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RESEARCH ARTICLE

Bridging Europe's Innovation Divide: How European Union Research Policy Drives Growth in Less Developed Regions

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Abstract

Background

This research examines the impact of competitive European research and development funding—specifically from the European Union's Seventh Framework Programme and Horizon 2020—on regional economic growth, research capacities, and innovation performance across **NUTS2 regions, representing mid-level administrative divisions within** European Union **Member States.** Given the persistent disparities in research and innovation output between more and less developed regions, we focus on how these funding mechanisms influence economic and scientific development, particularly in **less developed and peripheral regions.** While European Union research programs aim to foster knowledge production and technological advancement, their role in mitigating regional inequalities and supporting economic convergence remains an open question**.**

Methods

To assess the effects of **European Union Research and Development (EU R&D) funding,** we conduct a quantitative analysis using data from **Eurostat, PATSTAT, Web of Science, and the European Commission's CORDIS database.** We measure changes in three key indicators **—publication output, patent applications, and GDP per capita—** between 2011 and 2022. **GDP per capita**, representing a region's total economic output divided by its population, is a key indicator of regional economic performance. **Ordinary least squares regression models** are employed to evaluate the relationship between funding intensity and regional research and economic development, controlling for factors such as **regional R&D investments, international collaboration, and initial economic conditions.**

Results

Our findings reveal significant and persistent interregional disparities in research and innovation outcomes. While participation in European Union's Seventh Framework Programme **and Horizon 2020** is associated with stronger research capacities in already well-developed regions, no significant relationship is found between EU-funded R&D and increases in publications or patents at an aggregate level. However, a positive correlation emerges between EU R&D funding and **GDP growth in less developed regions**, suggesting that while direct scientific outputs may not always materialize, economic benefits arise through alternative channels such as **small and medium-sized enterprise (SME) engagement**, infrastructure improvements, and knowledge diffusion.

Conclusions

The study highlights the broader implications of transnational funding frameworks for regional economic convergence within the **EU**. Despite limited effects on immediate research outputs in less developed regions, competitive EU R&D programs contribute to economic resilience in lagging regions, raising important considerations for multi-level governance and international cooperation. These results align with debates in International Relations regarding the role of supra-national institutions in shaping equitable economic outcomes and addressing structural imbalances across Member States. As EU funding strategies evolve, a more integrated approach that strengthens innovation ecosystems in underperforming regions could enhance European research policy's inclusivity and long-term impact.

Keywords
Research and Development, Spatial Inequalities, International Collaboration, Regional Disparities in R&D, Structural Funds, Horizon 2020, Seventh Framework Programme

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Introduction
The impact of research and development on economic development and spatial inequalities in Europe is well-documented in economic literature. Early studies highlighted the importance of R&D investment for economic growth (Arrow, 1962; Romer, 1990) and emphasized the microeconomic effects of innovation and its role in maintaining competitive advantage (Dosi, 1988; Trajtenberg, 1990). Further studies examining the spatial dimension of R&D revealed substantial interregional disparities in R&D investment and R&D outputs. Developed regions with robust research infrastructure and innovation networks reap more significant benefits from R&D investments (Capello & Lenzi, 2013; Paci & Usai, 2009). By contrast, less developed regions with weaker absorptive capacities and innovation ecosystems face challenges in effectively leveraging these investments (Psycharis *et al.*, 2020; Rodríguez-Pose, 2001).

Addressing these disparities is crucial for fostering balanced regional development and ensuring that all regions can benefit from innovation-driven growth. Research and development policies are structured around a multilevel innovation policy mix that combines European, national, and regional funding sources. Studies indicate that these combinations impact various types of innovation differently; for example, European R&D grants are most effective for product and process innovations, while national funding best supports market innovations and patent applications (Acebo & Miguel-Dávila, 2024). Additionally, combinations of national and European R&D grants positively influence organizational and incremental innovation, respectively (Lenihan *et al.*, 2024).

The European Union's Cohesion Policy specifically addresses regional innovation disparities through various funding sources: European Regional Development Fund (ERDF), Cohesion Fund (CF), European Social Fund Plus (ESF+), and Just Transition Fund (JTF) (see ESSPIN Reports 4.3.1, 4.3.2). However, regional innovation support is not limited to the Cohesion Policy; the EU framework programmes (Framework Programmes (FPs) and Horizon Programmes) also play a crucial role in building regional R&D capacity and addressing disparities while transforming urban, regional, and country policies. These programmes aim to foster scientific excellence, innovativeness, and economic growth in Europe while directly addressing societal challenges at multiple spatial levels (Clerici Maestosi *et al.*, 2021; Kim & Yoo, 2019). FPs significantly influence national and regional development strategies. European priorities adopted by cities, countries, and regions made European policy an integral part of national, regional, and urban agendas (Lelková & Herbočková, 2022; Longo *et al.*, 2020). Funding from EU FPs supports the development of innovative technologies and products, increasing the competitiveness and growth of local and regional economies.

The positive impact of FPs at the regional and local levels is evident, yet both the distribution of funds and their impact vary significantly across territories (Celli *et al.*, 2024). More developed regions, with superior research infrastructure and higher R&D investments, typically attract more funding, deepening regional inequalities. Conversely, less developed regions often struggle to secure and utilize these funds effectively due to a lack of critical components like skilled labor and innovative firms.

In this context, our study aims to analyse how these European R&D policies affect regions' R&D capacity and economic growth, focusing on less developed areas. Our research questions are designed to investigate the following:

1. What are the effects of competitive European R&D funding on R&D capacity in less developed (NUTS2) regions?

2. What are the effects of competitive European R&D funding on economic growth in less developed (NUTS2) regions?

Literature review
The role of R&D in building capacities and economic growth
The impact of R&D on economic development and spatial inequalities in Europe is well-documented in economic literature. Arrow (1962) emphasised that R&D investments are crucial for economic welfare, highlighting that innovation creates new products and processes that significantly enhance productivity and economic growth. Romer (1990) expanded on this idea by introducing the concept of endogenous technological change, arguing that technological innovation is a central component of economic growth and is driven by intentional investment in R&D activities. Trajtenberg (1990) underscored the value of innovation by analysing patent citations, demonstrating that technological advancements have significant economic impacts and are critical drivers of economic value. Dosi (1988) explored innovation's sources, procedures, and microeconomic effects, emphasizing how technological advancements are essential for competitive advantage and long-term economic performance. These foundational studies collectively illustrate that R&D and innovation are necessary for achieving and sustaining economic growth and development.

Spatial effects of investments in R&D
Investments in R&D lead to the creation of new technologies, products, and processes that enhance regions' productivity and adaptive capabilities (Bronzini & Piselli, 2016; Fratesi & Perucca, 2019; García-Quevedo, 2004; Rodríguez-Pose, 2001). Regions that effectively invest in R&D experience substantial growth in innovativeness, translating into higher levels of competitiveness and economic development (Iammarino *et al.*, 2019). However, these effects vary among regions, and their intensity depends on regional characteristics. Well-performing regions with substantial territorial capital are better prepared to absorb and utilise innovative technologies, leading to higher returns on R&D investments (Capello & Lenzi, 2013; Paci & Usai, 2009). On the other hand, peripheral and lagging regions, which often imitate innovations rather than create them, struggle to fully leverage the potential of R&D investments (Psycharis *et al.*, 2020; Rodríguez-Pose, 2001). The effectiveness of R&D investments heavily depends on a region's

absorptive capacity, including factors such as the availability of skilled labor, existing research infrastructure, and innovative firms. Less developed regions often lack these critical components, resulting in lower returns from R&D investments (Celli *et al*., 2024; García-Quevedo, 2004). The quality of institutions and local innovation networks also play a vital role in transforming R&D investments into tangible economic benefits (Fratesi & Perucca, 2019; Iammarino *et al*., 2019).

European Union Framework Programmes shaping regional development and policies

In recent years, the EU has allocated substantial funds to support the R&D sector through seven FP editions, followed by Horizon 2020 (H2020) and HORIZON EUROPE. These initiatives aim to strengthen scientific excellence and R&D capacities to stimulate economic growth in the EU. The EU FPs also address European social challenges, primarily manifested in urban areas. In particular, the third pillar of Horizon 2020 focuses on challenges related to health, demographic change, well-being, food security, sustainable agriculture, marine and maritime research, bioeconomy, secure, clean, and efficient energy, smart, green, and integrated transport, climate action, resource efficiency, and raw materials (Clerici Maestosi *et al*., 2021; Kim & Yoo, 2019; Pacheco-Torgal, 2014). This does not mean that the other two pillars, namely i) supporting the best ideas and the most talented individuals and ii) enhancing industrial leadership by maximising the growth potential of European SMEs, do not impact regions and cities. Funding from European programmes supports the development of innovative technologies and products in regions, increasing the competitiveness of local economies. R&D projects generate new jobs, enable the modernisation of research infrastructure, raise qualifications through training components, and transfer best practices (Sorli, 2022; Szücs, 2020).

EU FPs forces structural changes in countries and regions, prioritising actions that address urgent challenges such as green and digital challenges (Varela-Vázquez *et al*., 2019). Cities, countries, and regions adopt European priorities, making European policy integral to their national and regional policies. Through financial support, promoting innovative urban concepts, and engaging various stakeholders, these programmes help cities become more sustainable, energy-efficient, and resilient to climate change transformation (Clerici Maestosi *et al*., 2021; Lelková & Herbočková, 2022; Longo *et al*., 2020; Tàbara *et al*., 2024). The EU continuously adapts its priorities and spending to new challenges and external shocks. For instance, in response to the COVID-19 pandemic, new support mechanisms were launched to mobilise research and innovation efforts supported by Horizon 2020 to manage the pandemic via diagnostics, treatments, and epidemiological research. H2020 also addressed social needs arising from the pandemic by accelerating Europe's digital transformation (European Commission, 2021).

Impact of EU framework programmes

The positive impact of FPs at the regional and local levels is unquestionable. However, the distribution of funds and their impact on specific territories vary (Bloom *et al*., 2019). The European Union's framework programmes have revealed significant disparities in the ability of regions to secure research funding. More developed regions like Western and Northern Europe typically attract more substantial funding due to their superior research infrastructure, higher R&D investments, and more robust research networks. These regions benefit from better access to resources and opportunities, enabling them to more effectively apply for and execute research projects. These regions not only enhance their research capabilities but also strengthen their position in the European research area, further deepening inequalities between regions (European Commission, 2020).

Less developed regions often struggle to secure and effectively utilise FP funds (Celli *et al*., 2024; Fratesi & Perucca, 2019; Szücs, 2020). The effectiveness of these investments heavily depends on a region's absorptive capacity, which includes factors such as the availability of skilled labor, existing research infrastructure, and the presence of innovative firms. Less developed regions often lack these critical components, resulting in lower returns from R&D investments (Celli *et al*., 2024; García-Quevedo, 2004; Rodríguez-Pose, 2001). In response to regional disparities, Horizon 2020 introduced "spreading excellence and widening participation" initiatives to support regions and countries with lower research performance. These initiatives targeted EU member states that joined after 2004 and certain regions in developed countries to increase their participation in EU-level research and innovation projects (European Commission, 2020). These measures included instruments to support capacity building, create links between leading research institutions and lower-performing regions, and provide policy and expert support. Despite these efforts, evaluations indicate the need for continued and increased support to reduce regional disparities in research and innovation. Academics also warned that the current allocation criteria of FPs may perpetuate spatial inequalities (Varela-Vázquez & González-López, 2020).

Several studies suggested policy solutions. Varga and Sebestyén (2017) highlighted that while FP research subsidies are a substitute for funding from other sources in regions of old EU member states, they are crucial for transferring external knowledge to lagging regions in central and eastern Europe. This helps compensate for the limited local knowledge in less developed regions, meaning that FP participation is more beneficial for economically weaker regions. Also, Varela-Vázquez and González-López (2020) revealed that coordinating projects under FPs is more effective in encouraging innovation in less developed regions than in developed ones.

Methods

This study relies on multiple data sources. First, socio-economic data were obtained from Eurostat (https://ec.europa.eu/eurostat/data/database). Second, patent application data were sourced from the PATSTAT database, compiled by the European Patent Office (https://www.epo.org/en). These data were geolocated and aggregated at the NUTS2 regional level to allow for spatial analysis. Third, scientific publication data were retrieved from the Web of Science (WoS) bibliographic database (https://www.webofscience.com/wos/woscc/basic-search), which indexes millions of publications from peer-reviewed journals, conference proceedings, and academic book publishers. Individual-level WoS data—including authors, affiliations, and citations—were provided by Clarivate as XML files, enabling the construction of NUTS2 regional indicators of research output.

The geolocation process was crucial in structuring the bibliometric and patent data. It relied on affiliation addresses processed via the Google Maps API, which allowed for the accurate assignment and aggregation of publication and patent data to NUTS2 regions**.** Data on EU research funding were obtained from the CORDIS website (https://cordis.europa.eu/projects/en), managed by the European Commission. This website provides detailed project-level data on the 7th Framework Programme (FP7) and H2020, two key EU-funded research and development (R&D) programs. To assess the impact of European R&D funding, this study employs ordinary least squares (OLS) regression analysis to examine the relationship between European R&D funding and regional research and economic performance. OLS regression allows for isolating the effects of EU funding by controlling for confounding factors (control variables), ensuring that unrelated regional characteristics do not drive observed relationships (Hayashi, 2000; Wooldridge, 2019).

Following standard regression analysis terminology, three dependent variables were introduced at the NUTS2 regional level:

1. The change in GDP per capita – an economic indicator measuring regional economic performance based on the total economic output per person.

2. The change in the number of patent applications per capita represents technological innovation and the impact of applied research**.**

3. The change in the number of scholarly publications per capita is a proxy for research capacity in basic sciences.

The main explanatory variable is the number of FP7 and H2020 projects per capita, serving as a proxy for European research and innovation policy funding. Several control variables were incorporated into the regression models to account for other factors that could influence regional research and economic performance:

- Gross domestic expenditure on R&D (GERD) as a percentage of GDP – measures the intensity of research spending in each region.

- The share of internationally co-authored publications – reflects global research collaboration and knowledge exchange.

- Average citations per publication – serves as an indicator of research impact and quality.

- Regional population size – controls for differences in regional scale and demographic effects.

- The baseline number of patent applications and publications accounts for pre-existing research and innovation capacities at the start of the studied timeframe.

- The baseline Gross Domestic Product (GDP) per capita (GDP).

The analysis covers the period from 2011 to 2022. The selection of the timeframe was largely directed by data availability. One important exception to the timeframe is related to patent application data, which have not been fully available in recent years. Therefore, for the variable "change in the number of patent applications per capita," we used the period of 2011–2020. The scope of the study encompasses the NUTS2 regions of EU countries. The scope is extended to several countries, including Turkey, for map presentations and correlation analyses (scatter plots). The basic regression analysis is based on data for 267 regions; for this subset, we had full bottom-line data for all indicators.

To assess how economic development levels influence the impact of R&D funding, we compare results across three categories of GDP per capita relative to the EU average:

- Less developed regions: GDP per capita below 80% of the EU average.

- Moderately developed regions: GDP per capita between 80% and 120% of the EU average.

- Highly developed regions: GDP per capita above 120% of the EU average.

To complement the statistical findings, spatial analyses and graphical representations are used to illustrate the following:

- Interregional disparities in research output, innovation capacity, and economic performance.

- Correlation patterns between FP7/H2020 participation and changes in scholarly publications, patent applications, and GDP growth.

- The geographic distribution of EU R&D funding absorption across less developed, moderately developed, and highly developed regions.

The combined approach of quantitative regression analysis and spatial visualization provides a comprehensive assessment of the impact of EU-funded R&D programs on regional innovation ecosystems and economic convergence.

Findings and discussion

Significant interregional inequalities exist in scholarly output across Europe, as measured by publications per capita between 2011 and 2022 (Figure 1). The gap between the highest- and lowest-performing NUTS2 regions (mid-level administrative divisions within European Union Member States) is substantial.

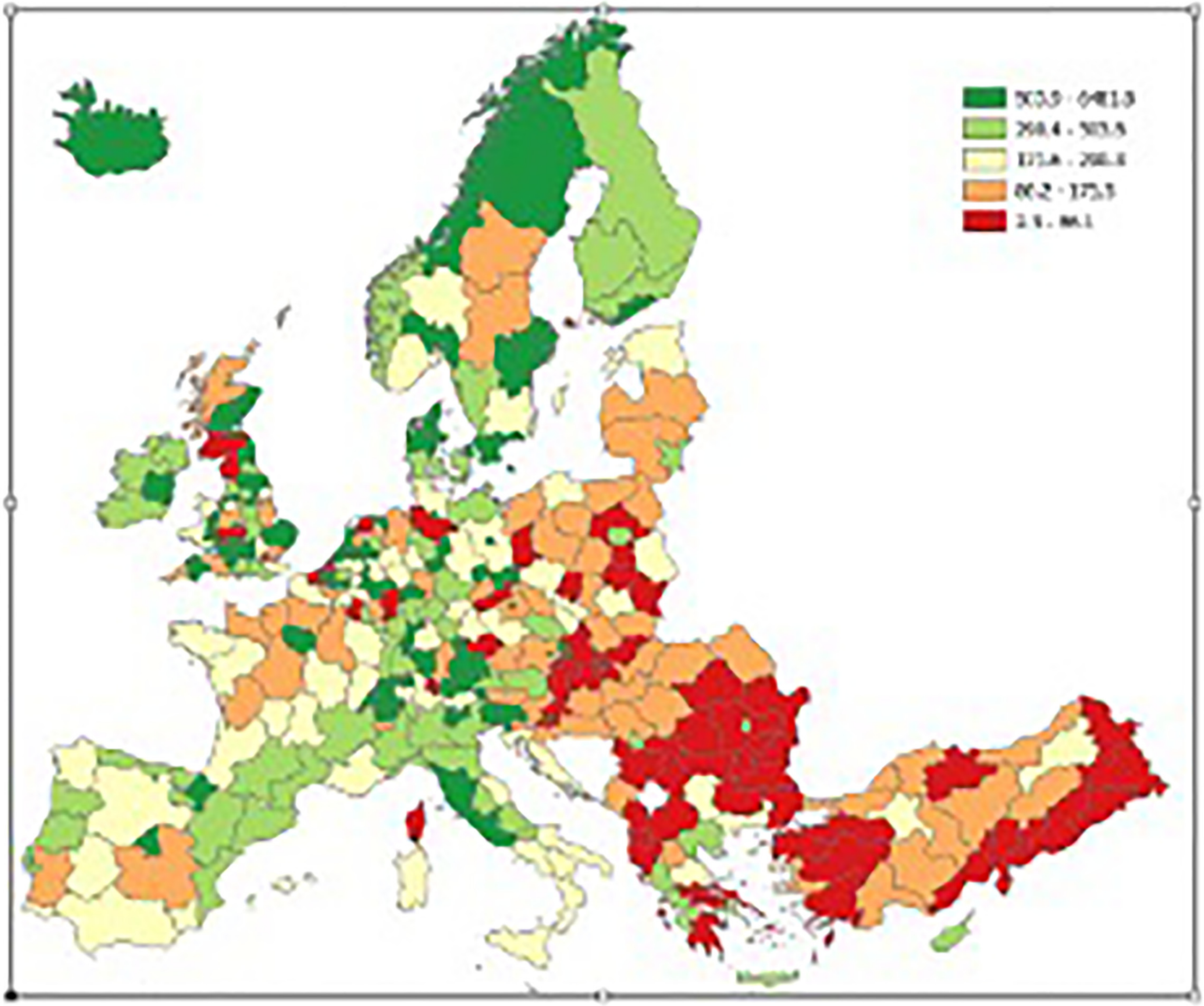

Figure 1. **Scholarly publications per 10,000 inhabitants (2011–2022).**

Inner London West recorded the highest score, with 6,481.8 publications per 10,000 inhabitants, while Inner London East had the lowest, with only 2.3 publications per 10,000 inhabitants. The spatial distribution of research productivity across European regions reveals a strong concentration of scientific activity in metropolitan areas. High-performing regions are found in both economically advanced and emerging countries, including Scandinavian nations, the United Kingdom, Benelux, Germany, Switzerland, northern and central Italy, and southern France. In contrast, regions with lower academic output are primarily located in central and eastern Europe, including Bulgaria, Romania, Hungary, Slovakia, Poland, and Turkey. Despite generally lower research productivity in central and eastern Europe, capital cities such as Budapest, Bratislava, Belgrade, Bucharest, Zagreb, Prague, Warsaw, and Sofia stand out as academic hubs with notably higher publication rates. Additionally, several low-performing regions exist within high-productivity countries. These include less industrialized areas such as Austria's Burgenland and Germany's Lüneburg, outermost territories like the French islands of Mayotte and Réunion, and regions with limited academic activity and fewer research institutions. Some countries exhibit significant interregional disparities in academic output. Notable variations are observed in the United Kingdom, Switzerland, and the Netherlands, where certain regions significantly outperform others. Conversely, Albania, Bulgaria, and Turkey display more uniform scholarly productivity, suggesting a more consistent but generally lower research output. These disparities in academic productivity result from long-term historical, economic, and infrastructural trends that have shaped Europe's research landscape. The concentration of research funding, institutions, and resources in better-equipped regions has further reinforced these patterns. Understanding these regional differences is essential for developing effective policies that support both high-performing and lower-performing regions in fostering scientific excellence and innovation.

The comparison of Figure 1 and Figure 2, along with Figure 3 illustrates a negative relationship between the number of scientific publications per capita in 2011 and their subsequent growth dynamics between 2011 and 2022. Regions with higher publication rates per 10,000 inhabitants in 2011 experienced smaller increases or even declines in scholarly output over time. Conversely, regions with fewer publications in 2011 generally showed a more significant increase in publications during the period. However, variability remains among regions with initially low publication output. While some experienced substantial increases, others showed minimal changes or even declines. This suggests that factors such as funding availability, institutional support, and regional policies play a crucial role in determining publication growth trajectories. In contrast, regions with high publication rates per 10,000 inhabitants in 2011 exhibited more stability in scholarly output throughout the analyzed period. Map A2 and Figure A1 (see Appendix) further illustrate this trend, emphasizing both the catch-up effect in regions with lower initial publication rates and the relative stability in high-output regions, reinforcing the observed convergence patterns in research productivity.

The spatial distribution of patent applications per capita from 2011 to 2022 partially reflects the distribution of scientific publications per capita (Figure 4). Regions in northern and western Europe report the highest number of patent applications per capita, while regions in eastern and southeastern Europe show

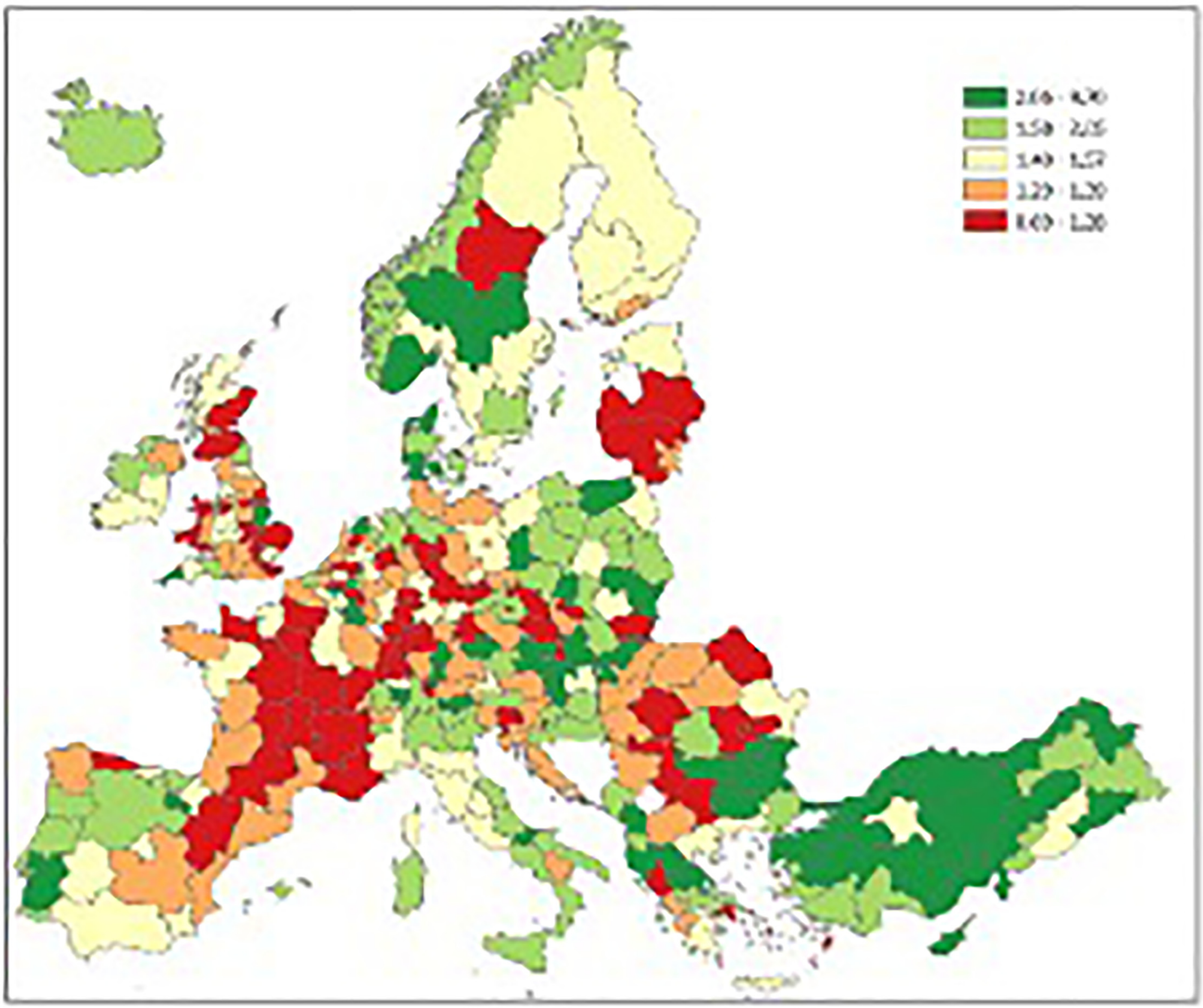

Figure 2. Change in the number of scholarly publications per 10,000 inhabitants from 2011 to 2022 (ratio).

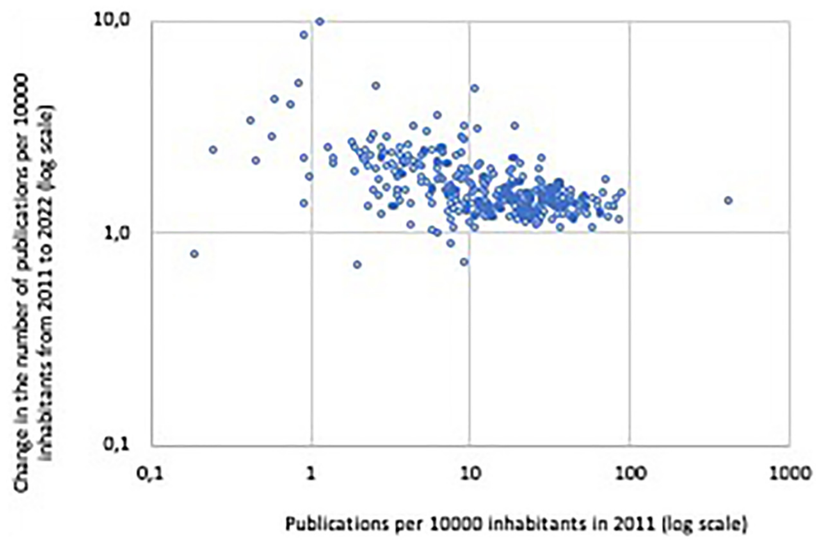

Figure 3. Publications per capita in 2011 and change in the number of publications per capita from 2011 to 2022.

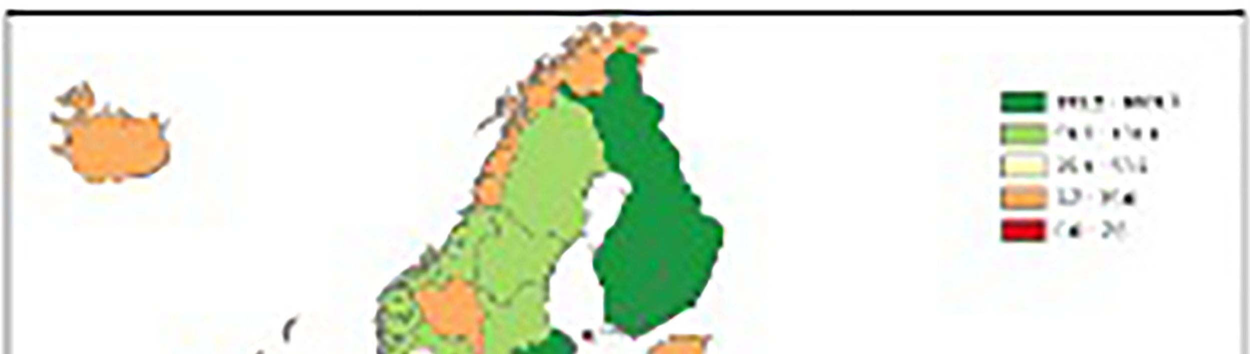

Figure 4. Patent applications per 100,000 inhabitants (2011–2022).

the weakest performance. Interestingly, some countries that perform poorly in terms of scientific publications outside their capitals, such as Poland, the Czech Republic, Spain, and Portugal, achieve better-than-average results in patent applications. Conversely, Italy, the United Kingdom, and Norway perform relatively better in scientific output, as measured by publications per capita, but rank lower in patent applications per capita. A careful interpretation suggests that research outcomes in the first group of countries may be more closely linked to market-driven technological innovations, leading to a higher number of patent applications. In contrast, the second group appears to focus more on fundamental scientific research, which, while valuable for long-term technological development, does not necessarily translate into immediate patenting activity. The spatial distribution of scientific publications exhibits a more mosaic-like pattern compared to the more consistent distribution of patent applications. In the case of publications, internal variations within certain countries are more pronounced, reflecting diverse research landscapes. The contrasting complexity of these spatial patterns—greater heterogeneity in publications and greater uniformity in patents—suggests that patent applications are more strongly influenced by national policies, whereas publication activity is shaped by a broader set of institutional and academic factors.

A significant increase in patent applications has been observed in western Turkish regions, Lithuania, most Italian regions (except for Molise and Calabria), many regions in the UK and Germany, Belgium, Poland (Lubelskie, Podkarpackie, Pomorskie), most of Bulgaria, Slovakia (Stredné Slovensko, Bratislavský kraj), France (Haute-Normandie, Aquitaine), Austria (Vorarlberg), Norway (Nord-Norge), Hungary (Nyugat-Dunántúl), and Switzerland (Ticino). Conversely, a significant decline in patent applications has been recorded in many eastern and western Turkish regions, Albania, most Greek regions (except for a few with no patent activity), Iceland, Estonia, all regions of Hungary apart from Nyugat-Dunántúl, many regions in the UK and Spain, Belgium, Portugal (Algarve, Azores, Madeira), most of Bulgaria, and Croatia (Pannonian Croatia, Adriatic Croatia). In Spain, Galicia, Asturias, and Extremadura also experienced notable decreases. Despite these contrasting trends, regions in southern and eastern Europe, where patenting activity has historically been lower, recorded some of the most substantial growth in patent applications (Figure 5).

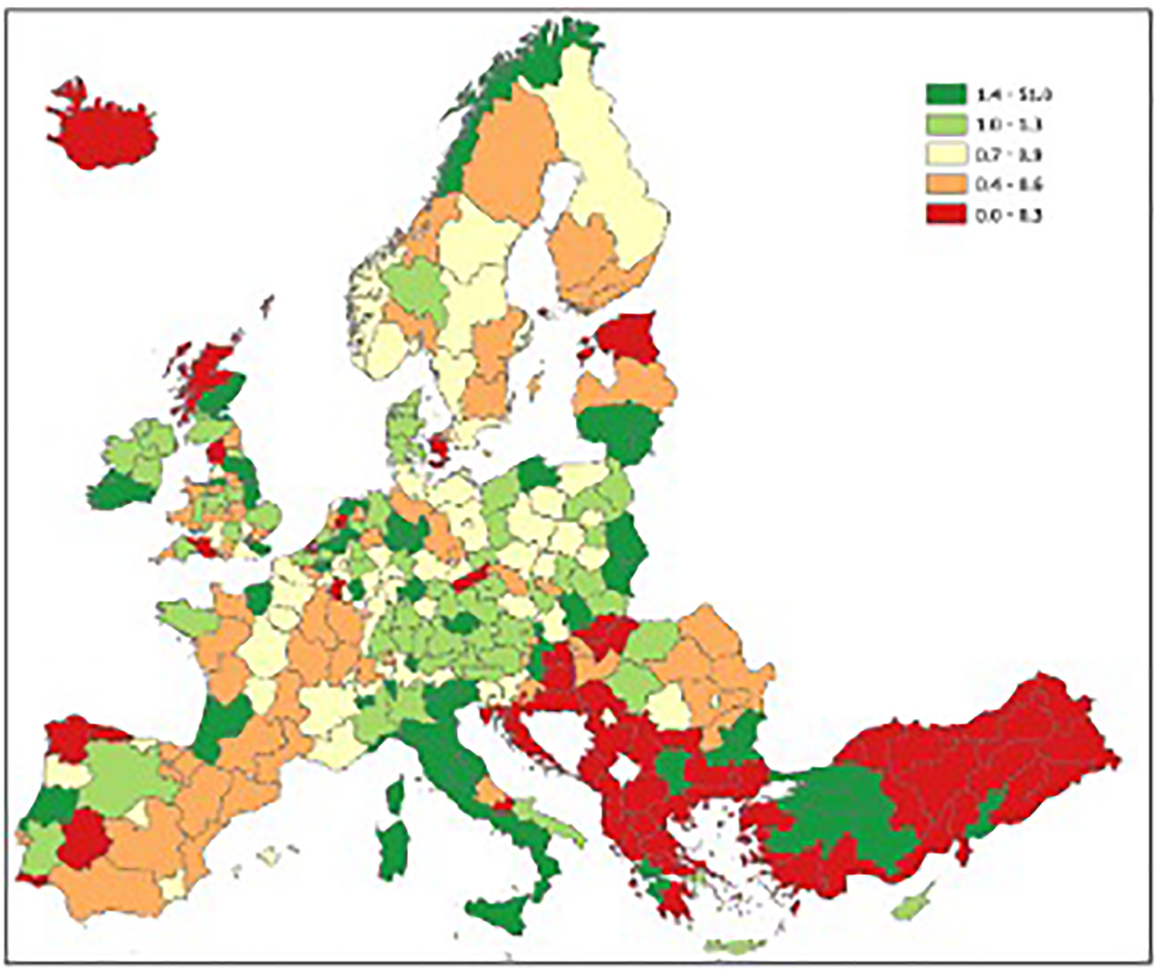

Figure 5. Change in the number of patent applications per 100,000 inhabitants from 2011 to 2020 (ratio).

Figure 6 sheds light on the findings from the comparison of Figure 4 and Figure 5, illustrating the negative correlation between the number of patent applications per capita in 2011 and their subsequent growth dynamics from 2011 to 2020. The figure shows that regions with fewer patent applications in 2011 experienced slightly faster growth in patenting activity. However, this increase is less pronounced than that observed for publications (Figure 3). This discrepancy suggests that while regions with lower initial publication output can catch up more significantly over time, the same trend is less evident for patent applications. The less varied growth pattern for patenting indicates that the initial level of patent activity has a weaker influence on future patenting advancements compared to publications. This implies that the factors driving publication growth—such as increased academic collaboration and research funding—have a more substantial impact than those driving patent growth, which may be more dependent on established technological infrastructure and national policies, including intellectual property rights regulations.

Significant interregional disparities in participation in the 7th Framework Programme and Horizon 2020 are evident across Europe. The intensity of participation, measured by the number of project partners per 10,000 inhabitants, ranges from zero in non-participating territories—such as Ceuta and Melilla (Spanish enclaves on the Moroccan coast), parts of northern Turkey along the Black Sea, and southeastern Turkey—to over 50 in cities like Brussels and London.

Figure 7 illustrates a northwest-to-southeast pattern, showing a noticeable decline in participation as one moves from northwestern Europe toward southeastern regions. High participation rates are concentrated in northern Europe, particularly in Iceland, Norway, Sweden, Finland, and parts of Western Europe, including Ireland, the United Kingdom, and the Netherlands. In contrast, low participation rates are mainly observed in central and eastern Europe, including Poland, Romania, Bulgaria, Albania, and Turkey. Countries such as Germany, France, and Italy exhibit moderate participation levels. Capital city regions emerge as key research hubs in nearly all European countries. Besides Brussels and London, cities such as Athens, Helsinki, Copenhagen, Ljubljana, and Zurich also record high participation levels, exceeding 20 partners per 10,000 inhabitants. Some important research centers located outside capital regions, such as Trondheim in Norway and Leuven and Walloon Brabant in Belgium, also demonstrate strong engagement in FP7 and H2020 projects.

Figures 8(a) and 8(b) suggest that FP7 and H2020 projects were primarily allocated to regions where the potential for innovation and research was already well established. Figure A3(a) in the Appendix shows a positive correlation between participation in FP7 and H2020, measured by the number of project partners per 10,000 inhabitants, and scholarly output in 2011, measured by the number of publications. Similarly, Figure A3(b) in the Appendix shows a positive relationship between participation in these programs and the number of patent applications per capita in 2011. This indicates that regions with higher participation in EU-funded programs were already more effective in producing both patents and publications. The allocation of resources to well-performing regions, which can generate valuable scientific and technological outputs, ensures greater effectiveness and enhances the impact of R&D funding. In contrast, low-performing regions face challenges in catching up, which may contribute to a concentration of scientific and technological advancements in already prosperous areas,

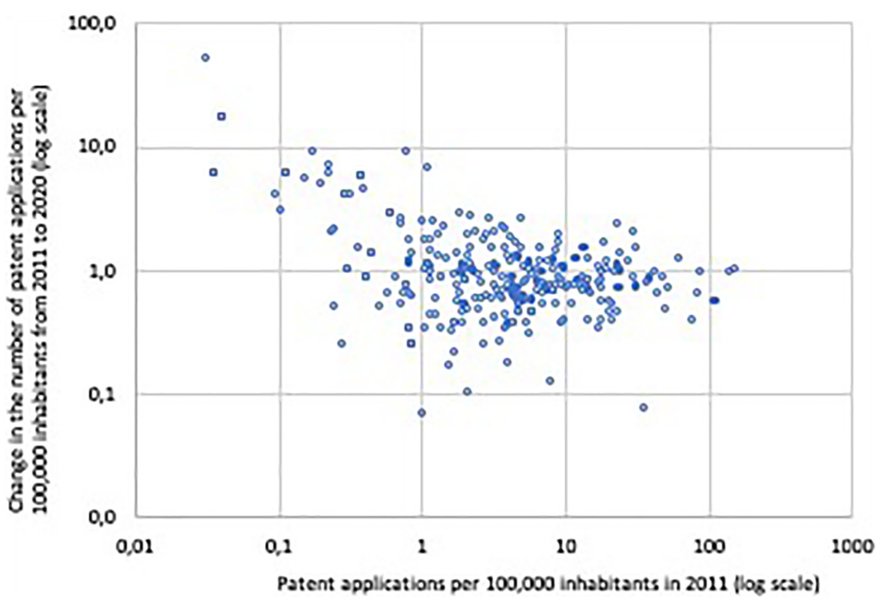

Figure 6. Relationship at the NUTS2 level: patent applications per capita in 2011 and change in the number of patent applications per capita from 2011 to 2020.

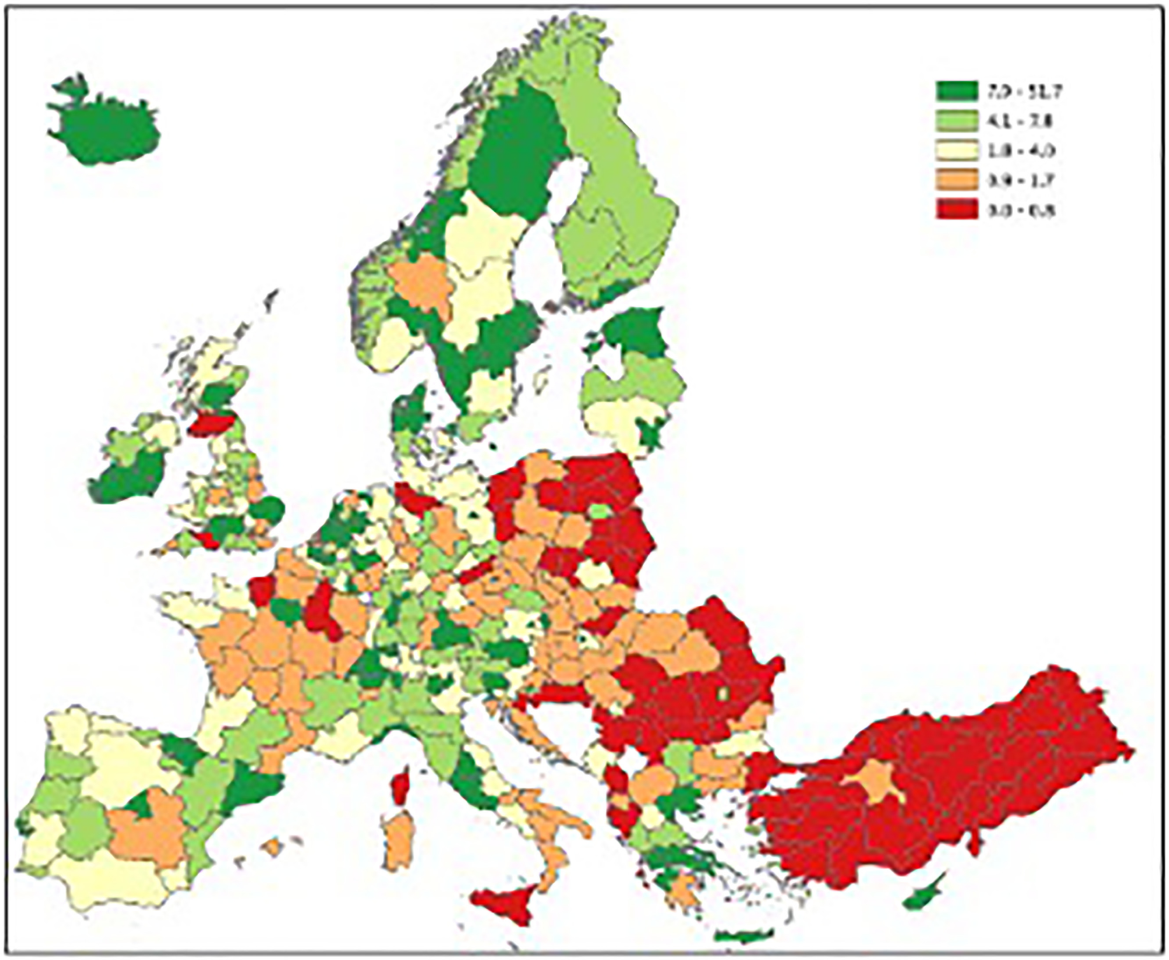

Figure 7. 7th Framework Programme and Horizon 2020 project partners per 10,000 inhabitants.

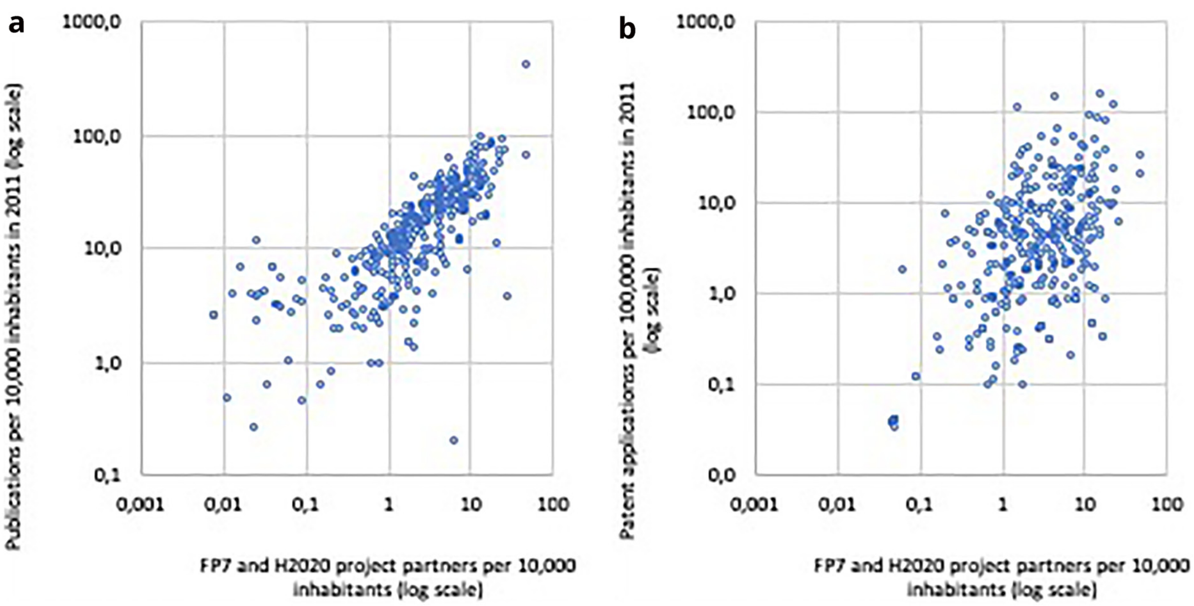

Figure 8. Relationships at the NUTS2 level: (**a**) FP7 and H2020 project partners per 10,000 inhabitants and number of publications per 10,000 inhabitants in 2011; (**b**) FP7 and H2020 project partners per 10,000 inhabitants and number of patent applications per 100,000 inhabitants in 2011.

further widening the gap between more and less developed regions. This pattern reflects the **Matthew effect**, where "the rich get richer and the poor get poorer" (Merton, 1968).

Figure 9 further illustrates the relationship between participation in FP7 and H2020 projects and the growth in publications (a) and patent applications (b). The data do not indicate a robust or clear correlation between the number of FP7 and H2020 projects per capita and the growth in publications and patent applications per capita. The dispersion of data points representing regions, forming a scattered pattern in the graphs, suggests that changes in scientific output vary significantly between regions regardless of their participation in FP7 and H2020 projects. The weakest regions in terms of project participation tend to show faster growth, particularly in publications. This may be attributed to the **low base effect**, where even minimal involvement in EU framework programs can substantially boost previously weak scientific output. In such cases, collaboration with stronger scientific regions is often a crucial factor in increasing research production. This pattern may be linked to the collaborative turn in science, referring to the exponential rise in co-authored publications driven by the increasing complexity and interdisciplinarity of contemporary research (Olechnicka *et al*., 2019).

The varied results can largely be attributed to national and regional policy differences. For instance, national policies that emphasize scientific publications often provide funding incentives for academic research and promote international collaboration, leading to higher publication output in regions with strong FP7 and H2020 participation. However, this does not necessarily translate into increased patent applications if local policies do not sufficiently support the commercialization of research results. Conversely, regions with policies that actively encourage intellectual property protection and entrepreneurship tend to generate more patent applications, even if their participation in research projects is relatively low.

These differences in growth dynamics highlight that the effectiveness of FP7 and H2020 project participation is highly dependent on the local and national policy context, which shapes regional opportunities and priorities in research and innovation. In summary, the intensity of participation in FP7 and H2020 projects alone does not determine growth in publications and patent applications. Instead, variations in national and regional policies, the level of support for research and innovation, and local development priorities play crucial roles in shaping these outcomes. This underscores the need for a tailored approach to supporting research and innovation, one that takes into account the specific conditions and needs of individual regions.

Regression analysis was performed to systematically investigate the relationships discussed above. For this purpose, an ordinary least squares (OLS) model was applied using data at the NUTS2 (Nomenclature of Territorial Units for Statistics) regional level. Three dependent variables were examined: the change in the number of publications per capita from 2011 to 2022, the change in the number of patent applications per capita from 2011 to 2022, and the change in GDP per capita from 2011 to 2022. The independent variable considered was the per capita expenditure from the 7th Framework Programme, the Horizon 2020 programme, and the combined expenditure of both programmes. Several control variables were included to account for additional factors influencing regional differences. Robust standard errors clustered by country were used in the modeling to address that national-level factors play a significant

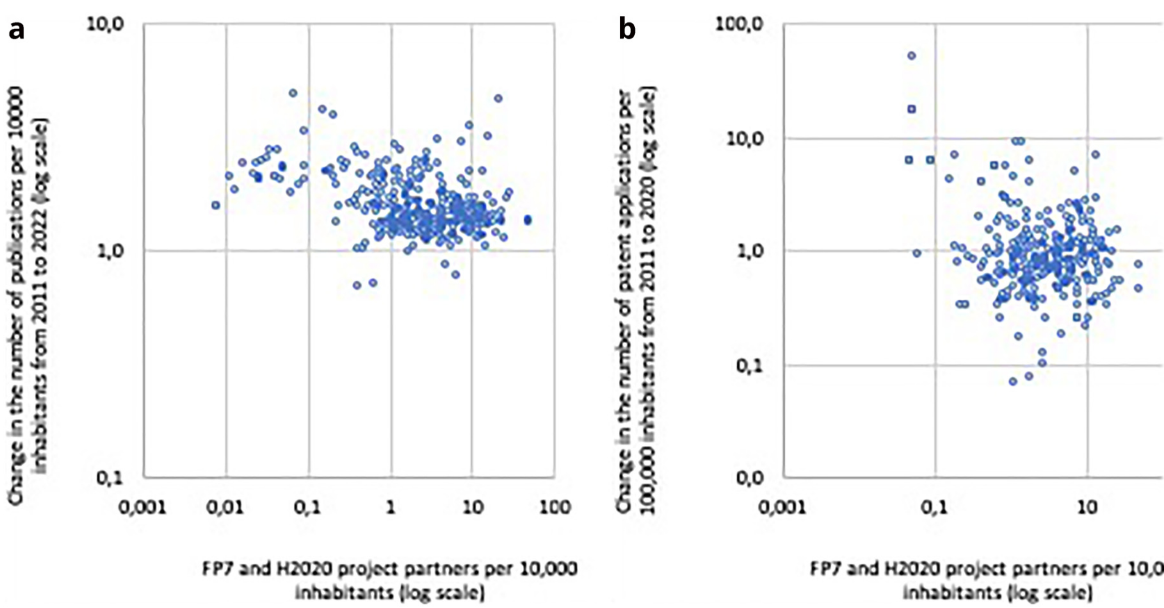

Figure 9. Relationships at the NUTS2 level: (**a**) FP7 and H2020 project partners per 10,000 inhabitants and change in the number of publications per 10,000 inhabitants from 2011 to 2022; (**b**) FP7 and H2020 project partners per 10,000 inhabitants and change in the number of patent applications per 100,000 inhabitants from 2011 to 2020.

role in the analysed phenomena and that regional observations within countries are not independent. The models presented in Table 1 provide separate specifications for the 7th Framework Programme, Horizon 2020, and their combined expenditures. The results from these specifications show similar estimates, leading to the decision to conduct subsequent analyses in Table 2 using only the total expenditure from both programmes.

Table 1. Regression results for three dependent variables (Robust standard errors in parentheses).

OLS variables and parameters	Models								
Dependent variable 1: change in GDP per capita in the period 2011–2022									
Dependent variable 2: change in the number of patent applications per capita in the period 2011–2020									
Dependent variable 3: change in the number of publications per capita in 2011–2022	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Control variable: GDP per capita in 2011	0.027	0.019	0.018	0.949**	0.914*	0.886*	-0.109***	-0.112***	-0.115***
	(0.058)	(0.061)	(0.057)	(0.444)	(0.472)	(0.440)	(0.026)	(0.026)	(0.027)
Control variable: GERD (intramural R&D ex. as % of GDP)	0.118*	0.110*	0.109*	0.447*	0.399*	0.399*	-0.019	-0.020	-0.021
	(0.058)	(0.060)	(0.059)	(0.226)	(0.214)	(0.223)	(0.023)	(0.022)	(0.023)
Control variable: Patent applications per capita 2011–2022	-0.032	-0.027	-0.027	-0.427**	-0.434**	-0.436**	0.012	0.015	0.014
	(0.021)	(0.019)	(0.020)	(0.195)	(0.191)	(0.192)	(0.012)	(0.013)	(0.013)
Control variable: Publications per capita in 2011	-0.201***	-0.208***	-0.208***	-0.158	-0.221	-0.232	-0.012	-0.012	-0.013
	(0.049)	(0.045)	(0.047)	(0.272)	(0.242)	(0.260)	(0.011)	(0.010)	(0.010)
Control variable: Share of internationally co-authored publications	0.184	0.203	0.200	-0.498	-0.392	-0.429	0.081**	0.090**	0.084**
	(0.163)	(0.164)	(0.164)	(1.084)	(1.101)	(1.117)	(0.039)	(0.038)	(0.039)
Control variable: Citations per publication	-0.170	-0.171	-0.171	0.411	0.395	0.405	-0.048	-0.047	-0.047
	(0.150)	(0.151)	(0.151)	(0.795)	(0.793)	(0.806)	(0.051)	(0.048)	(0.049)
7 Framework Programme projects per capita	0.010			-0.224			0.025***		
	(0.026)			(0.275)			(0.008)		
Horizon 2020 projects per capita		0.022			-0.153			0.025***	
		(0.028)			(0.215)			(0.006)	
7FP + H2020 projects per capita			0.023			-0.130			0.029***
			(0.026)			(0.239)			(0.008)
Control variable: population	✔	✔	✔	✔	✔	✔	✔	✔	✔
Control variable: country dummy	✔	✔	✔	✔	✔	✔	✔	✔	✔
Constant	1.716*	1.856**	1.851**	-6.595	-5.384	-4.986	1.604***	1.608***	1.636***
	(0.919)	(0.872)	(0.869)	(4.879)	(5.003)	(4.754)	(0.282)	(0.311)	(0.300)
Observations	266	267	267	166	166	166	266	267	267
R-squared	0.672	0.666	0.666	0.530	0.528	0.527	0.914	0.914	0.915

Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table 2. Regression results: change in the dependent variables in 2011–2022 by GDP per capita level in 2011.

OLS variables and parameters	Models: (1) GDP per capita 2011 < 80% of EU average (2): GDP per capita 2011 >= 80% & <=120% of EU average (3): GDP per capita 2011 > 120% of EU average								
Dependent variable 1: change in GDP per capita in the period 2011–2022									
Dependent variable 2: change in the number of patent applications per capita in the period 2011–2020									
Dependent variable 3: change in the number of publications per capita in 2011–2022	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
GDP per capita in 2011	-0.101	0.373*	0.077	0.900	1.213	-0.744	-0.149***	-0.062	-0.165
	(0.087)	(0.211)	(0.147)	(0.961)	(1.405)	(0.939)	(0.036)	(0.106)	(0.114)
GERD (intramural R&D ex. as % of GDP)	0.125	0.093	0.143	0.839***	-0.576	0.258	-0.025	0.000	0.009
	(0.081)	(0.057)	(0.130)	(0.211)	(0.419)	(0.369)	(0.019)	(0.017)	(0.044)
Patent applications per capita 2011–2022	0.007	-0.049	-0.080	-0.659**	-0.303**	-0.342	0.032**	-0.006	0.012
	(0.021)	(0.030)	(0.062)	(0.282)	(0.091)	(0.361)	(0.014)	(0.005)	(0.013)
Publications per capita in 2011	-0.237***	-0.182**	-0.255	0.052	-0.086	-0.961	-0.036**	0.015	-0.055
	(0.054)	(0.077)	(0.153)	(0.344)	(0.506)	(0.637)	(0.015)	(0.014)	(0.039)
Share of internationally co-authored publications	0.333**	-0.222	0.639**	0.060	2.554	-0.039	0.101**	-0.055	0.196*
	(0.147)	(0.221)	(0.290)	(1.325)	(2.000)	(1.392)	(0.044)	(0.057)	(0.109)
Citations per publication	-0.180	0.157	-0.510**	-1.935	-0.445	1.663	-0.048	0.020	0.052
	(0.222)	(0.267)	(0.209)	(3.380)	(1.853)	(0.975)	(0.084)	(0.029)	(0.116)
7FP + H2020 projects per capita	-0.003	-0.032	0.087	-0.638*	0.209	0.496	0.037***	0.010	0.032
	(0.022)	(0.096)	(0.083)	(0.354)	(0.249)	(0.393)	(0.007)	(0.009)	(0.042)
Control variable: population	✔	✔	✔	✔	✔	✔	✔	✔	✔
Control variable: country dummy	✔	✔	✔	✔	✔	✔	✔	✔	✔
Constant	3.448***	-2.381	1.823	-1.783	0.248	10.239	2.578***	0.545	2.746**
	(1.022)	(1.973)	(1.747)	(9.411)	(18.76)	(6.769)	(0.465)	(1.173)	(1.272)
Observations	116	74	77	52	51	63	116	74	77
R-squared	0.719	0.692	0.672	0.638	0.573	0.570	0.952	0.901	0.851

Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Table 2 presents the key findings of this study; it reports results for all three dependent variables in a subset of regions categorized based on GDP per capita in 2011: below 80% of the EU average, between 80% and 120% of the EU average, and above 120% of the EU average. This approach was used to assess the extent to which expenditures from the 7th Framework Programme and Horizon 2020 influenced changes in R&D activity, measured by the number of scientific publications and patent applications, as well as general economic development, measured by GDP per capita.

The results indicate that the increase in the number of scientific publications and patent applications was greater in regions where the initial levels of these indicators per capita were lower at the beginning of the analyzed period (2011). The negative coefficient for these variables suggests that regions with higher publication and patenting activity in 2011 experienced slower growth in subsequent years. In contrast, regions with lower initial levels saw greater increases over time. This pattern suggests a convergence in R&D potential at the regional level, as measured by the number of publications and patent applications per capita.

However, the results do not support the hypothesis that expenditure from the 7th Framework Programme (FP7) and Horizon 2020 (H2020) directly translates into an increase in scientific publications or patent applications at the regional level. This finding holds true for the entire sample and the three subsets of regions categorized by GDP per capita. While this lack of a direct relationship may seem surprising, it can be explained by the fact that FP7 and H2020 funding represent only one of many sources of R&D financing, and the overall level of funding is a more significant determinant, as reflected in the GERD variable (Gross Domestic Expenditure on R&D). It is important to emphasize that these results do not imply that FP7 and H2020 were ineffective. The absence of visible effects at the regional level does not necessarily mean that the programs had no impact at the individual or institutional level. This outcome may be an example of Simpson's paradox, where aggregated data obscure underlying relationships more granularly.

Interestingly, expenditure from the 7th Framework Programme (FP7) and Horizon 2020 (H2020) is positively associated with changes in GDP per capita at the regional level between 2011 and 2022. Regions that absorbed these funds at a higher rate experienced slightly faster economic growth than others (Table 1 for variable 3). This effect is statistically significant when considering the entire set of analyzed regions (Table 2). However, statistical significance is observed only in the poorest regions when the data is broken down by GDP per capita categories. This suggests that FP7 and H2020 funding accelerated economic development in less developed regions. This finding is somewhat unexpected, as these programs were not explicitly designed to target weaker regions for economic support. Furthermore, the results indicate that participation in FP7 and H2020 did not lead to a significant increase in scientific publications or patent applications in these regions. Instead, the positive impact on economic development may have occurred through alternative channels, enhancing the regional economic potential of less developed areas. This interpretation is plausible, as FP7 and H2020 funding supports scientific research and innovation-driven activities in enterprises, including small and medium-sized enterprises (SMEs). In poorer regions, access to project-based funding may play a crucial role in strengthening regional economic capacity, whereas in wealthier regions, reaching the critical mass necessary for measurable economic change may be more challenging.

Policy implications

The analysis provides several key observations relevant to development and regional policy. First, there is a persistent high interregional variation in the effects of research and development (R&D) activities, as measured by the number of scientific publications per capita and patent applications per capita. Significant disparities remain despite evidence of slow convergence, where regions with lower initial values experience higher growth rates. This pattern may result from a low base effect, where smaller regions experience higher relative increases simply due to their starting position. From a development and regional policy perspective, this underscores the importance of continued investment in building R&D capacity in weaker regions to reduce disparities and establish a foundation for long-term, sustainable competitiveness in the European economy.

Second, the results indicate that at the regional level, there is no clear evidence that R&D and innovation financing under FP7 and Horizon 2020 directly translated into higher publication or patent application rates per capita. One possible explanation is that the overall scale of these programs is relatively small compared to total R&D investments at the national or regional level. To achieve more visible and measurable scientific outputs, future policies should consider expanding the scale of such programs, particularly by increasing funding allocations.

Third, the results show that FP7 and Horizon 2020 funding contributed to economic development (measured by GDP per capita), particularly in lagging regions. This suggests that development and regional policies should continue to support R&D and innovation investments in regions with lower R&D absorption capacity as they generate tangible economic benefits. The findings also indicate that research policy can be an effective development policy in regions with stronger economic and innovation potential.

Based on this, allocating targeted R&D and innovation funding to lagging regions can be a viable policy strategy, particularly when combined with quality assurance mechanisms, such as competitive international recruitment. Additionally, encouraging collaboration with experienced international research partners can help transfer knowledge, expertise, and resources, improving the effectiveness of these investments.

These findings also contribute to the discussion on leveraging synergies between different EU funding mechanisms to foster innovation-driven growth in NUTS2 regions across Europe. In particular, the synergy between Horizon Europe and the European Regional Development Fund (ERDF) offers significant but underutilized potential. An integrated approach, such as through Smart Specialisation Strategies (S3), is necessary to enhance these synergies, ensuring more efficient resource utilization and greater impact (Jokelainen & Guerrero, 2023; JRC, 2021). Larger budget allocations could further amplify the impact of these programs on scientific and technological outputs (European Commission, 2023).

Ethics and consent

Ethical approval and consent were not required for this study because it did not involve human participants, animals, or identifiable personal data. The data used were entirely derived from publicly available sources.

Data availability

Underlying data

No data associated with this article.

Extended data

Zenodo: Bridging Europe's Innovation Divide: How European Union Research Policy Drives Growth in Less Developed Regions – SM. https://doi.org/10.5281/zenodo.15100476 [Chumachenko, A. (2025)]

- This project contains the following extended data: Appendix.docx (referenced and structured as supplementary material to provide additional evidence and methodological transparency)

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