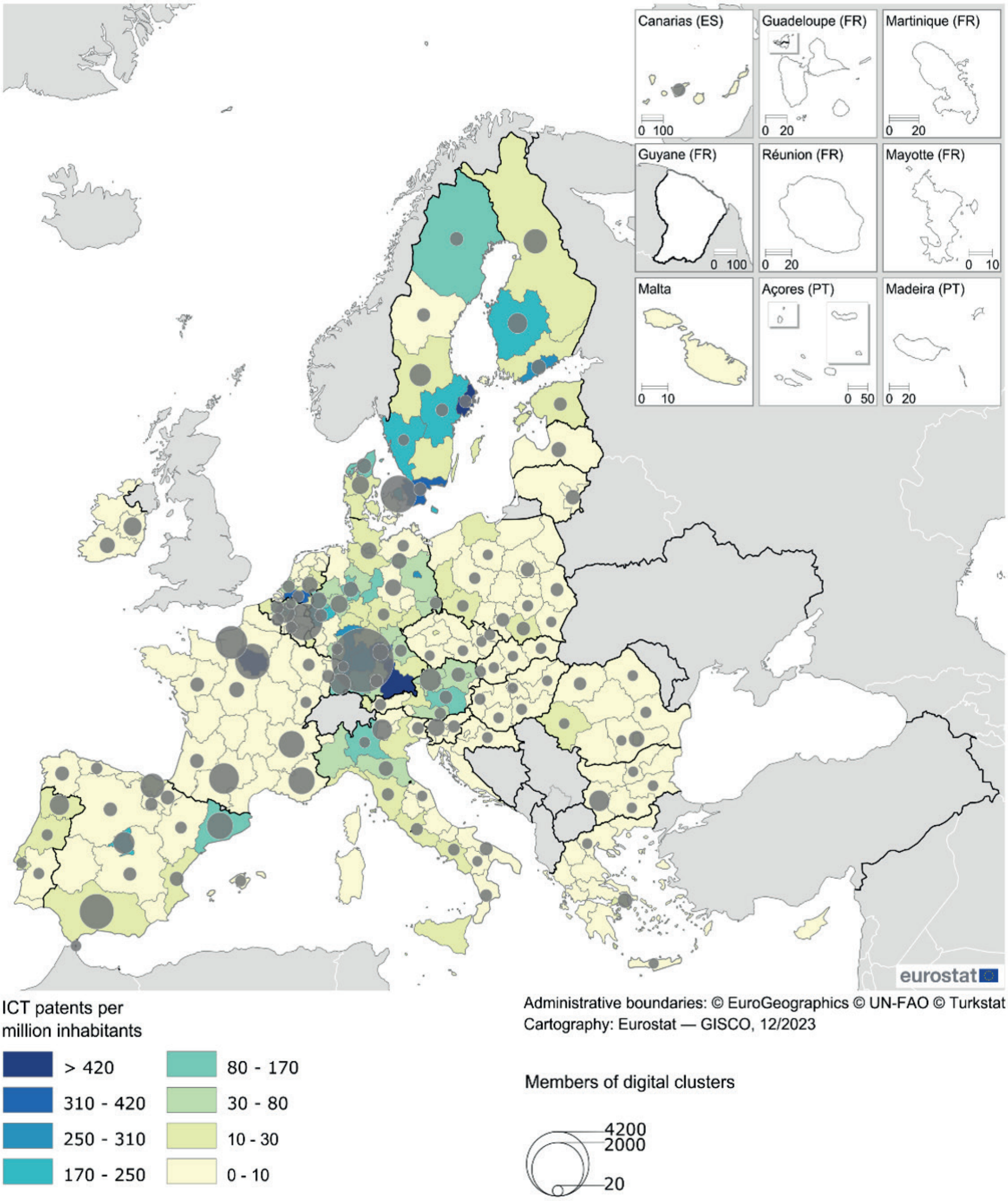
Figure 4.1-7 Members of green/digital industrial clusters registered with the European Cluster Collaboration Platform[6], 2021 and green/ICT patents per million inhabitants, 2018

Green patent clusters



6 The European Cluster Collaboration Platform hosts about 1 127 industrial clusters in Europe: Homepage | European Cluster Collaboration Platform.

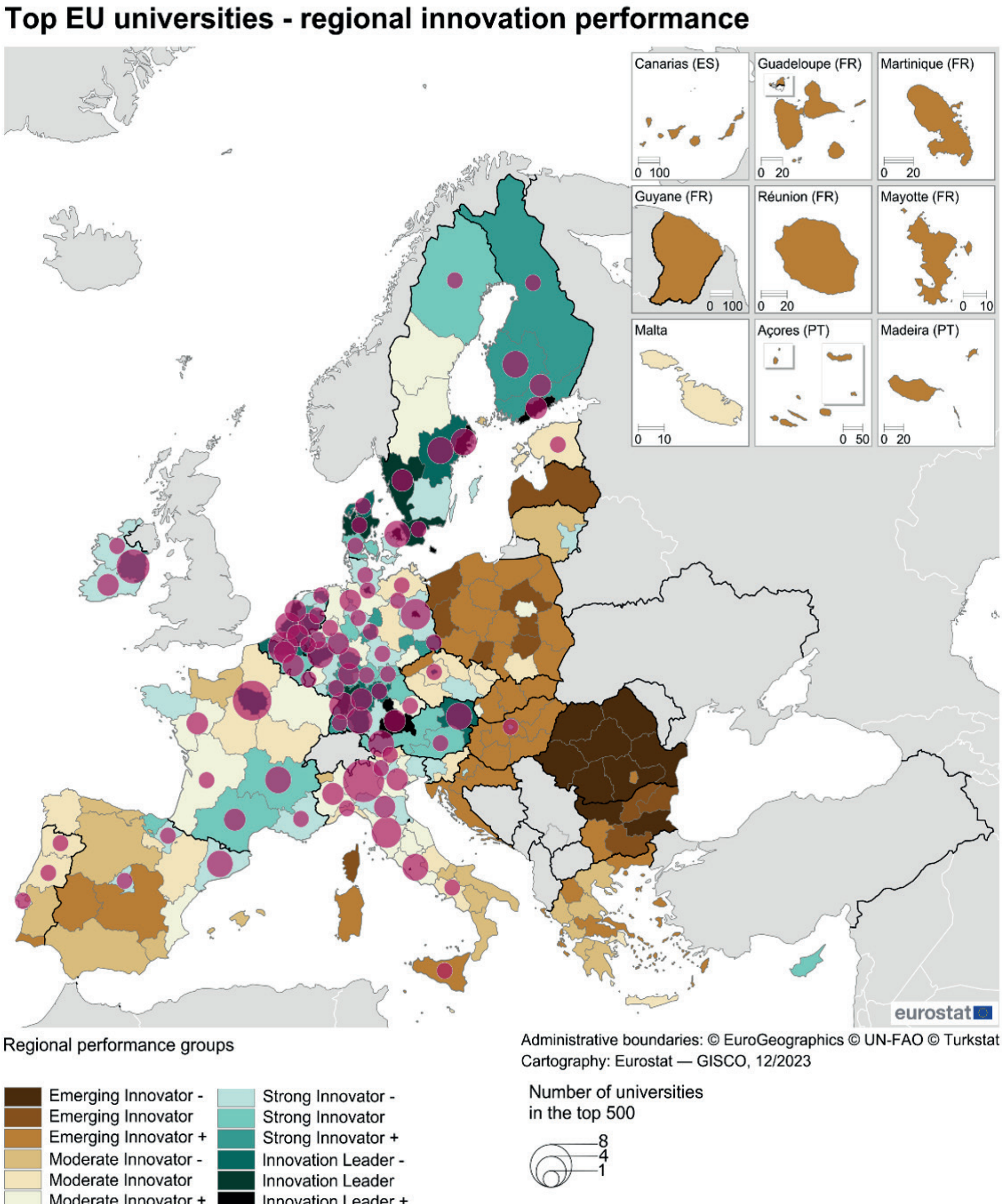
Digital patent clusters



Science, research and innovation performance of the EU 2024
Source: DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on Science Metrix using REGPAT data and on European Cluster Collaboration Platform data.
Note: Industrial clusters are registered under the European Cluster Collaboration Platform. Green industrial clusters are defined as ‘working in green sectors and/or technologies’ and digital clusters as ‘working in digital sectors and/or technologies’. Green patents are defined as patents in the fields of climate action; the environment; resource efficiency and raw materials; secure, clean and efficient energy; and smart, green and integrated transport.

152 of the top 500 universities included in the Times higher education impact ranking 2021 are located in the EU and are highly concentrated in top-performing regions according to the RIS 2023 (Figure 4.1-8). Collaboration between public research institutions and the business sector is one of the most important channels for knowledge diffusion and valorisation and significantly increases the performance of regional R&I ecosystems.

Figure 4.1-8 Distribution of the top 500 universities using the Times higher education impact ranking 2021 and RIS 2023 scores



Source: DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on RIS 2023 data and Times higher education impact ranking 2021.

Much place-based and social innovation in EU territories, including less populous areas, is difficult to measure with the usual research input and output indicators (Mihci, 2020). Social innovation refers to the process and the outcome of the process of development of new products, methods and services for and with society (Solis-Navarrete et al., 2021; Mulgan, 2006; Mulgan et al., 2007; Cajaiba-Santana, 2014).

At least 65 social innovation clusters[7] are scattered across the EU. Social economy enterprises, partnerships, cooperatives, and associations, sometimes organised in clusters, have proven to be innovative in dealing with socio-economic and environmental problems, while contributing to economic development and are often cited as key players for social innovation (European Commission, 2020). These social innovation clusters are often smaller in size than other industrial clusters, and also more diversified in terms of their types of members (see Table 4.1-2) and their sectors of intervention (health, waste management, energy, agriculture, housing, etc.). In addition, they have a geographical intervention scope that is predominantly local and regional, with no or few global or national activities. They also emerge in predominantly rural areas (see Table 4.1-2).

Table 4.1-2 Social, green and digital industrial clusters: a few characteristics

		Social innovation clusters	Clusters working in green sectors and/or technologies	Clusters working in digital sectors and/or technologies
Average number of members	Total	83	130	154
	SMEs	62	95	102
	Large companies	6	13	16
	Research organisations	5	11	13
	Associations/ cooperatives	9	0	0
Ratio of localisation in rural/urban regions (Eurostat typology)		1.2	1.0	0.7

Science, research and innovation performance of the EU 2024

Source: DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on European Cluster Collaboration Platform data.

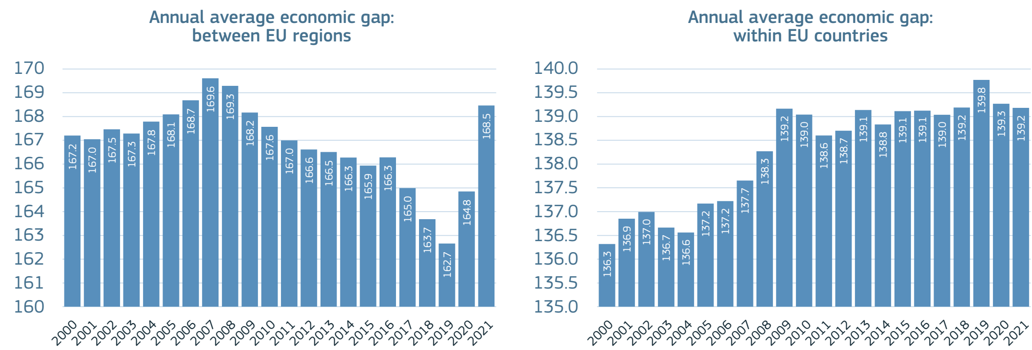
7 Identification of social innovation clusters has been the object of two studies financed by the European Commission.

2. Innovation divide and economic divide: what role for EU funding and policies?

Since the adoption of the Single European Act, the aim of EU R&I policy has been to strengthen the scientific and technological basis of EU industry and to make it more competitive at international level (Article 179 of the Treaty on the Functioning of the European Union (TFEU)). The TFEU also provides that the EU shall aim at 'reducing disparities between the levels of development of the various regions and the backwardness of the least favoured regions or islands' (Article 174).

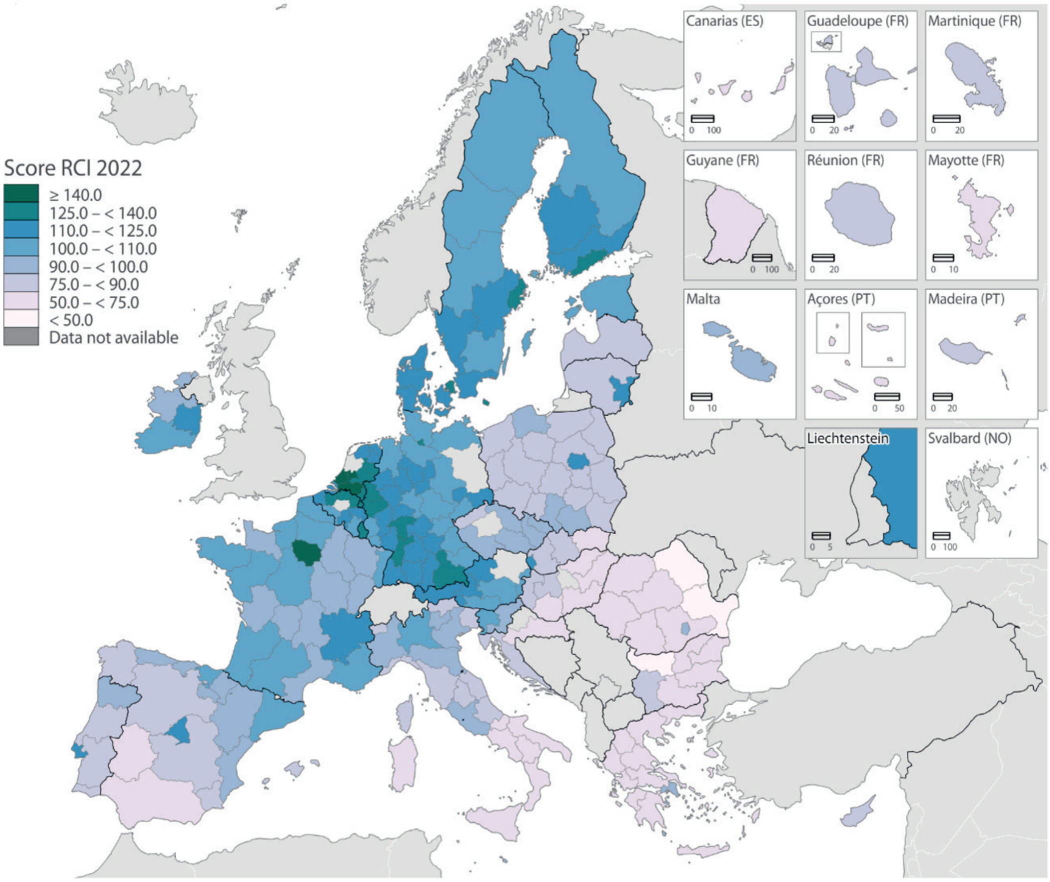
The EU has experienced the emergence of subnational economic development clubs, consisting of regions with wide differences in dynamics of income, employment, industrial composition, education, productivity, innovation, urbanisation and demography (Diemer et al., 2022). Regional disparities in the EU, as measured by the gap or distance between a given region's GDP per capita and that of the region with the highest GDP per capita in the EU, decreased between 2000 and 2019. However, this convergence process, which was reversed in 2020 and 2021 by the effects of COVID-19, hides very diverse trends. Firstly, regions that have reduced their economic gap to the leading region are mainly located in northern and eastern Europe (Figure 4.1-9). By contrast, many Mediterranean regions have been diverging. Secondly, in-country regional differences in productivity levels are on the rise, which accords with existing studies (Mongelli et al., 2016; OECD, 2023; European Commission, 2023b); Marques-Santos et al., 2024). This is the result of several countries, in particular (but not only) in eastern Europe, experiencing further economic concentration in a few, mostly metropolitan, areas. These disparities can be observed when looking at the evolution of the GDP per capita gap in European regions (Figure 4.1-9) and in the regional competitiveness index (Figure 4.1-10).

Figure 4.1-9 Annual average economic gap: between (left) and within (right) indexes, 2000-2021



Source: Joint Research Centre, Innovation Policies and Economic Impact Unit, based on Eurostat data.

Figure 4.1-10 Regional competitiveness index, 2022

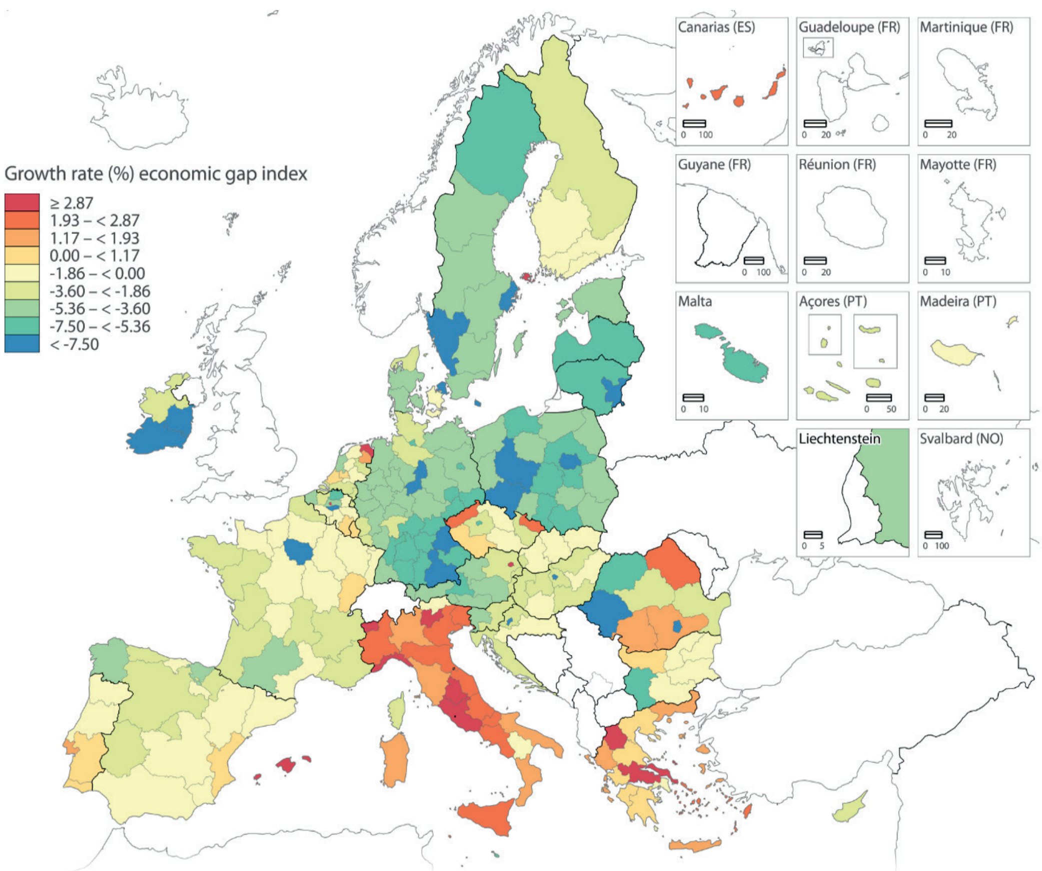


Science, research and innovation performance of the EU 2024

Source: DG Regional and Urban Policy.

Regions with weak innovation performance saw their economic gap vis-à-vis the richest region in their country widen significantly over the 20 years from 2000, whereas the best-performing areas experienced the opposite trend, though less markedly (Figure 4.1-11). At EU level, emerging innovator regions converged only modestly, whereas moderate innovator regions diverged, even before COVID-19 (Marques-Santos et al., 2024). These in-country disparities are also apparent when seen through the lens of RIS categories (Table 4.1-3). Interestingly, higher R&D expenditure seems to lead to increased regional convergence, both at EU and national level (Figure 4.1-12).

Figure 4.1-11 Changes in economic gap between European regions: growth rate (%) in 2019 compared with 2000



Science, research and innovation performance of the EU 2024

Source: Joint Research Centre, Innovation Policies and Economic Impact Unit, based on Eurostat data.

Note: 2019 has been chosen to avoid biases in the overall evolution of the productivity gap due to the COVID-19 effect in 2020-2021.

Table 4.1-3 Annual average economic gap (between EU regions and within EU countries) by RIS classification (RIS 2023)

Category	Between EU regions				Within EU countries			
	2000	2019	2020	2021	2000	2019	2020	2021
Emerging innovator	180.2	176.1	177.5	179.5	141.6	153.9	154.6	154.2
Moderate innovator	167.3	165.4	168.1	171.3	136.5	140.5	139.8	139.7
Innovation innovator	153.0	146.3	149.0	154.7	127.4	124.4	123.2	123.3

Science, research and innovation performance of the EU 2024

Source: Joint Research Centre, Innovation Policies and Economic Impact Unit, based on Eurostat and EIS data.

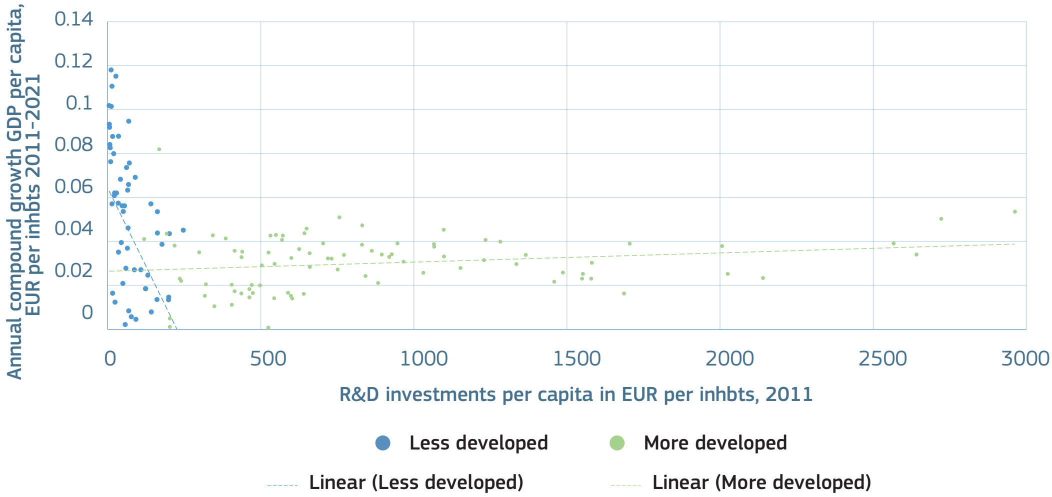
Figure 4.1-12 Relationship between change in economic gap between EU regions (left) and within countries (right) and R&D expenditure per capita in the previous year, 2000-2021

Science, research and innovation performance of the EU 2024
Source: Joint Research Centre, Innovation Policies and Economic Impact Unit, based on Eurostat data.
Note: The figure above is a binscatter constructed using panel data of 4 977 observations. Binned scatterplots provide an alternative way of visualising the relationship between two variables, based on a large number of observations, by computing the mean of the x-axis and y-axis variables within each bin and then creating a scatterplot of these data points.

Regions in the core of Europe with a higher initial level of investment in R&D have achieved a marginally greater degree of economic growth, while less-developed regions are less capable of generating innovation from R&D inputs (Rodríguez-Pose and Wilkie, 2019). In more-developed regions, the regression line between R&D expenditure and economic growth has a slightly positive slope (Figure 4.1-13). The clear negative regression line reinforces the idea that the effort to generate more innovation in many less-developed regions has not delivered on the final objective of unleashing greater economic activity and growth. This may curtail their capacity to grow in the medium to long term.

Hence, the basic tenet of the linear model of innovation – that R&D investment leads to greater innovation, and, in turn, to growth – is challenged in the EU, in particular across most of its less-developed regions. This has been explained in the literature by the fact that the capacity to generate innovation out of R&D inputs relies on the presence of strong institutions (Rodríguez-Pose and Di Cataldo, 2015).

Figure 4.1-13 From investment in R&D to economic growth in European regions according to their level of development, 2011-2021



Science, research and innovation performance of the EU 2024

Source: DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on Eurostat data and the Science, Research and Innovation Performance of the EU Report, 2020.

Note: More- and less-developed regions are defined using the cohesion policy classification for the 2021-2027 programming period: more-developed regions have an average GDP/head (PPS) for 2015-2016-2017 of >= 90% of the EU average; less-developed regions have an average GDP/head (PPS) for 2015-2016-2017 of <= 75% of the EU average.

The EU FP for R&I and the ESIF[8] **jointly contribute to achieving the TFEU objectives of strengthening the EU scientific and technological base, fostering R&I collaborations, and reducing spatial disparities** (Art 174 and 179 TFEU). The vast majority of regions in north-western Europe, owing to their high performance in R&I, participate primarily in Horizon Europe. By contrast, eastern European regions and a non-negligible number of southern regions receive a larger share of structural funding for R&I to support their convergence (Čučkovic and Vučković, 2021; Izsak and Radošević, 2017; Figure 4.1-14) Therefore, structural funds, being to a significant extent earmarked for regions that are less developed and typically performing less well in R&I, compensate for the low capacity of these regions to tap into EU FP for R&I funding.

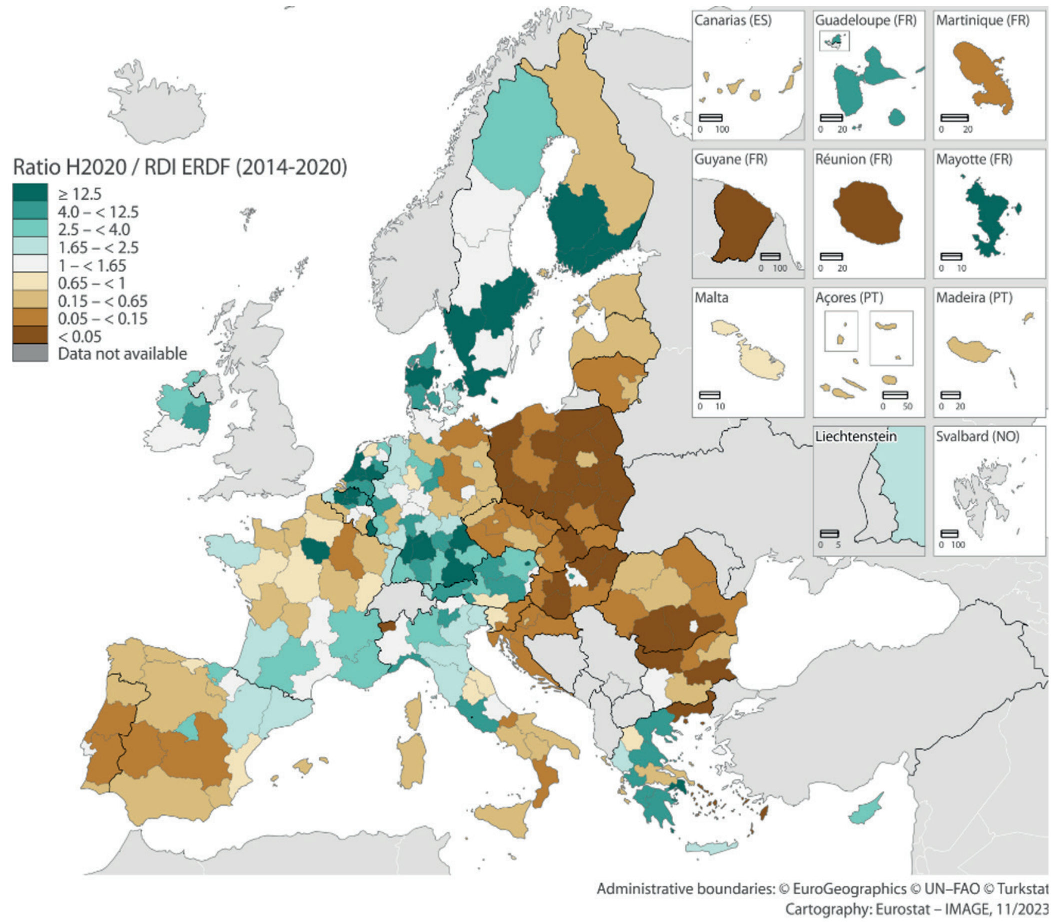
However, Europe is experiencing a 'closed-club effect' (Protogerou et al., 2010; Balland et al., 2019; Enger, 2018; Peiffer-Smadja et al., 2023), **which is linked with a high risk of widening the R&I divide**. Displaying a ratio of the use of Horizon 2020 to that of cohesion funds (only the R&I part of the European regional development fund (ERDF)), Horizon 2020 funding is much more concentrated than that of ESIF (Figure 4.1-14). The excellence criteria for funding awards under Horizon 2020 can further strengthen the competitive advantage of already-advanced regions, creating a cycle resulting in high concentration of public funding.

8 ESIF include the ERDF and the European social fund (ESF). In this analysis, we focus only on the funds dedicated to R&I activities under ESIF.

Complementary actions under the EU FP for R&I and ESIF, are therefore important to support cohesion, counterbalance the closed-club effect and promote the overall competitiveness of the EU. These may take the form of supporting territorial development, enhancing institutional capacity, and improving public administration and good governance at regional and local levels (Robinson and Acemoglu, 2012; Rodríguez-Pose and Di Cataldo, 2015 on the importance of institutional context for innovation and competitiveness).

The EU FP for R&I mainly supports R&I projects in sectors that allow research organisations and companies to collaborate to tackle societal challenges and compete with international players. However, it also dedicates resources to the development and improvement of research infrastructure, the governance of R&I systems and the integration of civil society into R&I.[9] This creates synergies with smart specialisation policies and ESIF which improve R&I assets and increase research capacities that are fundamental to meeting the TFEU objectives.

Figure 4.1-14 Distribution of the ratio of use of Horizon 2020 funds to cohesion policy funds (only the R&I part of ERDF funding) across EU NUTS 2 regions, 2014-2020

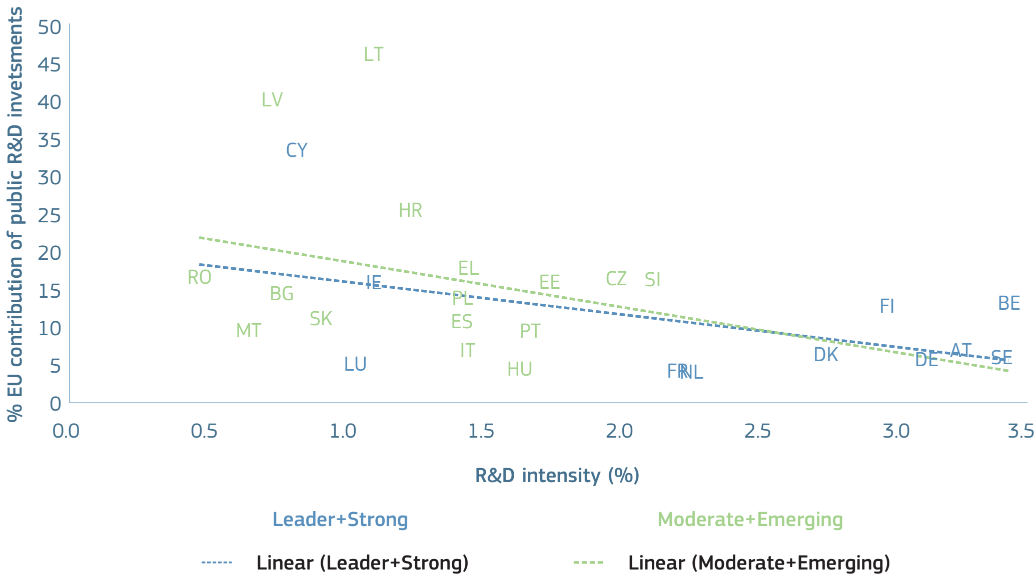


Science, research and innovation performance of the EU 2024
Source: Joint Research Centre, Innovation Policies and Economic Impact Unit, based on Territorial Economic Data viewer data and Marques Santos et al (2023).

9 For more detailed analysis, please refer to the evaluation of Horizon 2020.

Overall, European funding has strong potential to narrow the divide. There is a higher reliance of low R&I performers – those which dedicate fewer resources per capita to R&D – on EU funding, in particular ESIF, to support their R&I systems (Figure 4.1-15). In eastern Europe and some parts of the Mediterranean, even middle-income and more-developed regions depend on ESIF allocations to a greater extent than on EU FP for R&I resources (Molica and Marques-Santos, 2024). This observation is also valid across groups with different performance levels according to the European Innovation Scoreboard 2023.

Figure 4.1-15 Contribution of EU funding to public R&D investment by EU Member State R&D intensity and EIS profile (2023), 2021 or latest year available



Science, research and innovation performance of the EU 2024

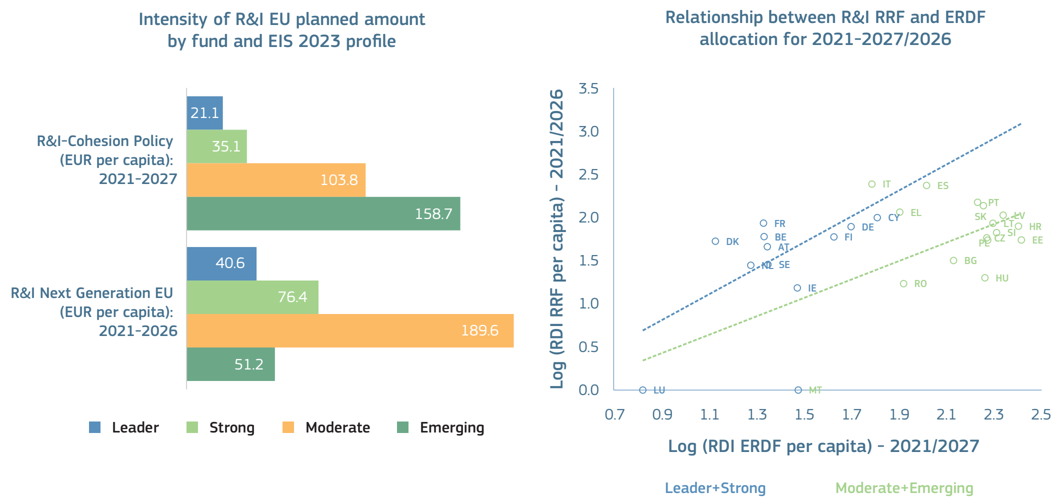
Source: DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on Eurostat and EIS data.

Note: R&D investment data for Germany and the Netherlands are 2019 data. R&D public investment corresponds to government, higher education and rest of the world public investments. The total EU contribution might be underestimated due to reporting methods in some Member States.

The RRF is also expected to play a role in reducing the innovation gap. A number of countries with weaker innovation performance enjoy high per capita levels of both RRF and ERDF funding for R&I (Italy, Greece, Portugal, Latvia, Croatia, Estonia, Czechia and Poland; Figure 4.1-16). However, the per capita intensity of the R&I resources supplied under the RRF is also relatively significant in a few strong innovator countries (Belgium, France, Germany and Denmark), whereas it appears modest in some of the less-developed (and least innovative) countries (Romania, Hungary and Bulgaria) (Molica and Marques-Santos, 2024).

Overall, differences between per capita levels across EU countries are more pronounced for R&I ERDF funds than for the equivalent resources under the RRF, pointing to a weaker redistributive nature of the latter. This can be partially explained by the different allocation methodologies of the two instruments. The RRF allocation method takes more account of the size of the country alongside the impact of COVID-19 on national GDP. Planning decisions are also a factor.

Figure 4.1-16 Intensity and relationship of planned EU R&I funding amounts under cohesion policy funding (ERDF part) and RRF for the period 2021-2027 (2026), by EIS profile (2023)



Science, research and innovation performance of the EU 2024
Source: Joint Research Centre, Innovation Policies and Economic Impact Unit, based on Cohesion Open Data Platform, FENIX, Eurostat and EIS data.

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CHAPTER 4.2

R&I CONNECTIVITY

Key questions

- What is the state of play of R&I collaborations within the EU?
- What can R&I policy do to improve connectivity within the European R&I ecosystem?

Highlights

- Please replace by: The overall number of R&I collaborations has drastically increased in the EU.
- The European regional co-patenting network is fragmented along national lines and characterised by a strong cross-border effect.
- Complex technologies, such as digital ones, are those showing the highest shares of inter-country collaborations.

Policy insights

- EU R&I policies play a major role in increasing connectivity of the European R&I ecosystems.
- The EU Framework Programme for R&I has created an important collaboration network. This network makes it possible to steer R&I collaborations across the EU and overcome cross-border effects.
- Please repharse: Pillar 2 of the Framework Programme and initiatives such as Interreg, i.e., the European programme for territorial cooperation and promotion of cross-border exchanges between regions, fulfil the role of steering R&I collaborations across the EU.

The increasing geographical concentration of research and innovation (R&I) activities coexists with the increasing internationalisation of research collaborations, in a sort of “local-global duality” (Hidas et al., 2013): knowledge production activities have become increasingly interconnected in the last decades, due to globalisation. Collaborative R&I allows researchers and other innovative actors to engage in mutual learning endeavours, increasing the quality of the research output to have a stronger impact on the innovation system and, in turn, on the economy as a whole (Chesbrough, 2003; von Hippel, 2005; Hoekman et al., 2009; Wanzenbock et al., 2014).

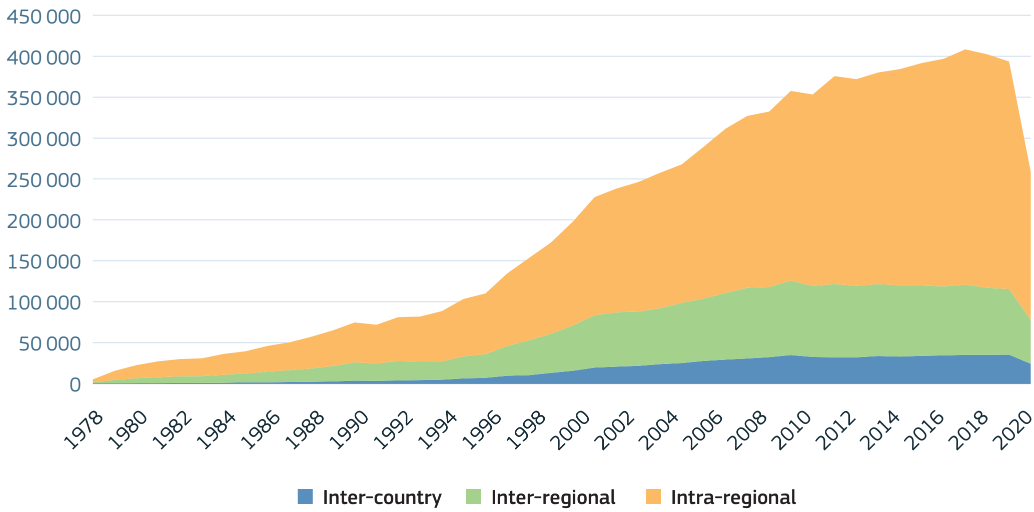
As a result, the number of scientific and innovation collaborations has increased. Nevertheless, this increase is also characterised by specific geographical and sectoral patterns in the EU. Furthermore, the EU has consistently supported collaborative projects in R&I, notably through the European Framework Programme for R&I (European Commission, 2022), and other initiatives, such as the Interreg programme. This chapter proposes, in this second part, an overview of the role and importance of European R&I policies and initiatives to improve the connectivity of EU R&I ecosystems.

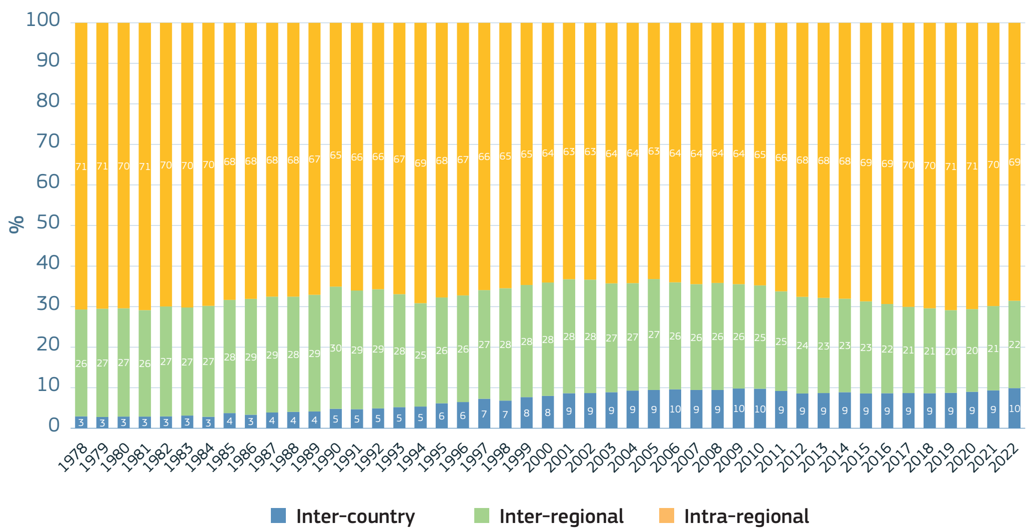
1. The state of play of R&I collaborations within the European Union

There is an increasing geographical concentration of R&I activities and an increasing internationalisation of research collaborations. Both phenomena coexist in a sort of ‘local-global duality’ (Hidas et al., 2013) where the globalisation process has caused knowledge production activities to have become increasingly interconnected in recent decades. Collaborations in R&I allows researchers and other innovative actors to engage in mutual learning endeavours. This increases the quality of the research output and leads to a stronger impact on the innovation system and, in turn, on the economy as a whole (Chesbrough, 2003; von Hippel, 2005; Hoekman et al., 2009; Wanzenbock et al., 2014).

The overall number of EU R&I collaborations has increased significantly. Co-patenting, while not the sole indicator of collaboration in the domain of R&I, can be considered a concrete result of successful collaboration between two or more innovators. Co-patenting in Europe has increased considerably since 1980, from 1000 to over 100 000 by 2020 (Figure 4.2-1). This trend is also observed globally (Breschi and Malerba, 2005; Agostini and Caviggioli, 2015; Belderbos et al., 2022) and can be explained by: (1) a growing significance of R&D collaborations, notably because of the many interdependencies among various high-tech industry process and product components (Agostini and Caviggioli, 2015); (2) the diminishing reluctance among firms to co-own patents (Hagedoorn, 2003) and the recognition of co-patenting as a useful strategy for companies (Belderbos et al., 2014); (3) dedicated public support for cooperation in R&I, involving both firms and higher education institutions.

Figure 4.2-1 Evolution of numbers of intra-regional, inter-regional and inter-country co-patents and the yearly percentage of each type of co-patent from 1980 to 2020 (all EU, UK, NO, IS and CH NUTS 2 regions)





Science, research and innovation performance of the EU 2024

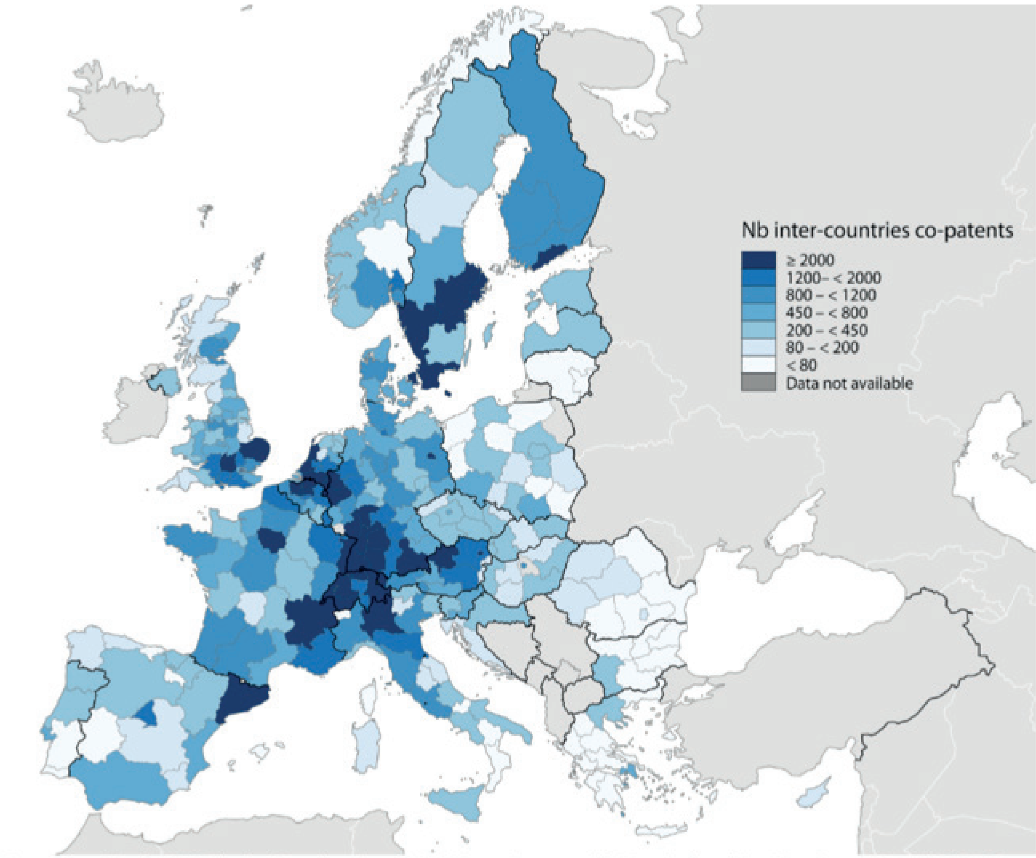
Source: DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on REGPAT dataset.

Notes: Labels correspond to the three types of co-patents (inter-country, inter-regional, intra-regional). Inter-country co-patents involve at least two organisations located in different European countries; inter-regional co-patents involve at least two organisations located in different European regions but in the same country (intra-country); intra-regional co-patents involve only organisations located in the same region.

In Europe, a large majority of collaborations resulting in co-patents occur between organisations located in the same region (63-71% of all co-patents filed each year are the result of intra-regional collaboration). This can be explained by the role of spatial proximity, which creates a web of social, face-to-face interactions and networks that enable the rapid and effective diffusion of ideas and knowledge spillovers (Chakravarty et al., 2021) thereby boosting the overall productivity of local actors in the innovation system (Fleming et al., 2007).

Only 3-10% of co-patents filed each year involve organisations located in two different European countries. Inter-country co-patents mostly involve entities located in cross-border regions (next to one another but in a different EU Member State), notably along the Rhine valley, connecting German, Belgian, French and Swiss regions. R&I connectivity is also strong between entities located in capital cities, which have an excellent track record of patenting activity (Figure 4.2-2). Maintaining such extra-regional and inter-country collaborations may further stimulate and sustain the creation of knowledge capabilities and innovation (e.g., Cano-Kollmann et al., 2016).

Figure 4.2-2 Number of inter-country co-patents by NUTS 2 regions, 1979-2020 and co-patents network by NUTS 2 regions - adjacent cross-country regions collaborations

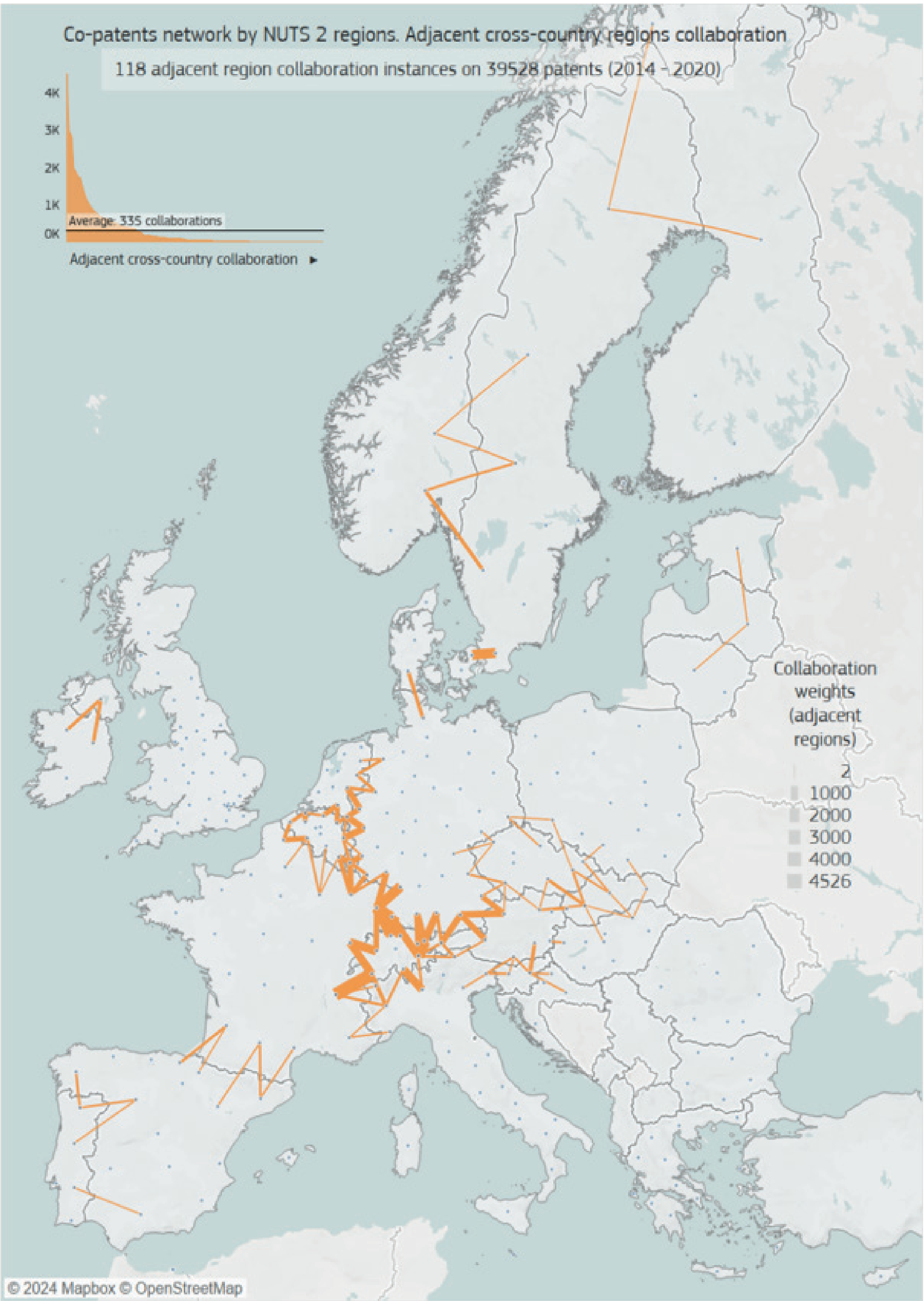


Data may be missing for NUTS2 that have been discontinued from 2013 onwards.
Source: DG Research and Innovation– Common R&I Strategy and Foresight Service Chief Economist Unit based on REGPAT data.

Administrative boundaries: © EuroGeographics © UN-FAO © Turkstat
Cartography: Eurostat – IMAGE, 08/2023

Science, research and innovation performance of the EU 2024

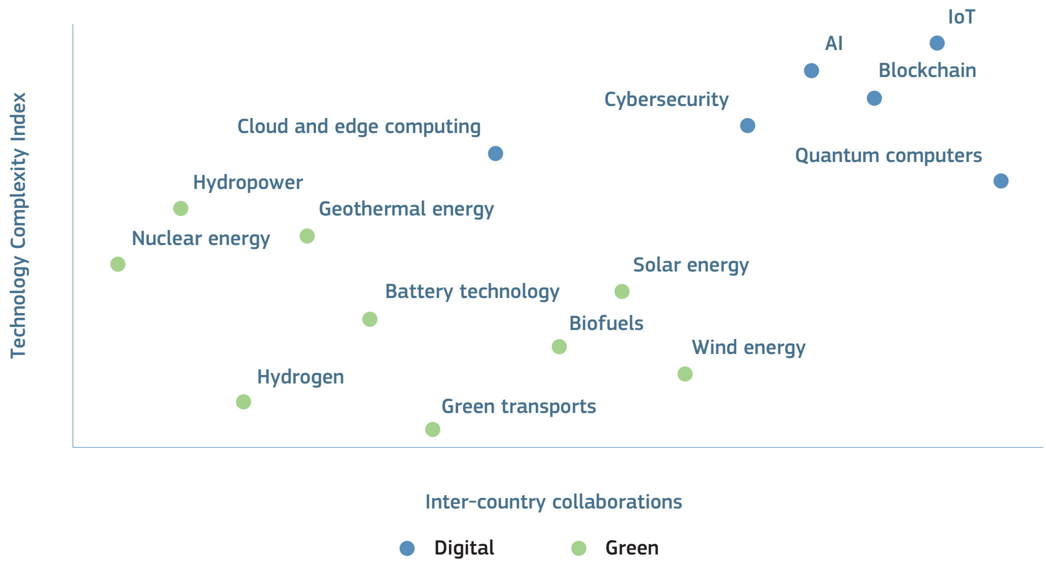
Source: DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on REGPAT data.



Source: Joint Research Centre, Innovation Policies and Economic Impact Unit.

European R&I collaboration capacity is critical for innovation in complex technologies. Complex technologies are defined based on their rarity on the international scene: the fewer countries there are to file patents in a specific technology class, the more complex this technology class is.[1] There is an exponential positive correlation between the ranking by complexity index of a specific technology category and its share of European inter-country collaborations (Figure 4.2-3). Digital technologies, such as artificial intelligence (AI), Internet of things (IoT), blockchain and cybersecurity, are those with the highest shares of inter-country collaborations, suggesting that collaboration is more crucial for these complex technologies (a result corroborated by Bachtrögler-Unger et al., 2023). As complex activities combine many capabilities, it is harder for others to copy and develop them. They may then provide a more sustainable source of competitiveness for Europe (Maskell and Malmberg, 1999; Fleming and Sorenson, 2001; Balland and Rigby, 2017; Rigby et al., 2022). These results underline the importance of improving interlinkages between European R&I ecosystems to develop complex technologies and achieve greater competitiveness.

Figure 4.2-3 European inter-country collaborations by technology ranked according to complexity index, 2014-2020



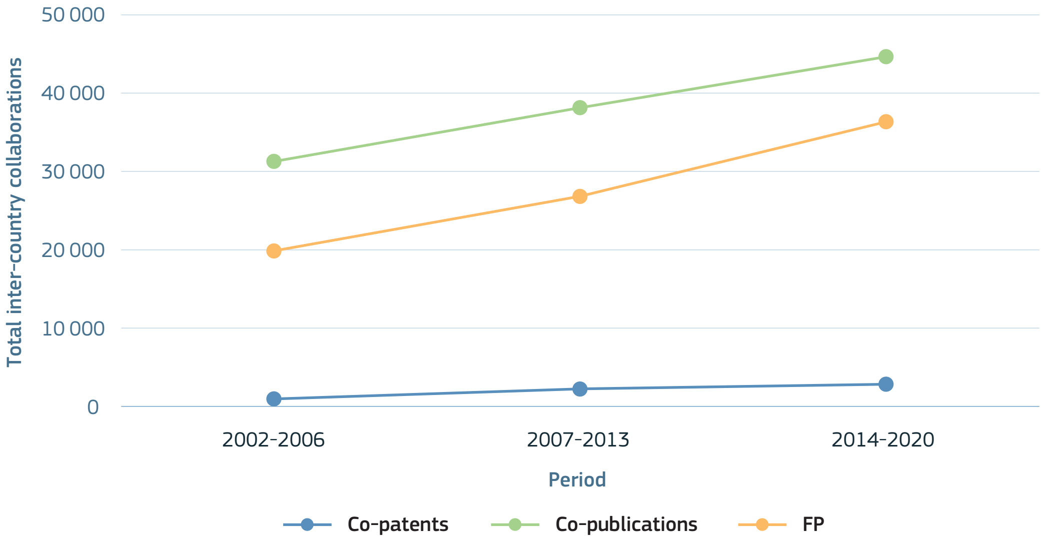
Science, research and innovation performance of the EU 2024
Source: DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on REGPAT data (EPO).

1 For more information, see box 2.2-1 in chapter 2.2.

2. The role of EU policies in connecting European R&I ecosystems

European R&I policies play a major role in increasing the connectivity of European R&I ecosystems and in supporting international collaborations (European Commission, 2022; Figure 4.2-4). The EU FP for R&I went from supporting about 20 000 international collaborations through its 2002-2006 edition (FP6) to more than 35 000 through its 2014-2020 edition (Horizon 2020). With three quarters of its funding going to instruments supporting collaborative R&I[2], Horizon 2020 even supported more than 2 million collaborations between individual organisations worldwide. Finally, 74 % of respondents to a stakeholder consultation carried out for the evaluation of Horizon 2020 agreed that participating in the programme improved cooperation with partners from other countries (within the EU and beyond) (European Commission, 2017).

Figure 4.2-4 European collaborations under the EU FP for R&I compared to total European inter-country collaborations resulting in co-patents and co-publications, 2002-2020



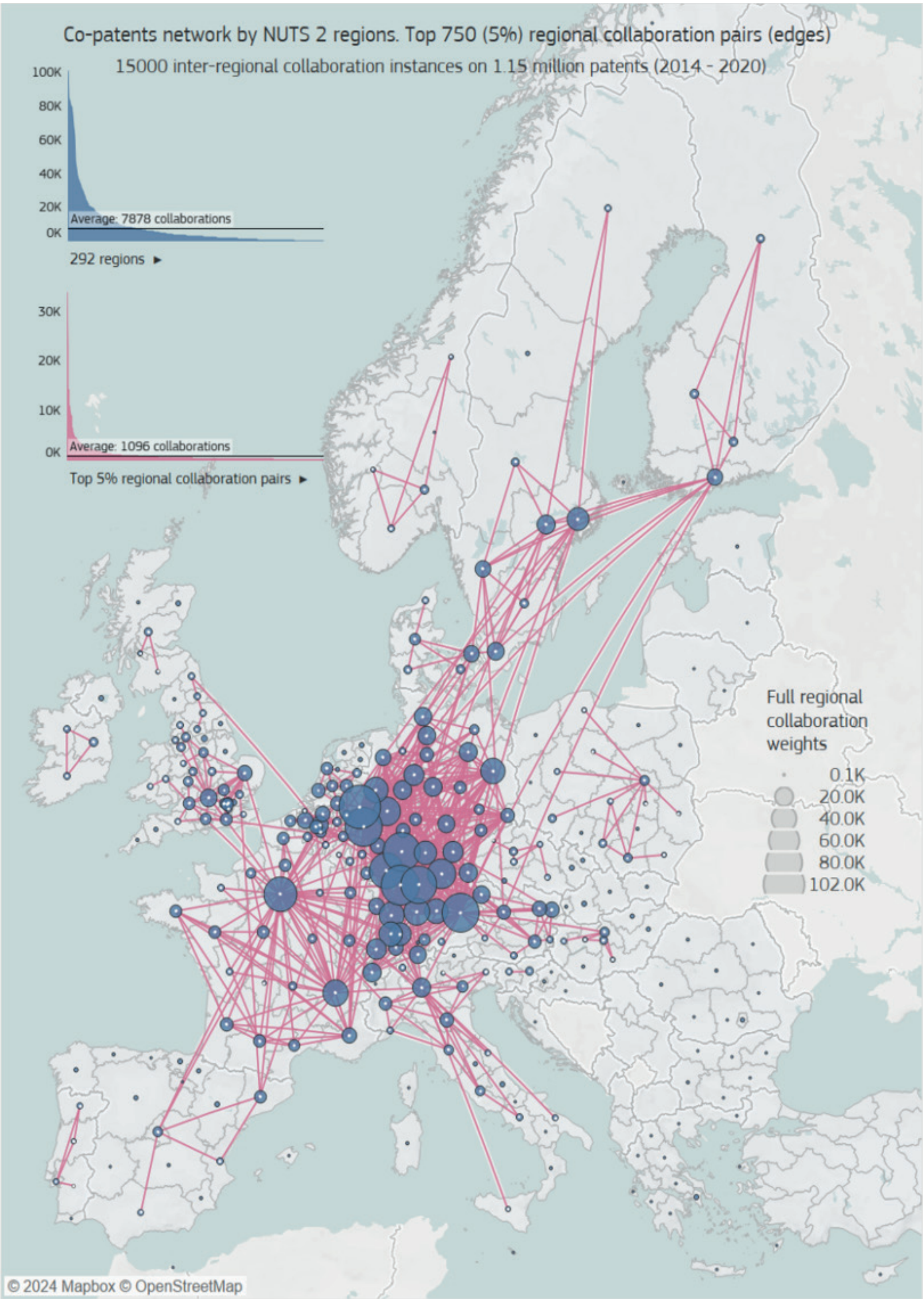
Science, research and innovation performance of the EU 2024
Source: DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on REGPAT and Corda data.

2 E.g. R&I actions, innovation actions, Marie Skłodowska-Curie actions, innovative training networks (ITN), and coordination and support actions.

Co-patenting activity in Europe is quite highly concentrated amongst regions with excellent track records of patenting activity. There is a large concentration around a few regions, with German and capital regions being key nodes of the network (Figure 4.2-5a). Similarly, the network of regions collaborating on scientific publications shows concentration, albeit to a lesser extent than for co-patenting, with key nodes situated in eastern and southern Europe (Figure 4.2-5b). The large concentration around capital regions is in line with academic literature findings on the presence of agglomeration economies in capital regions, i.e., the advantages that firms enjoy when they are located near one another. The spatial proximity allows firms to benefit from various external economies of scale such as labour market pooling, infrastructure sharing and network effects, which can result in increased productivity and innovation (e.g., Duranton & Puga, 2004; Jacobs et al., 2014).

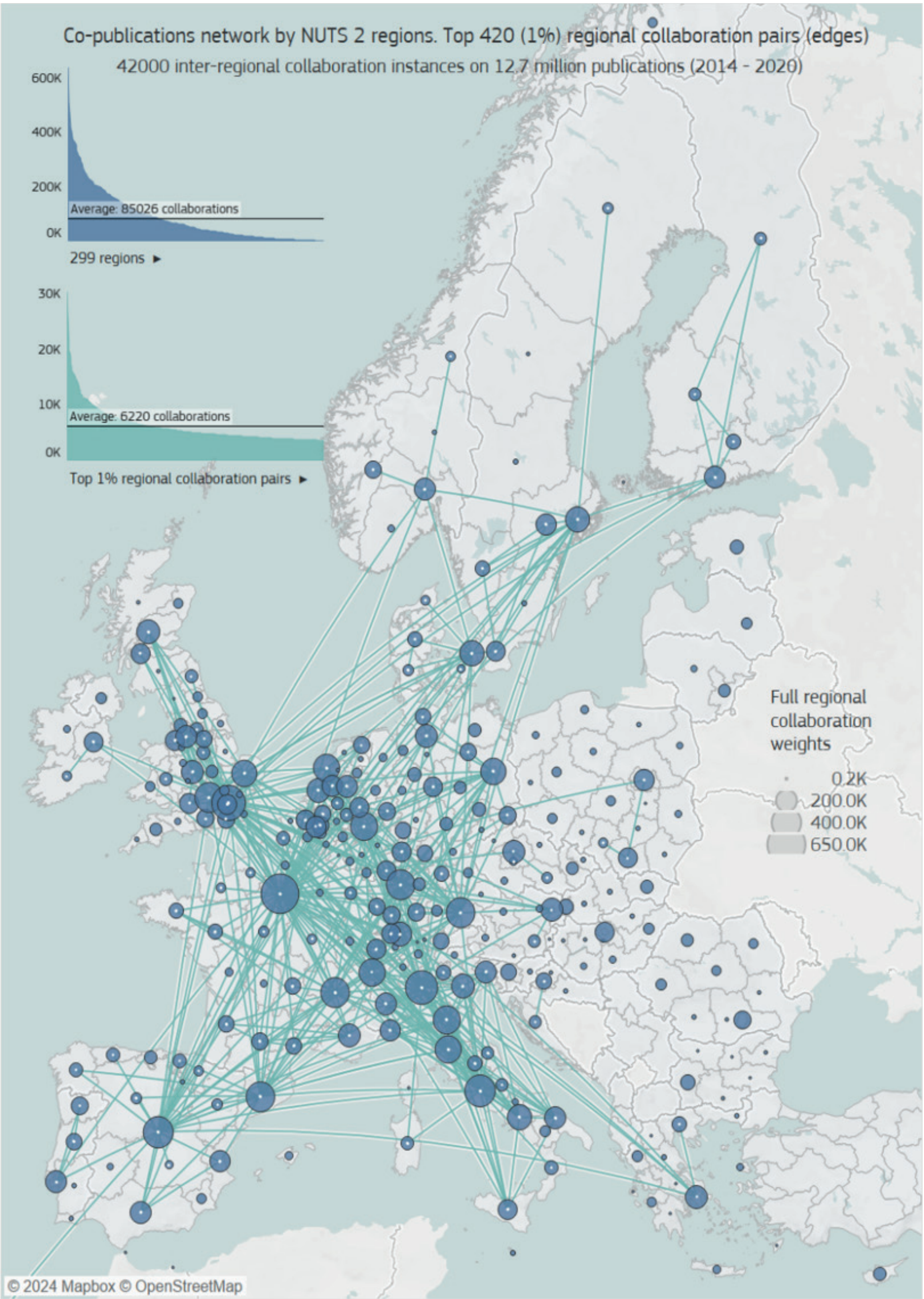
The EU FP for R&I created an important R&I collaboration network during 2014-2020 (Figure 4.2-5c). Compared to the European regional co-patenting network (Figure 4.2-5a), which is fragmented along national lines and characterised by a strong cross-border effect, the EU FP for R&I network makes it possible to steer collaborations across the EU and to overcome the cross-border effect. Interreg, the European programme for territorial cooperation aimed at fostering cross-border exchange between regions, also plays a role in steering collaboration across the EU (Figure 4.2-5d, Table 4.2-1) as well as synergies between programmes.

Figure 4.2-5a Connection maps linking NUTS 2 regions in Europe based on organisations which co-patent together



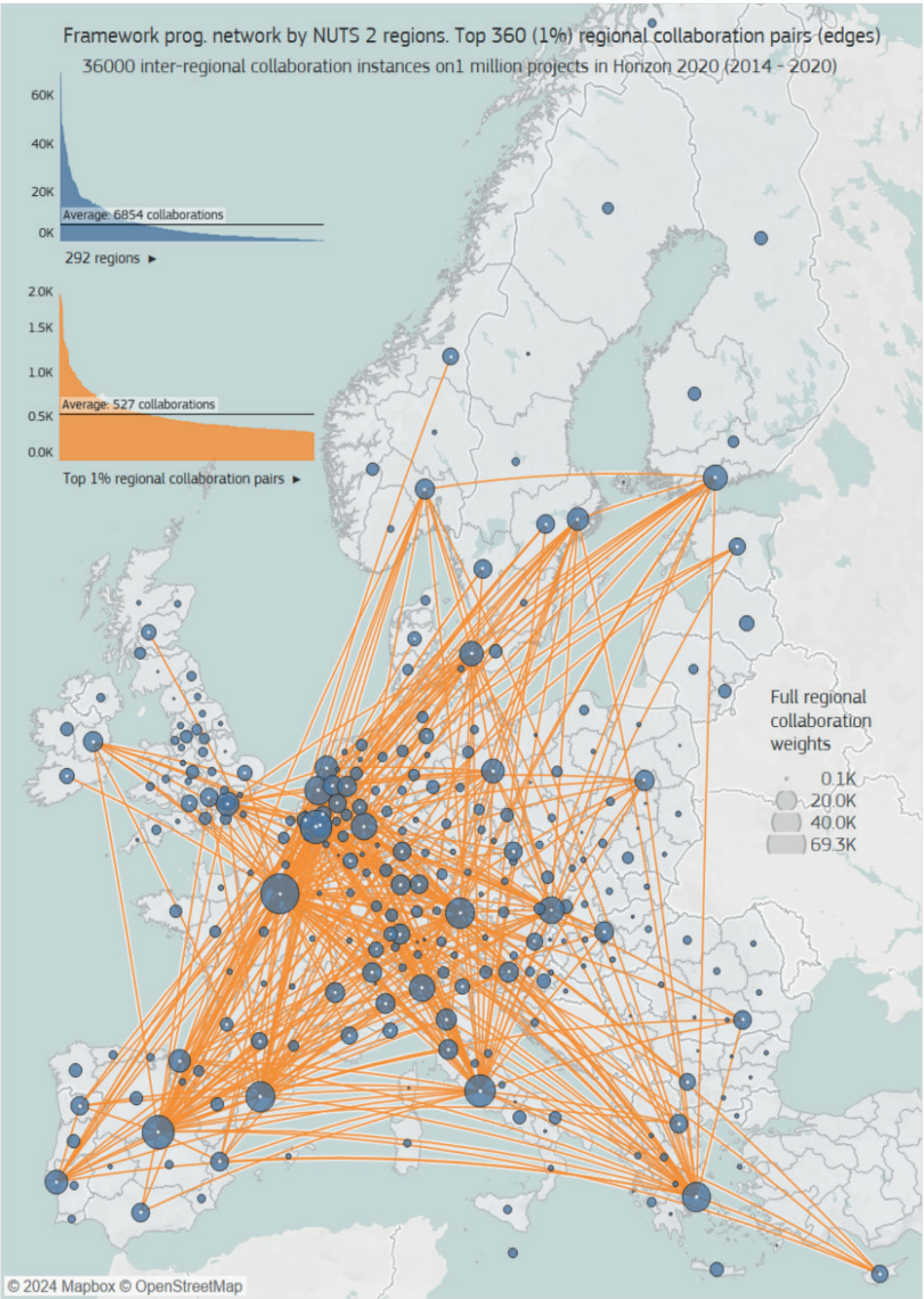
Source: Joint Research Centre, Innovation Policies and Economic Impact Unit and DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on REGPAT.

Figure 4.2-5b Connection maps linking NUTS 2 regions in Europe based on organisations which co-publish together



Science, research and innovation performance of the EU 2024
Source: Joint Research Centre, Innovation Policies and Economic Impact Unit and DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, using Science Metrix data based on Scopus.

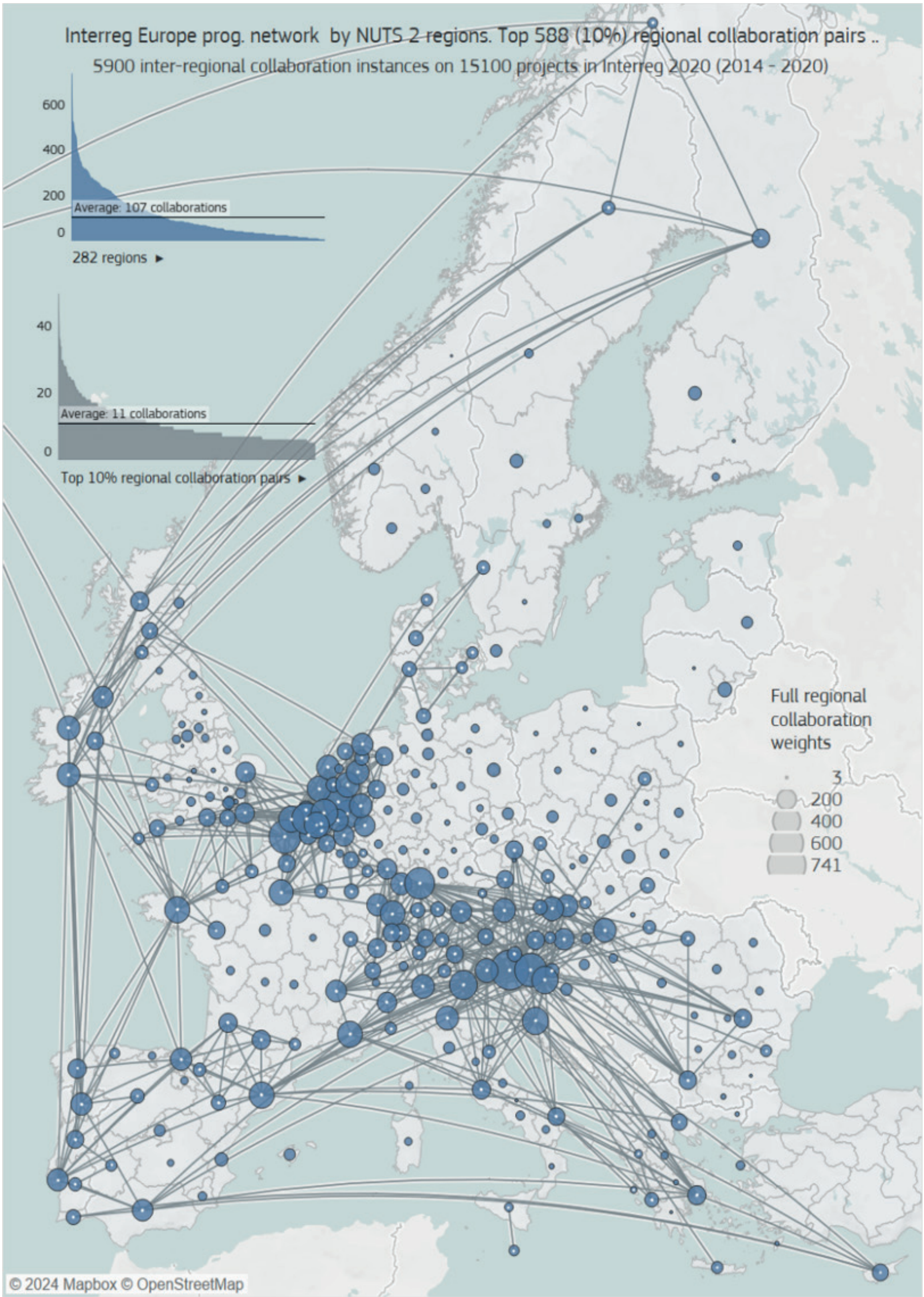
Figure 4.2-5c Connection maps linking NUTS 2 regions in Europe based on organisations that are involved in collaborations under the EU FP for R&I 2014-2020



Science, research and innovation performance of the EU 2024

Source: Joint Research Centre, Innovation Policies and Economic Impact Unit and DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on keep.eu and eCorda data.

Figure 4.2-5d Connection maps linking NUTS 2 regions in Europe based on organisations that are involved in collaborations under Interreg 2014-2020



Source: Joint Research Centre, Innovation Policies and Economic Impact Unit and DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on keep.eu and eCorda data.

Table 4.2-1 Collaborations through Interreg and the EU FP for R&I (Horizon 2020) resulting in joint publications and joint patents, 2014-2020

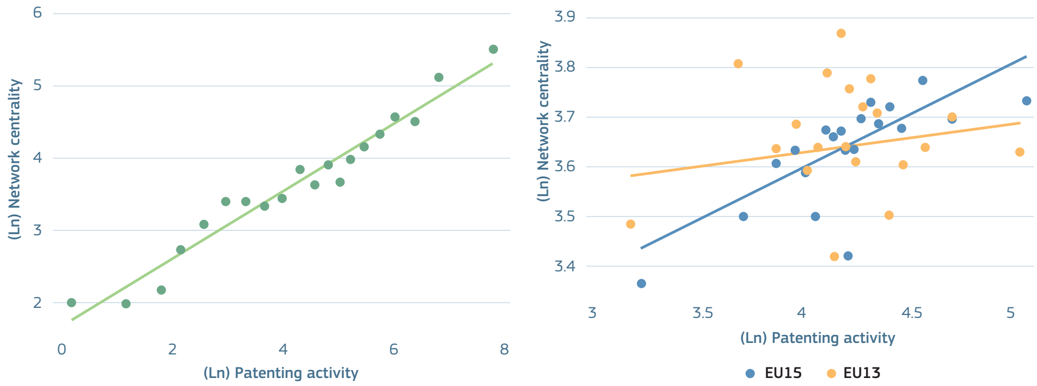
General characteristic	Inter-regional collaborations through Interreg	Inter-regional collaborations through Horizon 2020	Inter-regional collaborations resulting in a joint publication	Inter-regional collaborations resulting in a joint patent
Number of regions	283	297	299	297
Number of collaborations	5 883	35 985	41 596	15 101
Average (standard deviation) number of collaborations per region	41.576 (25.963)	242.32 (54.27)	278.234 (33.243)	101.690 (59.799)
Geodesic distance (length of shortest path) between any two regions	2.14	1.94	1.968	4.653
Diameter (longest distance in the network)	4	2	2	4
Density	0.147	0.75	0.819	0.344
Clustering (two of your partners are partners with each other)	0.401	0.852	0.892	0.599

Science, research and innovation performance of the EU 2024

Source: Joint Research Centre, Innovation Policies and Economic Impact Unit and DG Research and Innovation, Common R&I Strategy and Foresight Service, Chief Economist Unit, based on REGPAT, keep.eu and eCorda data.

R&I collaboration networks created by the EU FP for R&I can accelerate the patenting activity of the regions involved (Lalanne and Meyer, 2024). For a European region, having a central position in the network of R&I collaborations under the EU FP for R&I positively impacts its patenting activity (Figure 4.2-6). This relationship between network centrality and patenting activity is much less strong for EU-13 regions (countries that have joined the EU since 2004) than for EU-14 regions (countries that joined before 2004).

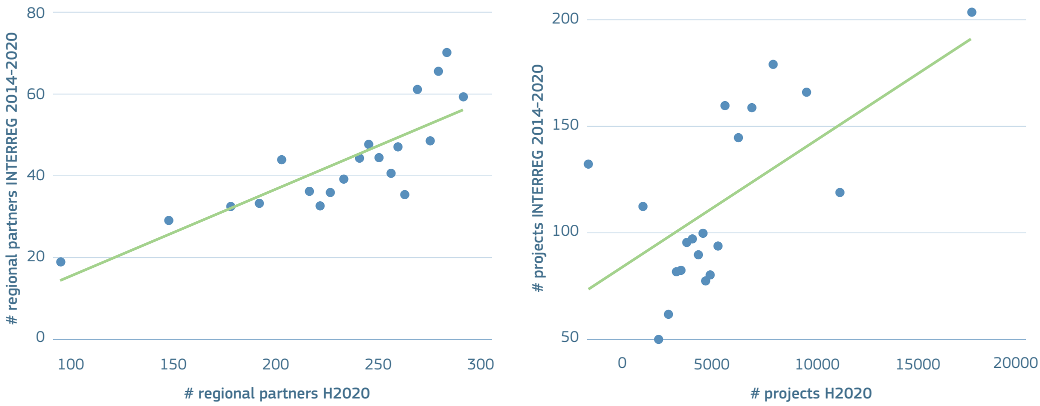
Figure 4.2-6 Relationship between centrality of a region in R&I collaboration networks created by the EU FP for R&I and patenting activity of the region, overall (left figure) and distinguishing between EU-13 and EU-15 regions (right figure)



Science, research and innovation performance of the EU 2024
Source: Lalanne and Meyer (2024), Joint Research Centre, Regional Economic Monitoring Team (JRC B7-REMO).

Strong synergies between European R&I policy instruments can further reinforce cohesion between European R&I eco-systems. Participation of a region in Interreg programmes may have enhanced its participation in Horizon 2020, thereby increasing its relevance as an international partner (Figure 4.2-7). Nevertheless, differences exist between the two instruments, and these must be considered when exploring the topic of synergies. Interreg is comprised of a patchwork of programmes with varying levels of funding intensity, geographical coverage, and thematic scope (Lalanne and Meyer, 2024). These characteristics limit the scope for cooperation and access to funds across different territories, which was not the case for Horizon 2020. For instance, approximately 70% of Interreg funding is channelled to cross-border programmes, for which only border areas are eligible.

Figure 4.2-7 Correlation between numbers of regional project partners in Interreg 2014-2020 and Horizon 2020, with GDP serving as a control variable



Science, research and innovation performance of the EU 2024

Source: Lalanne and Meyer (2024), Joint Research Centre, Regional Economic Monitoring Team (JRC B7-REMO).

Note: The graphs are binned scatterplots with GDP controls of the number of regional project partners in Interreg 2014-2020 and Horizon 2020, i.e., they divide the data into equally sized bins with regard to the number of regional project partners in Horizon 2020 and compute the average number of regional project partners in Interreg 2014-2020 lying in each bin.

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