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European Regional Policy

Spatial Heterogeneity in the Distribution of European Research and Development Funds and its Effects on Territorial Cohesion

Fernando Rubiera Morollón, Tania Fernández García***

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Abstract:

The latest research and development (R&D) framework programmes of the European Union (EU), "Horizon 2020" and "Horizon Europe", have significantly increased the resources available to promote science and innovation in Europe. However, the strong competitiveness of the research teams and their search for excellence may cause inequality in the spatial distribution of investment effort in R&D. The aim of this paper is to analyse the geographic distribution of R&D spending in the EU. A greater concentration of funds is observed in the most advanced and dynamic economies, capable of promoting more competitive research teams and projects. Through an empirical analysis, estimated by a spatial convergence model, it is found that EU R&D funds are preventing cross-regional convergence in Europe by driving growth mainly in wealthier regions. Based on these results, it seems relevant to consider spatial correction mechanisms for the distribution of R&D resources so that they achieve greater territorial cohesion in Europe.

Keywords: Research and development (R&D); competitiveness; productivity growth; regional disparities; territorial cohesion; European Union (EU).
JEL Classification: E65; O30; R58.

Heterogeneidad espacial en la distribución de los fondos europeos de investigación y desarrollo y sus efectos sobre la cohesión territorial

Resumen:

Los últimos programas marco de investigación y desarrollo (I+D) de la Unión Europea (UE), el "Horizonte 2020" y el "Horizonte Europa", han incrementado significativamente los recursos disponibles para promover la investigación científica y la innovación en Europa. No obstante, la fuerte competitividad de los equipos de investigación y la búsqueda de la excelencia puede estar causando una distribución desigual de estos recursos. El objetivo de este trabajo es analizar el reparto geográfico del esfuerzo inversor en I+D de la Unión Europea. Se ha observado que ciertamente se produce una fuerte concentración de los fondos europeos de I+D en las áreas más dinámicas capaces de promover proyectos de investigación más avanzados y competitivos. Se ha estimado un modelo de convergencia con dependencia espacial que muestra como la política de I+D europea está impidiendo la convergencia entre regiones al impulsar el crecimiento de las más desarrolladas. Teniendo en cuenta estos resultados sería conveniente introducir factores de desarrollo regional en la asignación de fondos e incorporar criterios de equilibrio geográfico en la construcción de los consorcios de investigación internacionales.

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Palabras clave: Investigación y Desarrollo (i+D); competitividad; aumento de productividad; desigualdades regionales; cohesión territorial; Unión Europea (UE).
Clasificación JEL: E65; O30; R58.

1. Introduction

Research and development (R&D) is one of the keys to modern economic growth. The economies of advanced societies depend on the economic progress and productivity boost generated by scientific and innovative projects. However, R&D requires hard investment efforts for the results to begin to materialize. In the "Lisbon Strategy", the European Union (EU) has committed to promoting these major research, science, innovation and development projects. Thus, the objective of reaching a level of investment in R&D in Europe that represents 3% of gross domestic product (GDP) has been set. Although there have been significant delays in achieving this objective, what is most relevant is that there is enormous heterogeneity between countries that is amplified when the analysis is done at a more spatially disaggregated level. There are areas in Europe that are already well above the 3% target, while others are a long way off. The design of European funds to support R&D is based on the search for excellence. This makes it very competitive and complex for less developed regions to access resources. It is worth asking, therefore, if the policies to support R&D in Europe are fostering greater spatial inequality.

With these ideas in mind, the first objective of this paper is to review the spatial effects of European R&D policy. It is proposed to analyse in great detail the spatial distribution of European R&D funds and the evolution that they have had over the last decades. We will see that there is certainly a marked concentration of these funds in the more developed regions, which leads us to wonder how this spatial distribution of R&D resources may be affecting the dynamics of territorial cohesion.

In order to answer this question a beta-convergence model is proposed. As a relevant novelty, regarding to the extensive literature on convergence in Europe, the specific effect that R&D funds can have on the convergent or divergent behaviour of the regions is measured. Furthermore, aware of the spatial dependence of the data and the possible slipovers in both growth and R&D effects, we implemented several spatial econometrics models.

The results are interesting and open the debate. It is observed how the spatial distribution of European R&D funds negatively affects the territorial cohesion dynamics. All of this leads to extracting some relevant economic policy conclusions.

The structure of the paper is the following. First, in the second section, a description of the evolution and current situation of R&D in Europe is first presented. The role of research, science and innovation in the growth and competitiveness of economies is reviewed, and then it is examined how R&D has become one of the key parts of community policy. The third section shows the distribution of investment in R&D throughout European geography using different indicators broken down at different spatial levels. All this leads to a fourth section where a simple empirical approach is used to evaluate to what extent spatial inequalities in R&D may affect territorial cohesion in Europe. The work ends with a section of conclusions and general recommendations for economic policy.

2. The 3% objective: Improving the competitiveness and productivity of the EU through investment in R&D

2.1. The role of R&D in economic growth

Research and the generation of knowledge have been considered important for promoting economic development by many historical scholars, such as Francis Bacon, and by some classical economists, such as Adam Smith and Schumpeter, who profoundly discussed the capabilities of individuals (workers and entrepreneurs) to promote technological change. However, since the second half of the last century, innovation has been positioned as the fundamental variable for promoting territorial economic growth.

Specifically, in 1957, Robert Solow managed to demonstrate that technological change is the only factor that could boost long-term territorial economic growth. At first, there was a perception that technological change and thus economic growth was beyond the control of economic agents; individuals were not considered capable of promoting technological change, which was considered an exogenous variable (Solow, 1957). However, during the 1980s, theories predominated in considering economic growth an endogenous process. The work of Romer (1994) emphasized that growth is not "the result of forces that impinge from the outside" (Romer, 1994); since then, growth has no longer been considered an exogenous outcome. Individuals are considered capable of promoting technological change and thus territorial economic growth.

Feldman and Florida (1994) argued that economic agents (mainly governments and firms) need to create an "infrastructure" to promote innovation. In this sense, investment in R&D has been considered the fundamental basis for the construction of R&D infrastructure. Principally, investment was supported by the linear model of innovation, which is one of the predominant theories that study the links between technological change and economic development. This model established that to promote technological change, the generation of new knowledge (basic research) must come first, followed by applied research and finally, the development phase and subsequent market introduction of innovations (Godin, 2006). Ultimately, this process has an impact on economic growth; in other words, investment in R&D has a direct impact on economic growth (Rodríguez-Pose and Crescenzi, 2008). In the context of the OECD countries, the economic effects of this principal source of innovation have been increasingly analysed since the middle 1960s, when the increasing concern about the potential impact of innovation on economic growth (OECD, 2015) based on Solow theory, made European countries to be interested in collecting harmonized statistical data on R&D expenditures which made possible deeper analysis. Several studies focusing on different geographical areas have found a positive and significant influence of R&D expenditures on territorial economic growth rates (Rodríguez-Pose and Crescenzi, 2008; Kaneva and Untura, 2017; Rodríguez-Pose and Villarreal, 2015; Crescenzi, 2005; among others). Therefore, empirical evidence clearly supports the idea that R&D is a key variable in enhancing economic growth.

Additionally, a major part of the literature, in addition to exploring the links between R&D expenditures and economic growth, has widely analysed the impact of innovation on territorial productivity levels. Raising the output per worker, or in other words, productivity, has been considered crucial for increasing territorial competitiveness (OECD, 2007) and individual well-being (Krugman, 1994); thus, it is obviously and intrinsically linked with territorial economic growth. Adam Smith (1776) presented an argument for the importance of technological change for increasing the output per worker. Empirical evidence, for instance, in the context of the United States (US) manufacturing industries (Griliches, 1973) and the pharmaceutical industry (Minasian, 1962) or the contexts of the Spanish regions, (Bengoa et al., 2015, López and Martínez, 2017; Gambau and Maudos, 2006; among others) all support this theory; they found a strong, positive link between these variables.

In summary, the introduction of endogenous growth perspectives, the greater availability of harmonized statistical data related to R&D investment and the major amount of empirical evidence mainly since the 1980s are three factors that have contributed significantly to the current international consensus that R&D activities contributing to innovation are important for promoting territorial economic growth, competitiveness and productivity.

2.2. The 3% EU objective

Although during the 1990s, the EU experienced meaningful institutional development and macroeconomic stability, there was still a related objective: increasing territories' economic growth rates and employment (Sapir, 2003). To reach these goals, by the beginning of the present century, the European Commission had launched a strategic plan called the "Lisbon Agenda" or "Lisbon Strategy". The aim of the plan was to convert the EU by 2010 into one of the most dynamic and competitive economies in the world (European Parliament, 2000). Several lines of action were established, for instance, improving macroeconomic policy or redesigning convergence policies, but specifically, an increase in R&D expenditures was expected to boost innovation and knowledge generation. Historically, investment in R&D did not seem to be one of Europe's strengths. A group of experts who developed a report under an initiative from the president of the European Commission argued that the EU had lower efficiency levels than the US; they justified this outcome with the argument that lower investment effort in R&D limited their capacity to transform investments into outputs (Sapir, 2003). Additionally, Sheehan and Wyckoff (2003) highlighted that in the 1990s, the most important European economies had weaker productivity levels than other world powers such as the US or Japan. They presented lower R&D expenditure as the main explanation.

The higher awareness of the EU about the importance of R&D as a source of competitiveness and economic growth made them set an R&D target in the "Lisbon Strategy": invest in R&D a 3% of the GDP by 2010. The EU choose this target because it wanted to close the existing gap in R&D investment effort with most dynamic and productive economies, such as Japan, which reached 3% of its GDP in 2000 (Sapir, 2003). However, in particular, the EU chose that target due to its potential positive impact on the economy. The European Commissioner for Research, Innovation and Science, Philippe Busquin, justified the 3% target by arguing that it could contribute to a 0.5% additional increase in the GDP growth rate and generate 400 thousand additional jobs every year after 2010 (European Commission, 2003). Through a meeting in Barcelona, a research group of the European Commission helped establish the methods to reach this target (EUA, 2002). As a result, the European Commission elaborated "An Action Plan for Europe", which detailed the procedures required to obtain that goal. However, through a communique called "More Research and Innovation" in 2005, the European Commission argued that practically R&D investment levels in the EU had remained constant since the introduction of the "Lisbon Strategy" (European Commission, 2005). The communique emphasized that R&D expenditures were not rising at the appropriate growth rate for reaching the 3% target and reinforced the importance of developing some of the proposed actions included in the previous action plan and those that were integrated into the "Lisbon Strategy".

Despite the work carried out by the "Lisbon Strategy" and the advances in R&D investment, especially during the period from 2007 to 2010, in 2010, the EU was still a long way from reaching its goal. The European Commission developed a new strategy in 2010, called "Europe 2020", which addressed the great financial and economic crisis in Europe of the moment. Therefore, growth objectives and the need to enhance productivity and competitiveness became especially relevant and timely. Aware of the importance of creating knowledge-based economies due to their potential impact on territorial economic growth rates, the European Commission decided again to prioritize increased resources devoted to R&D. In particular, they once again set the R&D investment target at 3% of GDP by 2020 (European Commission, 2010).

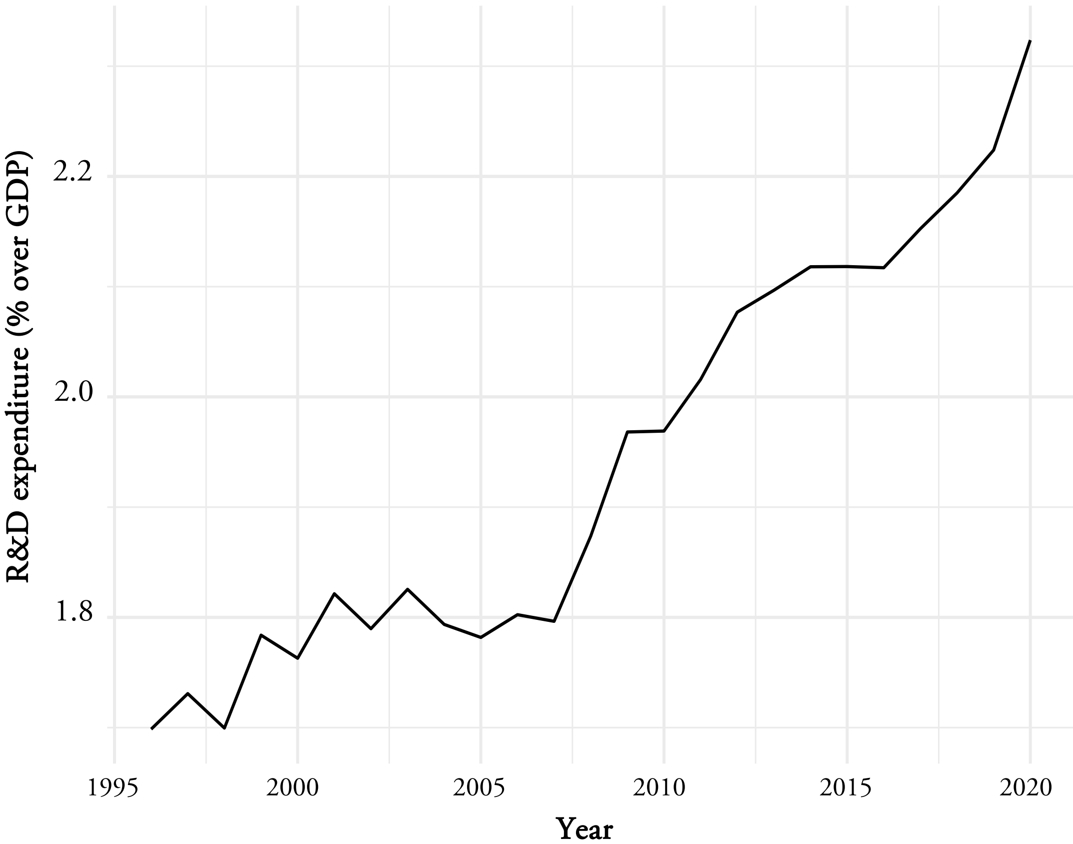
Although there was a noticeable increase in R&D expenditures in the EU during 2010-2020 and the EU managed to overcome the 2% barrier, it did not reach the R&D target of 3% of GDP by 2020. At present, the European Commission has folded R&D strategies into the "Strategic Plan 2020-2024". In this document, the European Commission highlights the importance of having invested in R&D during recent decades since it had observable effects on the competitiveness of EU territories (European Commission, 2020). The 3% target seems to still be taken as a strategic reference, but there is one important and novel component: they argue strongly for boosting territorial innovative infrastructures by notably increasing the EU R&D budget.

As mentioned, and as argued by some researchers such as Hervás-Oliver et al. (2021), the main variable with which the EU tried to enhance territorial innovation during recent decades has been through R&D increases, or in other words, through a linear model of innovation. They seemed to believe that R&D would directly boost economic growth independently by generating new knowledge and innovations (Godin, 2006). However, much of the current literature has observed that although R&D investment is highly relevant, innovation must be interpreted from a multidimensional perspective; for instance, characteristics related to the endowments of human capital in the territories or related to the innovative capabilities of the firms (Fernández-García et al. 2022), their interaction and collaboration (Hervás-Oliver et al., 2021) and the socioeconomic characteristics of the territories (Rodríguez-Pose and Crescenzi, 2008) are variables that could determine the innovative potential of the territories and thus, in turn, their economic growth rates.

2.3. Advances in investment in R&D in Europe

As discussed in the previous section, in recent decades, the EU has tried to increase R&D investment to promote territorial economic growth. However, this has been a difficult goal. Figure 1 summarizes the evolution of investments in R&D in the EU during the period from 1996 to 2020. Two stages are clearly observed. First, there was a long period of more than a decade (1996-2007) in which levels of R&D expenditures were practically stagnant and close to 1.8% of GDP. This trend clearly justifies the concern of the European Commission for the limited progress in R&D investment after the introduction of the "Lisbon Strategy", and in particular, during the period from 2000 to 2005. Second, there is a following stage that begins between 2008 and 2010 and clearly reflects constant growth in R&D spending in the EU until the present. Despite these gains, the graph confirms the criticisms above; Europe has a long way to go to reach the 3% EU target for R&D, with levels of investment currently close to only 2.3% of GDP.

Figure 1.
Evolution of R&D expenditures, measured as a % over GDP, in EU countries, 1996-2020



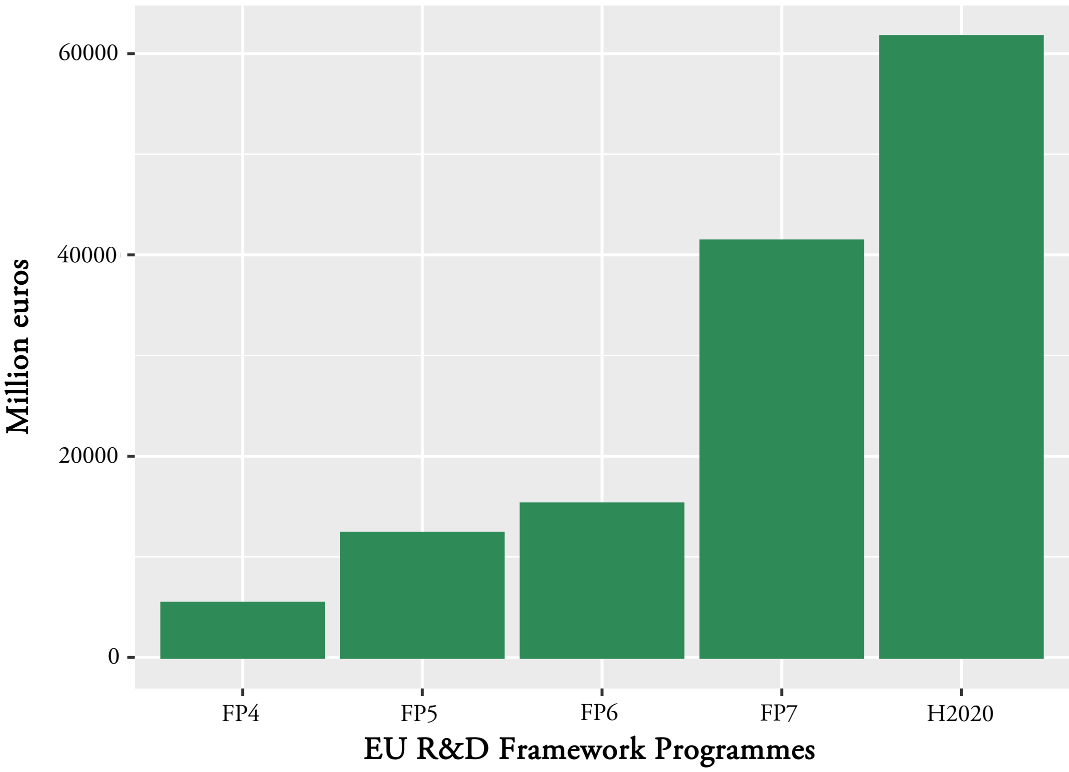
Source: Own elaboration using data from the World Bank.

To achieve these objectives, the EU established multiannual framework programmes to promote R&D in recent decades. Specifically, since 1994, there have been six R&D framework programmes: "FP4" (1994-1998), "FP5" (1998-2002), "FP6" (2002-2006), "FP7" (2007-2013), "Horizon 2020" (2014-2020) and the current programme, "Horizon Europe" (2021-2027).

Figure 2 shows the EU net contribution, expressed in millions of euros, by each R&D framework programme. It should be noted that the "Horizon Europe" framework programme is not included since the allocation of funds has not yet finished. In particular, the amount of funds allocated to each programme clearly evolves in a very similar way to the growth previously observed in Figure 1 for the case of R&D. The first three programmes, specifically between 1994 and 2006, allocated a reduced amount of funds.

However, in each framework programme, the allocated funds increased significantly. Notably, a great leap was observed in “FP7”. In the period 2007-2013, the EU invested more than 40000 million euros, almost tripling the amount of funds allocated through the previous programme (FP6). This larger allocation in the “FP7” is consistent with the greater awareness of a need for investment exposed in the “Europe 2020” strategy after the failed attempt to reach the R&D target in 2010. At present, the “Horizon Europe” framework programme promises to be the largest investment in history, having a budget of 95950 million euros (European Commission, 2020).

FIGURE 2.
Total EU net contribution (in millions €) through the last five R&D framework programmes between 1994 and 2020



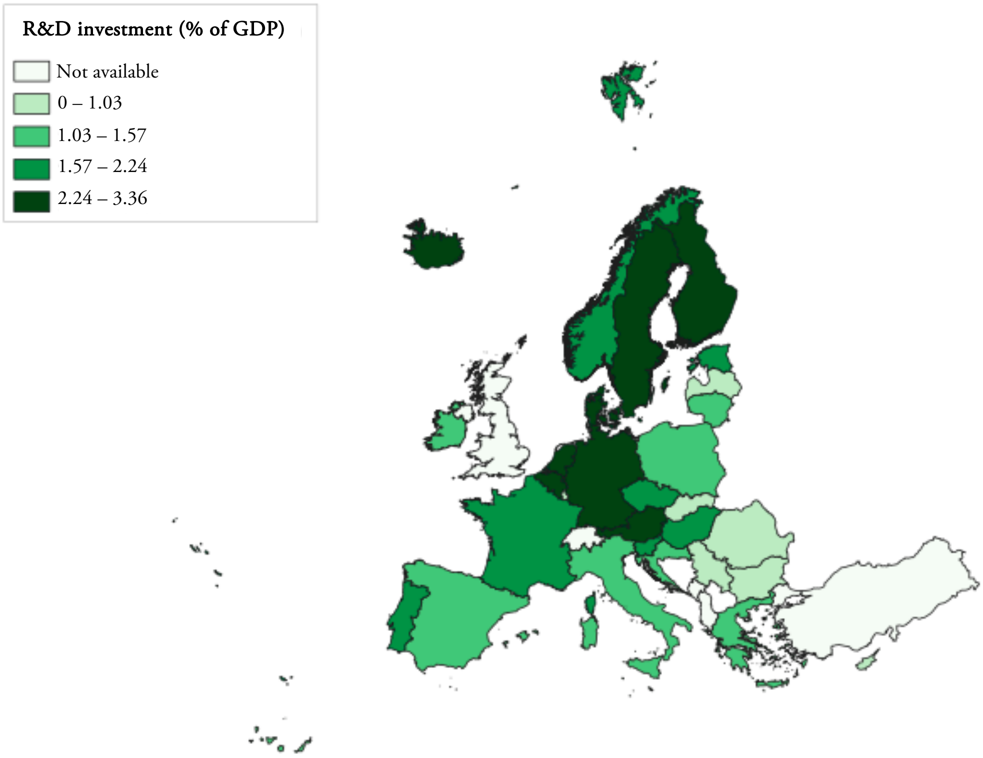
Source: Own elaboration using data from Horizon Dashboard.

3. Spatial distribution of R&D expenditures and H2020 funds across Europe

3.1. An analysis of the spatial patterns of R&D investment effort

In recent decades, there has been a pattern of heterogeneity in the geographical distribution of R&D investments in the context of EU countries. Figure 3 represents the actual context of expenditures in R&D in each of the EU countries; however, it could also summarize the historical distribution of R&D investment. First, central and northern European countries have been investment leaders. Moreover, at present, Sweden (3.36%), Belgium (3.22%), Austria (3.19%) and Germany (3.13%), which are some of those countries that have led over time, have managed to surpass the goal of 3% investment in R&D. Additionally, there are other countries geographically nearby that are very close to reaching the EU R&D target, such as Finland (2.98%), Denmark (2.81%) or Iceland (2.77%). Second, there are other countries that have been characterized by low investments in R&D, mainly EU countries located in the east and south of Europe. Countries such as Romania (0.47%), Malta (0.63%) and Bulgaria (0.77%) are currently far from reaching EU R&D investment objectives.

FIGURE 3.
R&D expenditures measured as a % over GDP in each European country (NUTS0), 2021

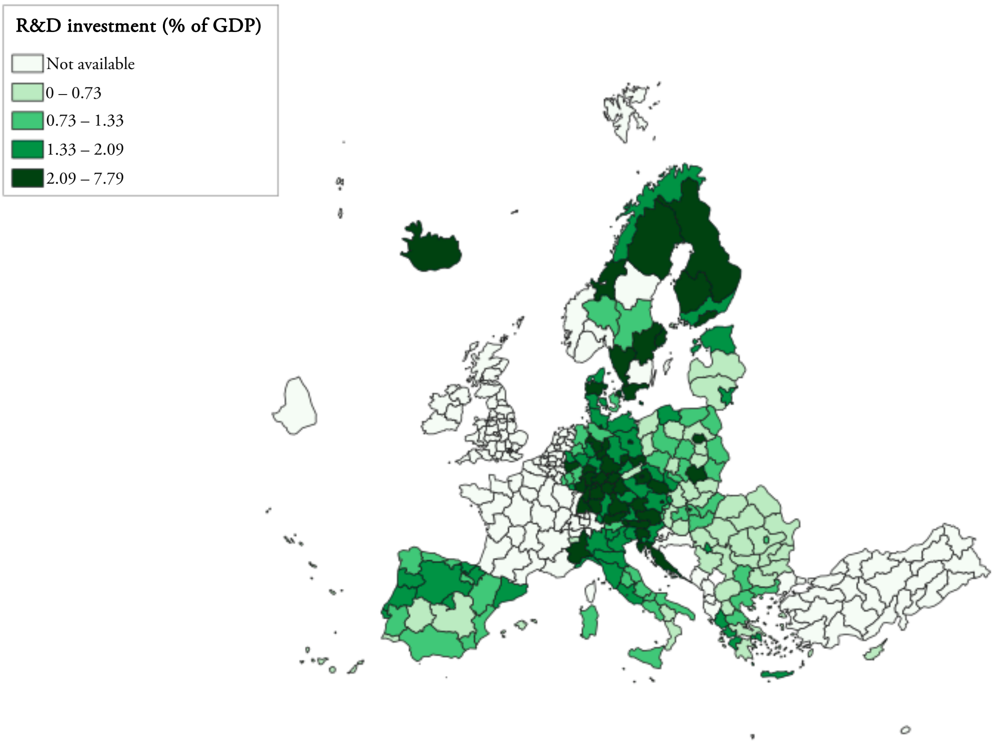


Source: Own elaboration using data from Eurostat.

Figure 4 represents the investment effort in R&D of the European territories at the lowest spatial level of data aggregation (NUTS2) for which there exist available statistical information. The year 2019 has been taken as a reference since it is the closest for which there are available data for more than half of the European NUTS2 regions. A similar geographic distribution to that observed in Figure 3 is now presented in Figure 4. On the one hand, regions located in the north and centre of Europe are those that have invested in R&D to a relatively large extent, on average. Regions belonging to Germany, with investment levels over 7% of GDP, stand out notably. Additionally, regions belonging to Sweden, Norway and Denmark present investment levels close to 5% of GDP. On the other hand, peripheral regions, mainly those belonging to eastern countries of Europe, are those with lower spending in R&D, specifically, below 1% of GDP on average.

However, Figure 4 shows that there exists great territorial imbalance between countries. A great disequilibrium in terms of R&D investment effort is also perceived within countries. For instance, in Spain, there is a noticeably large gap between some regions. The Basque Country (1.99%), the Community of Madrid (1.7%) and the Foral Community of Navarra (1.7%) showed high R&D expenditures in 2019 in contrast to other regions, such as the Balearic Islands (0.39%) and the Canary Islands (0.46%), which presented low R&D investment efforts.

FIGURE 4.
R&D expenditures measured as a % over GDP in each European region (NUTS2), 2019



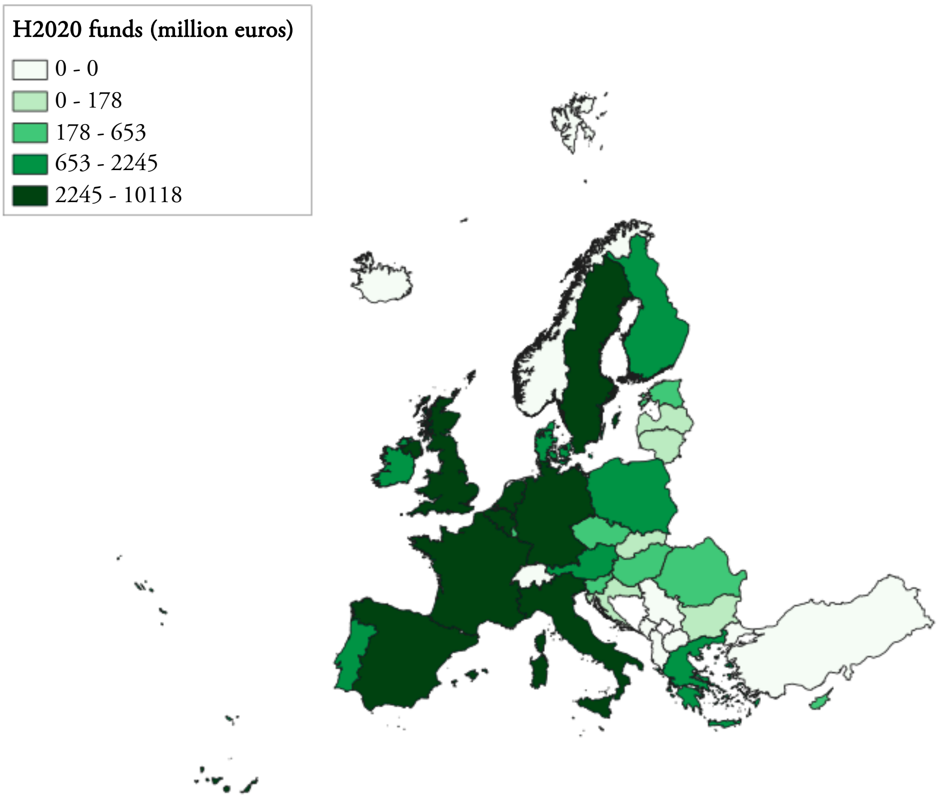
Source: Own elaboration using data from Eurostat.

3.2. Spatial distribution of H2020 funds: The largest allocation of EU R&D funds until the present

Apart from analysing the geographical patterns of the total investment in R&D through the previous section, the geographical allocation of the last EU R&D framework programme, "Horizon 2020", is worthy more detailed analysis since, given its large fund, could have represented a large part of the total R&D spending in the EU regions.

Figure 5 reflects the geographical distribution of the "Horizon 2020" funds in EU countries. As observed in the case of the R&D investment by geographical distribution, great heterogeneity is again observed in the allocation of H2020 funds. First, territories that were especially characterized by low investments in R&D (eastern EU countries) are those that benefited less from H2020 funds. Second, countries that historically have been innovation leaders, such as Germany, the Netherlands or Sweden, are among those that benefited the most. Table A1.1 presented in Annex 1 reflects the top five European beneficiaries (by nation) of the last three framework programmes. The distribution of the past few rounds of funding clearly follows a spatial pattern; in the past two decades, the same countries have benefited the most from the framework programmes.

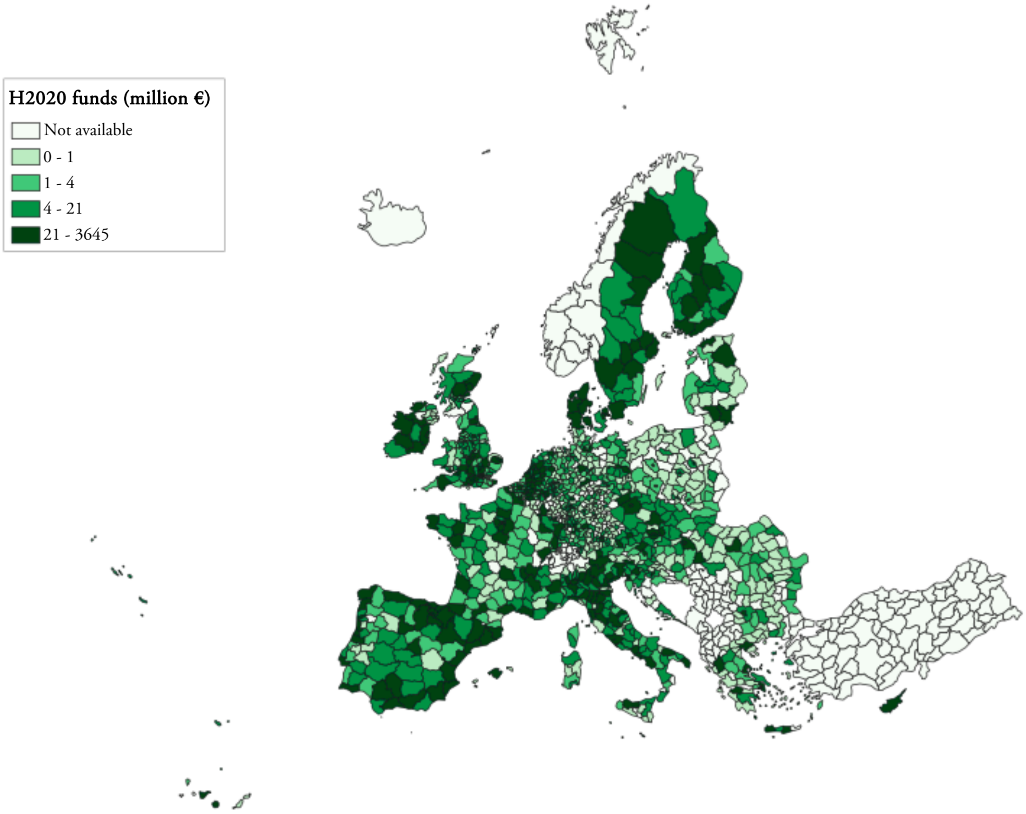
FIGURE 5.
H2020 funds received by each European country, measured in millions of euros



Source: Own elaboration using data from Horizon Dashboard.

Figure 6 reflects the geographical distribution of H2020 funds in the EU regions at the NUTS3 specification, being the lowest level of spatial data aggregation for which there is available information. Again, and more clearly, the data reflect that there was great heterogeneity in the allocation. On the one hand, 50% of the least benefited regions each received less than 4 million euros. However, specifically, on the other hand, the 25% of regions that most benefited received between 21 and 3600 million euros. Notably, this is a very wide range, meaning that the amount of funds received by this group of favoured regions is also very uneven. This is the first evidence of the huge concentration of H2020 funds. Of particular note, only 25% of European regions received more than 90% of the budget. Moreover, less than the 1% of the European regions concentrate above the 30% of the H2020 budget. This group of regions is presented in Table A1.2 in Annex 1, which shows the top fifteen European regions that benefited most from H2020 funds. It should be noted that the regions in that list are the most dynamic areas of Europe. In particular, these are the regions where most important capitals of Europe are located.

FIGURE 6.
H2020 funds received by each European region (NUTS3), measured in millions of euros



Source: Own elaboration using data from Horizon Dashboard.

4. R&D AND TERRITORIAL COHESION IN THE EU: A PRELIMINARY EMPIRICAL ANALYSIS

4.1. DESCRIPTION OF THE EMPIRICAL MODEL AND THE ECONOMETRIC STRATEGY

Apart from the general objective of investment in R&D to boost the European economy, it is expected that this investment will play an important role in encouraging territorial cohesion and convergence between regions. However, in view of the analysis carried out in the previous section, it is possible to think that the existing inequalities in the European region's investment effort in R&D and also in the territorial allocation of resources for R&D through European policies (R&D framework programme funds) throughout EU geography which tend to concentrate in the richest and most dynamic regions are causing the opposite effect.

In this final section, we ask ourselves if the spatial distribution of the European region's investment effort in R&D and specifically, the territorial allocation of resources for R&D through European policies far from underpinning cohesion between regions in Europe, may be causing greater territorial inequality. To do so, we propose to develop a β-convergence model which is reflected by Expression [1]. First, through the relationship between the dependent variable $\left(\frac{Y_i^t - Y_i^T}{Y_i^T}\right)$, which represents the economic growth of territory (i) in a certain period between (T and t), and the economic performance ($Y_{i,T}$) of territory (i) in the initial period (T), the β parameter is estimated. This will allow us to observe if there has been economic convergence between European regions. Second, as the main focus of this analysis, through a set of parameters (γ_k), the effect of other initial socioeconomic conditions (such as the effect of initial R&D

investments and, especially, the effect of R&D European funds) on economic growth will be tested. It should be noted that β convergence analysis has been the most common method for analysing the relationship between R&D expenditures and territorial economic development, as shown by Rodríguez-Pose and Crescenzi (2008) considering the case of European regions, by Kaneva and Untura (2017) for the context of Russian regions and by Rodríguez-Pose and Villarreal-Peralta (2015) for the case of Mexican regions, among others.

$$\left(\frac{Y_i^t - Y_i^T}{Y_i^T}\right) = \alpha + \beta Y_i^T + \sum_{k=1,m} \gamma_k x_{ik}^T \tag{1}$$

Specifically, this analysis is developed for the context of the European regions at the NUTS2 level of spatial aggregation, since it is the most disaggregated spatial level for which there is statistical information related to territorial R&D expenditures, which is one of the main variables in this analysis. The period of analysis is delimited from 2008 to 2019. This is the span of time for which information is obtained for a higher number of observations, specifically, for a total of two hundred European regions. Apart from analysing which are the effects of the total R&D expenditures and also the effects of the R&D European funds on the territorial economic development and observing for the presence of economic convergence, other control variables related to the socioeconomic and demographic characteristics of the territories were included. Table 1 summarizes all variables considered in the analysis as well as their definitions.

Equations [2] and [3] are the expressions through which the β convergence model is estimated by employing the variables included in Table 1.

$$\left(\frac{Y_i^t - Y_i^T}{Y_i^T}\right) * 100 = \alpha + \beta Ln\left(Y_i^T\right) + \gamma_1 R\&D_i^T + \gamma_2 Education_i^T + \gamma_3 Ln\left(Density_i^T\right) + \gamma_4 EmploymentRate_i^T + \varepsilon \quad (T = 2008\,; t = 2019) \tag{2}$$

$$\left(\frac{Y_i^t - Y_i^T}{Y_i^T}\right) * 100 = \alpha + \beta Ln\left(Y_i^T\right) + \gamma_1 FP7_i^T + \gamma_2 Education_i^T + \gamma_3 Ln\left(Density_i^T\right) + \gamma_4 EmploymentRate_i^T + \varepsilon \quad (T = 2008\,; t = 2019) \tag{3}$$

The links between some socioeconomic and demographic variables and the growth of the territories are analysed through both expressions, but specifically, through Expression [2] the links between total R&D expenditures and the growth of the regions are explored. Expression [3] permits to analyse the links between R&D European funds and the growth experienced by the territories. As mentioned, independent variables refer to the year 2008, the initial period that is taken as a reference. In this sense, the R&D framework programme considered in the analysis, and included as an explanatory variable, is the FP7(2007-2013) the closest to the initial period of analysis (2008). It should be noted that R&D expenditures, variable considered in Expression [2], and R&D European funds, variable considered in Expression [3], cannot be included in the same equation due to the existence of perfect multicollinearity between mentioned factors; R&D framework programmes are one of the main components of the European regions R&D expenditure.

On the one hand, expressions [2] and [3] are estimated through one of the most common econometric techniques, ordinary least squares (OLS). However, on the other hand, we are aware that in Europe predominates a great heterogeneity in socioeconomic and demographic characteristics. In this sense, we suspect that the territories' level of development and also their economic growth rates could be conditioned by their location in the European geography. Table 2, which presents the Global Moran I and Geary C test which are statistics typically used for observing if there is a process of spatial autocorrelation between the observations, has allowed us to confirm that the growth rates experienced by each European region between 2008 and 2019 are not independent of each other, or what is the same, there is a process of spatial autocorrelation between European regions income growth rates. In summary, we complemented our analysis with a more sophisticated methodology which permitted us to account for the observed spatial dependence between the observations[2]. The spatial autoregressive model (SAR) and spatial durbin model (SDM) are estimated for both model specifications, that is, for those reflected in expressions [2] and [3]. Estimates are developed using a "Queen" contiguity matrix, however, other neighbourhood structures were considered obtaining very similar results.

Table 1.
Variables description

Variables	Definition
Dependent variable	
Economic growth rate	GDP per capita growth rate in each region, from 2008 to 2019.
Investment in R&D and Education	
Total R&D	Investment in R&D made by all sectors as a percentage of the GDP in each region in 2008.
Tertiary education	Percentage of people with tertiary education in each region in 2008.
Log of FP7 research funds	Amount of funds received by each region from FP7 programme, measured as a logarithm.
Economic and demographic variables	
Log of GDP per capita	GDP per capita in each region in 2008 measured as a logarithm.
Employment rate	Employed persons as a percentage of the total population in each region in 2008.
Log of Population density	Number of people per square kilometre in each region in 2008 measured as a logarithm.

Source: Own elaboration.

Table 2.
Global Moran´s I and Geary C test for detecting spatial autocorrelation. Dependent variable: European region's income growth rates between 2008 and 2019

Test	Statistic	p value
Global Moran´s I	0.72	0.00
Geary C test	0.14	0.00

Source: Own elaboration.

4.2. Results

Table 3 presents the main results, where OLS, SAR, and SDM estimates are presented for each model specification, [2] and [3]. On the one hand, through specification [2], the relationship between investment in R&D by European regions and their economic growth between 2008 and 2019 is particularly examined. On the other hand, through specification [3], the links between European R&D framework programmes

[2] The choice of the spatial econometric models is based on the Lagrange multiplier test results. In this case, the SAR and SDM models are the ones with the highest probability of being the data-generating process.

and the economic growth of European regions in the period under study are explored. By replicating the same analysis for both specifications, [2] and [3], we gain a more comprehensive understanding of the relationship between R&D investment, European R&D framework programmes, and regional economic growth in Europe.

There are three main and general results from Table 3. First, in the period from 2008 to 2019, there was a process of convergence in income per capita between the European NUTS2 regions. In other words, every estimate presented in Table 3 shows that, on average, those regions that had a lower level of income per capita in 2008 are those that experienced greater economic growth rates during the period of analysis. Second, both OLS and the spatial models, SAR and SDM, related to specification [2] show that investment in R&D was a key factor in the growth of the European regions between 2008 and 2019. In other words, it is consistently observed that R&D investment had a significant and positive effect on the growth of the European regions in the period of analysis. Third, estimates related to Expression [3] presented in Table 3 reflect that the European funds earmarked for the promotion of R&D, in this case, the FP7 funds, had a significant and positive effect on the growth of the European regions from 2008 to 2019. There is a principal conclusion: European R&D framework programmes (FP7) and the total expending destined by the regions for R&D activities generated significant effects on the growth of the European regions, on average.

Table 4 shows the marginal effects (total, direct, and indirect impacts) calculated from the SDM estimates which permit a greater understanding of the results. First, the direct effect measures how the increase in one of the explanatory variables in territory (i) favours that area (i). Second, the indirect effect, measures how region (i) would be benefited if all of its neighbours increase a certain explanatory variable. Finally, the total effect could be interpreted as the impact that an increase in a certain variable in territory (i) has on the closest neighbours (LeSage, 2008). In this sense, it can be understood as a spillover effect. There are two important conclusions from Table 4. First, the total investments in R&D and European funds for the promotion of R&D disbursed in a specific territory (i) significantly promoted the growth of income per capita of that territory (i), in other words, mentioned factors generated a significant and positive direct effect. These results are in line with that previously observed in Table 3. Second, total R&D expenditures and European funds for the promotion of R&D disbursed in a specific territory (i) promoted the economic growth of neighbouring territories, on average (significant total effect). In conclusion, total R&D expenditures or R&D framework programmes that are allocated to a territory not only favoured the economic growth of that territory, but the positive effects were also extended to neighbouring areas (spillover effect).

Other factors that typically have been considered a source of economic growth are also observed, such as the population density of the territories or the employment rate, which are also significant in this analysis for explaining the European regions' economic growth in the period 2008-2019 in each of the specifications. Education did not have a significant effect on growth when it was included in the model at the same time as R&D expenditures. Notably, these findings can be justified by the fact that there is a large correlation between the variables. Regions that had higher R&D investments are those that had more highly qualified individuals in the European regions.

TABLE 3.
Growth model estimates through OLS, SAR, and SDM. Dependent variable: GDP per capita growth rate in the period 2008-2019

	Expression [2]						Expression [3]					
	OLS		SAR		SDM		OLS		SAR		SDM	
Constant	259.13	***	147.01	***	130.37	***	211.97	***	112.86	***	93.57	***
	(15.23)		(17.15)		(18.62)		(15.15)		(16.21)		(16.62)	
Log GDP pc	-32.63	***	-18.29	***	-15.84	***	-29.19	***	-15.66	***	-13.13	***
	(1.85)		(2.11)		(2.32)		(1.85)		(2.07)		(2.19)	
R&D	4.99	***	3.30	***	3.56	***						
	(0.91)		(0.74)		(0.77)							
Tertiary education	0.02		-0.01		0.11		0.27	*	0.15		0.27	**
	(0.13)		(0.11)		(0.15)		(0.13)		(0.10)		(0.14)	
Log FP7							1.11	***	0.55	**	0.60	**
							(0.27)		(0.22)		(0.25)	
Log Density	3.06	***	1.67	***	0.49		2.91	***	1.56	**	0.95	
	(0.73)		(0.60)		(0.83)		(0.75)		(0.62)		(0.88)	
Employment rate	1.08	***	0.59	***	0.60	***	1.02	***	0.56	***	0.60	***
	(0.14)		(0.12)		(0.17)		(0.14)		(0.13)		(0.17)	
Lag Log GDP pc					-0.73						0.16	
					(1.70)						(1.82)	
Lag Tertiary education					-0.19						-0.22	
					(0.19)						(0.17)	
Lag R&D					-0.56							
					(1.28)							
Lag Log FP7											0.09	
											(0.47)	

TABLE 3. CONT.

Growth model estimates through OLS, SAR, and SDM. Dependent variable: GDP per capita growth rate in the period 2008-2019

	Expression [2]						Expression [3]					
	OLS		SAR		SDM		OLS		SAR		SDM	
Lag Log Density					1.52						0.03	
					(1.11)						(1.16)	
Lag Employment rate					-0.11						-0.12	
					(0.24)						(0.25)	
Observations	200		200		200		200		200		200	
R2	0.63						0.60					
Global Moran I	0.31	***					0.34	***				
Rho			0.49	***	0.58	***			0.50	***	0.58	***

Note: Standard errors are reflected in parentheses. *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.
Source: Own elaboration.

TABLE 4.

Marginal effects (direct, indirect, and total) for model specification [2] and [3]. Dependent variable: Income per capita growth rate between 2008 and 2019

Expression [2]								
	Direct		Std. Err.	Indirect		Std. Err.	Total		Std. Err.
Log GDP pc	-17.71	***	2.27	-21.39	***	3.83	-39.10	***	4.39
R&D	4.06	***	0.84	5.68	**	2.84	9.74	***	3.21
Tertiary education	0.09		0.14	-0.28		0.32	-0.19		0.32
Log Density	0.83		0.80	3.91	**	1.92	4.74	**	2.01
Employment rate	0.65	***	0.15	0.51		0.37	1.16	***	0.37

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TABLE 4. CONT.

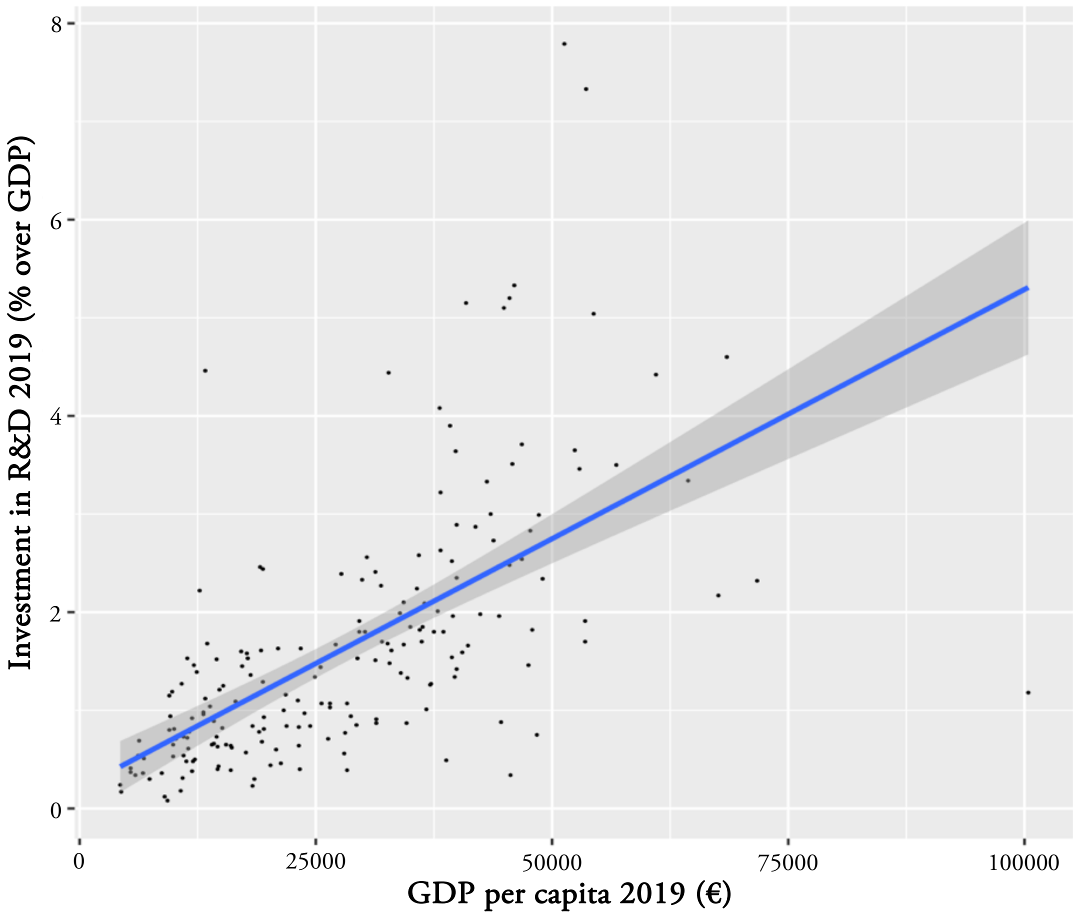
Marginal effects (direct, indirect, and total) for model specification [2] and [3]. Dependent variable: Income per capita growth rate between 2008 and 2019

Expression [3]									
	Direct		**Std. Err.**	**Indirect**		**Std. Err.**	**Total**		**Std. Err.**
Log GDP pc	-14.58	***	2.17	-16.16	***	3.75	-30.75	***	4.28
	Direct		**Std. Err.**	**Indirect**		**Std. Err.**	**Total**		**Std. Err.**
Log FP7	1.22	***	0.37	0.92		1.03	2.14	**	1.07
Tertiary education	0.32	**	0.13	-0.24		0.31	0.08		0.32
Log Density	0.87		0.89	1.25		2.09	2.12		2.19
Employment rate	0.54	***	0.17	0.58		0.42	1.13	***	0.42

Note: *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.
Source: Own elaboration.

There are some conclusions to be drawn from these results. On the one hand, although our model suggests that, on average, there has been a convergence between regions, several considerations must be made. First, although eastern or peripheral regions of Europe, those that had lower development in the initial period of analysis, experienced high GDP per capita growth rates in the period from 2008 to 2019, such as regions from Bulgaria (between 62% to 82%) and Romania (between 55% to 80%), notably, northern and central regions of Europe, specifically those in Belgium or Germany, also had very high GDP per capita growth rates of approximately 40%. This context is summarized in Figure A2.1 in Annex 2, which reflects the GPD growth rate experienced by each European region included in the analysis in the period from 2008 to 2019. Second, Figure A2.2 in Annex 2 shows income per capita in 2019 for European regions at the NUTS2 specification, revealing that there existed high income inequalities not only between countries but also within them (between regions). There is one important conclusion: We are witnessing a relative convergence in terms of per capita income in European regions. Low-income regions have had high income growth rates, but they did not manage to catch up with high-income ones because high-income areas continued growing at higher rates than expected. In this sense, most developed areas in 2008 continue to be areas with higher levels of well-being.

FIGURE 7.
Correlation between R&D expenditures (% over GDP) and GDP per capita (€) in each European region (NUTS2), 2019



Source: Own elaboration using data from Eurostat.

On the other hand, factors that are relevant for promoting economic growth in our empirical analysis are variables that at present are showing better performance in most developed regions of Europe. Higher population density, employment rates and education are also factors true of those places that benefit highly from funding. However, specifically, through Figure 7, which presents the correlation between European regions' R&D expenditures and GDP per capita, we observe that at present a positive relationship exists between the variables. In conclusion, there is a huge concentration of R&D investment effort in most developed areas as opposed to distributions of funding that would be needed for entering an absolute convergence process in income per capita. In this sense, richer regions of Europe are those that have a higher probability of continuing to grow in the future. Through these results, it can be concluded that there is a long path for closing the gaps in income between European regions, but it can be confirmed that R&D is a fundamental piece of this process.

5. Conclusions and policy recommendations

In the 1990s and early 2000s, with the full success of the institutional development and economic growth of the EU, the objective was to revitalize and boost the EU's competitiveness through ambitious science and innovation policies (the "Lisbon Strategy" or "Lisbon Agenda"). The EU's R&D spending was significantly lower than that of other high-development environments, such as the US or Japan. Thus, successive framework programmes to promote science in Europe began to increasingly mobilize more resources. The ambitious goal of reaching an R&D expense of 3% of the GDP of the EU was set. However, the great recession put a brake on the expansion of resources allocated to R&D, causing 3% of GDP to remain a permanently postponed reference target. Even in 2020, the average spending in the EU on R&D stood at 2.3%. However, even more relevant than the reduction in the growth of the quantities available for R&D has been the concentration of resources. With less rapid growth in R&D funds, there was a tendency to concentrate available resources on the most competitive projects, centres and environments capable of transforming this investment in the scientific system into results of economic value. In recent years, with the "Horizon 2020" and "Horizon Europe" framework programmes, we have witnessed a new deployment of resources into R&D, but the philosophy of scientific excellence and competitiveness for resources continues to prevail over its spatial distribution.

The objective of this work has been to review the spatial distribution of European R&D funds. We were concerned whether the competitive nature of R&D projects, as a logical result from the perspective of obtaining the best investment results, could cause a concentration of resources in countries with stronger and more dynamic economies capable of carrying out scientific and technological efforts. Consequently, we were concerned whether EU R&D policy negatively affects territorial cohesion in Europe.

It has been verified that the distribution of spending on R&D is far from homogeneous throughout European geography. In percentages of GDP, it can be seen how the economies of central and northern Europe are well above those of the south and east. These inequalities grow significantly if we descend in the spatial scale at which the analysis can be carried out. Thus, when the NUTS3-type regions are used, high intranational heterogeneity is identified. The case of Spain is quite symptomatic, with very high inequalities in R&D spending between the richest and most developed regions and reduced percentages of R&D spending in the poorest. Likewise, by applying a simple convergence model, we see that the role of R&D expenditures and R&D framework programmes are essential to regional growth but that, to the extent that it tends to concentrate in the most developed regions, R&D investment ends up having an effect contrary to that of the desired convergence of less developed regions with more developed ones.

Although some of the conclusions presented in this paper will require further analysis to accurately corroborate them, some preliminary economic policy conclusions can be drawn. First, it is worth asking to what extent it is relevant to reach a goal such as 3% of GDP in spending on R&D if it is accompanied by enormous spatial heterogeneity. This objective may be very imprecise, and it is worth considering whether it is better to increase spending on R&D in Europe as a whole, reducing the existing heterogeneity, even if this means delaying the achievement of better global averages. Second, the EU should consider how it can better integrate economic and social cohesion policy with science and innovation policy. If only scientific excellence and the profitability of investments matter in terms of concrete results, spatial inequality and social tensions between the more and less developed territories of the EU may be increased. However, it would be easy to introduce corrective spatial factors in the calls for applications so that research centres located in less developed regions would have advantages or projects that establish connections between different countries and regions would be favoured, guaranteeing the presence of more and less developed regions in the scientific consortium.

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Annexes

Annex 1

Table A1.1.
Top European countries beneficiaries of last three R&D framework programmes

FP6 funds		FP7 funds		H2020 funds	
Country	**Millions (€)**	**Country**	**Millions (€)**	**Country**	**Millions (€)**
Germany	3024.02	Germany	7248.88	Germany	10118.36
United Kingdom	2343.59	United Kingdom	7123.87	United Kingdom	7847.75
France	2169.94	France	5437.73	France	7444.62
Italy	1455.06	Italy	3722.52	Spain	6380.64
Netherlands	1103.85	Netherlands	3443.48	Italy	5699.70
Spain	941.49	Spain	3342.60	Netherlands	5381.34

Source: Own elaboration using data from Horizon Dashboard.

Table A1.2.
Top fifteen European regions (NUTS3) most benefited from H2020 funds

Ranking	Region (NUTS3)	Millions (€)	% of total H2020 funds
1	Paris	3645.32	5.92
2	Munich	2175.74	3.53
3	Madrid	1856.65	3.02
4	Barcelona	1629.09	2.65
5	Rome	1431.00	2.32

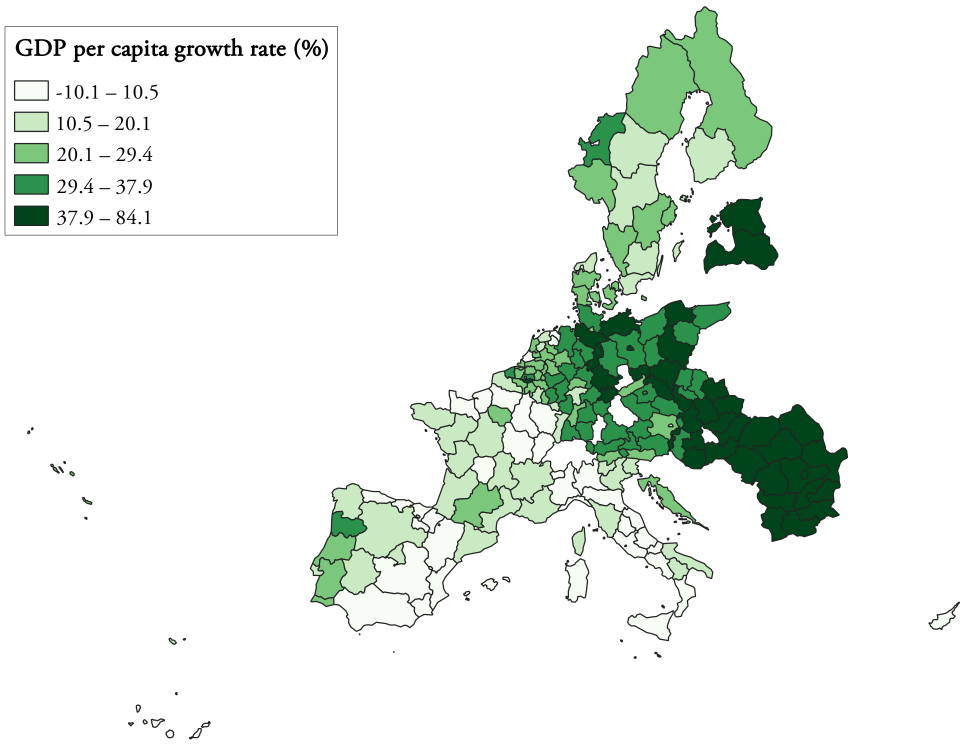
TABLE A1.2. CONT.
Top fifteen European regions (NUTS3) most benefited from H2020 funds

Ranking	Region (NUTS3)	Millions (€)	% of total H2020 funds
6	Brussels	1307.02	2.12
7	Amsterdam	1140.80	1.85
8	Wien	1003.23	1.63
9	Helsinki	987.63	1.60
10	London	847.16	1.38
11	Stuttgart	824.46	1.34
12	Stockholm	811.21	1.32
13	Milan	806.08	1.31
14	Dublin	788.36	1.28
15	Berlin	728.80	1.18
	Total	**19982.55**	**32.45**

Source: Own elaboration using data from Horizon Dashboard.

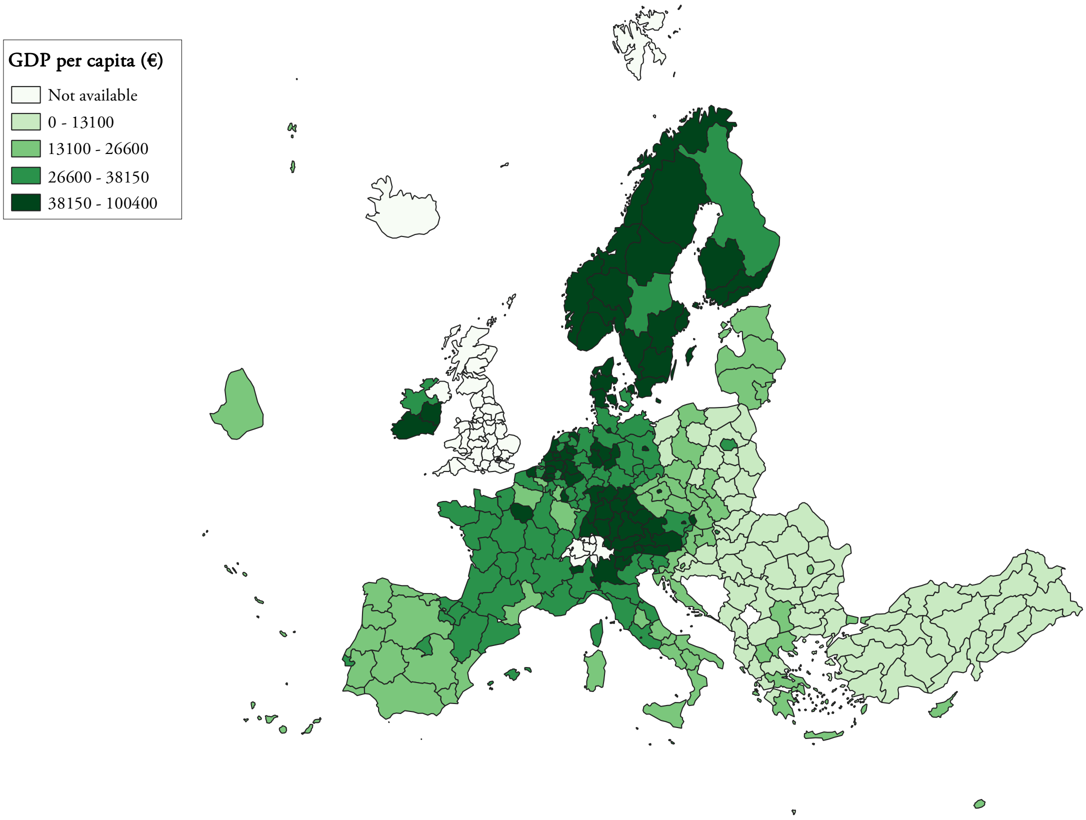
ANNEX 2

FIGURE A2.1.
GDP per capita growth rate from 2008 to 2019 in each European region (NUTS2)



Source: Own elaboration using data from Eurostat.

FIGURE A2.2.
GDP per capita in each European region (NUTS2), 2019



Source: Own elaboration using data from Eurostat.