CHAPTER 12

THE RESEARCH AND INNOVATION DIVIDE IN THE EU AND ITS ECONOMIC CONSEQUENCES

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Summary

This contribution looks at the economic consequences of the R&I divide across EU regions and highlights the policy challenge they represent. It reviews the theoretical factors behind current levels of territorial polarisation, maps the current state of this divide, and presents an econometric approach to identifying the effects.

The core of the argument is that research and development (R&D) investment alone does not trigger the same returns on investment everywhere because of several factors. These are linked to the cost of technology accessibility in different places, the distance to the technological frontier, positive externalities from larger and denser regions, the quality of local institutions, and hampered knowledge sharing.

Many of these factors disadvantage the less-developed regions in their efforts to broaden their innovation capacities with the aim of unleashing greater economic activity and growth. Nevertheless, most of the R&D growth in less-developed regions has been in the higher education sector, which has led to a substantial improvement in scientific output. The chapter discusses how to improve the efficiency of investment in R&I systems and strengthen innovation-driven economic growth.

In its conclusions, it not only diagnoses the situation but also suggests elements of innovation policy for less-developed regions. These aim to close the innovation divide between more- and less-developed areas in the EU while increasing the EU's competitiveness through a stronger role for innovation as a trigger of economic dynamism.

1. The policy challenge

One of the main aims of the European Union is to enhance the competitiveness of all European economic actors in what has become an increasingly integrated world. Given Europe's history, economic structure and social model, there is a consensus that this cannot be achieved by cutting costs and reducing workers' rights. If Europe is to keep and improve its place in the world, a different route is required. And this route needs to rely on inventiveness and creativity, rather than cheap labour. For the EU, increasing competitiveness and preserving the European social model entails moving up the technological and innovation scale (EU, 2014).

To achieve this goal, both individual European countries and the EU as a whole have put research and innovation (R&I) policy at the heart of their innovation efforts. Innovation policies in Europe – both at the national and European-wide scale – have, to a greater or lesser extent, remained anchored in the belief that more investment in research and development (R&D) leads to greater innovation and that innovation triggers economic growth. Consequently, a considerable – and, until the beginning of the crisis, growing – amount of resources has been devoted to R&D across Europe. Most of this effort has been aimed at achieving a quantitative target: securing an R&D investment of 3% of GDP, of which two thirds are expected to be accomplished by the private sector. The 3% of GDP target reflects not just a belief in the benefits of greater R&D

investment but is also a political response to the perception that the EU as a whole has been falling behind its main competitors in innovative capacity. For most of the 1990s and 2000s, investment in R&D in the EU languished at levels slightly below 2% of GDP. Japan (generally over 3%) and the US (just short of 3%) have been pulling ahead. At the same time, emerging countries, such as South Korea and, more recently, China have caught up and surpassed the EU in terms of relative R&D investment (Dosi et al., 2006; Crescenzi et al., 2007). Hence, geopolitics and the fear of being left behind has contributed to setting the 3% of GDP objective as one of the main pillars of, first, the Lisbon Strategy and, later, the Europe 2020 Strategy (Uppenberg, 2009). High hopes have been put on the economic impact of achieving such an objective: the Europe 2020 Flagship Initiative estimated the benefits of reaching an investment in R&D of 3% of GDP by 2020 at 3.7 million additional jobs and an annual GDP increase of EUR 800 billion by 2025 (EU, 2014).

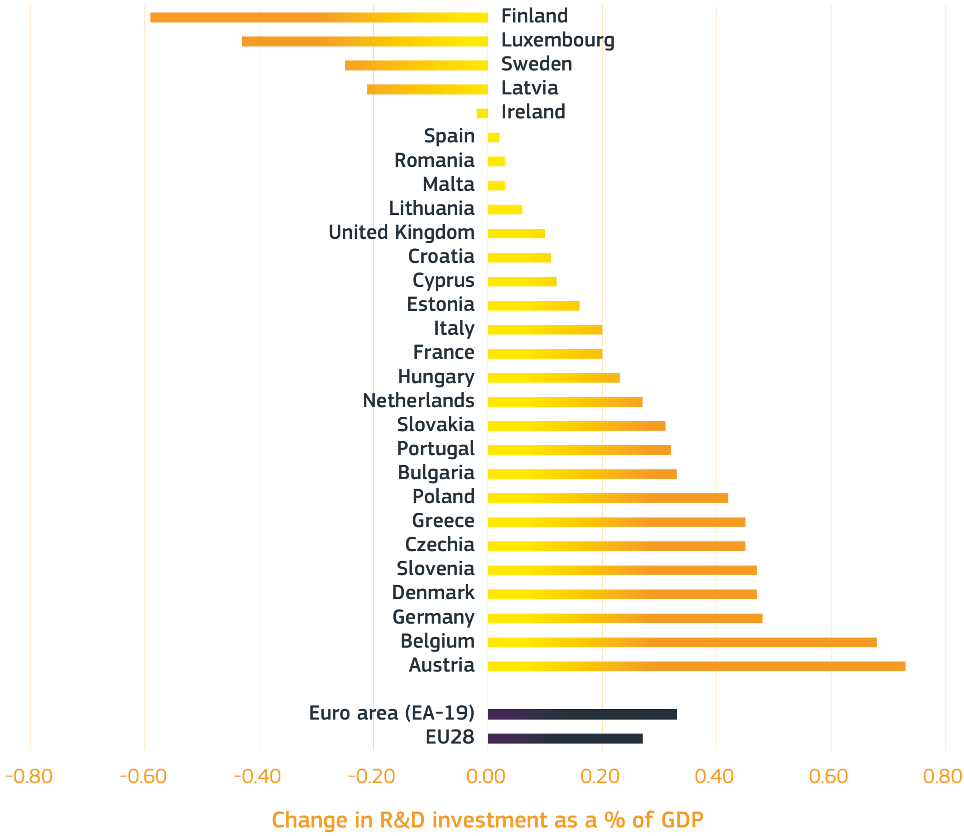
Nevertheless, the adequacy of such a quantitative target has been questioned from almost the very beginning (e.g. Kok, 2004; Van Pottelsberghe de la Potterie, 2008). The target has also proved elusive (Van Pottelsberghe de la Potterie, 2008). Europe as a whole has not only failed to come close to it but has also been incapable of keeping up with the R&D drive of its competitors – from the United States to Japan, South Korea or China (Dosi et al., 2006; Crescenzi et al., 2007, 2013). Over the last 20 years, competitor countries have either consistently invested more in R&D (e.g. Japan, South Korea and the United States) or, as in the case of China and South Korea, increased their innovation efforts to a far greater extent than the EU as a whole.

In addition, the overall pursuit of R&D and innovation at the European level has not been without victims. Investment in R&D, despite some geographical catching up, has not become much more territorially even than three decades ago. In the name of excellence, scarce public and private R&D resources have become highly concentrated, both within countries and across the EU. This is an outcome of targeting R&D towards those economic agents considered to have the greatest capacity to generate new products and processes. The problem is that the most innovative actors are geographically concentrated in specific countries and in specific cities and regions within these countries (Usai, 2011). Core countries and core urban regions host and attract a disproportionate share of innovative firms and research centres and, consequently, scientists. The shift from an 'old' to a 'new' digital economy – or from Industry 2.0 to Industry 4.0 (Schwab, 2017) – further fuels the clustering of research activities into large agglomerations and the redesign of global innovation value chains to the benefit of core areas (Brun et al., 2019). In these core and innovation-prone environments, positive externalities from the agglomeration of R&I activities arise (Audretsch and Feldman, 1996; Rodríguez-Pose, 1999). This widens the innovation divide as the dominant conviction is that – following the endogenous growth theory (Romer, 1986; Lucas, 1988) – increasing returns on investment in R&D will mainly happen in innovation-prone areas. From this perspective, if Europe is to remain innovative and competitive, the R&D effort should be concentrated in those regions where the greatest returns can be achieved.

Yet, conscious of the growing innovation divide, the EU and European countries have tried for years to prevent the scientific and knowledge gap between R&D rich and poor countries, cities and regions from growing. The public sector has deliberately channelled public R&D into universities and public research centres in some of the less-well-off areas with the aim of bringing them closer to the technological and innovation frontiers and triggering the conditions for innovation to take hold. In 2016, or the most recent year for which data are available, the public sector (universities and government research sectors) was responsible for 100% of all R&D investment in South-East Romania. It represented more than 90% of all R&D expenditure in South-West Oltenia (Romania), the Ionian Islands, the Aegean Islands, Crete, the Peloponnese, and Thessaly (Greece), the Overseas Departments (France), and the Azores (Portugal). Furthermore, the number of relatively less-developed regions where the public R&D investment exceeds 80% of the total remains huge. It includes, among others, Trier and Leipzig in Germany, most of Greece outside Athens, Extremadura, the Balearic and the Canary Islands in Spain, Corsica in France, Molise, Calabria and Sardinia in Italy, Lubelskie in Poland, or Nord-Est in Romania (DG Regio data).

The Great Recession, however, triggered a reduction in the overall amount of public expenditure in R&D, without necessarily dynamising the role of the private sector in the innovation realm in lagging-behind areas. The prolonged crisis, the hit it made on public finances and local firms, and the ensuing austerity had an immediate knock-on effect on the R&I effort. The first impact of the crisis was a decline in R&D investment in whole swathes of Europe and, although a recovery has ensued, it has been slow and territorially uneven. In 2016, R&D investment in the EU28 was marginally higher than in 2006. The R&D effort across the whole of the EU jumped from 1.76% of GDP in 2006 to 2.03% in 2016. However, some countries have yet to return to the levels of R&D intensity witnessed in pre-crisis times. This includes the two countries with the highest levels of R&D intensity before the crisis (Sweden and Finland) as well as that with the lowest relative investment, Latvia (Figure 12-1). The post-crisis recovery of R&D intensity has been almost negligible in many Member States which, in 2006, registered levels of R&D intensity at 1.2% of GDP or lower. In Latvia, Ireland, Spain, Romania, Malta, Lithuania, Croatia, Cyprus, Italy and Hungary, R&D intensity growth between 2006 and 2016 was below the EU average for the period (Figure 12-1). The highest growth in R&D intensity has occurred in countries such as Austria, Belgium, Germany and Denmark, all of which were above the EU average in 2006.

Figure 12-1 Change in R&D intensity in the EU28 by country (2006-2016)



Source: Author's elaboration using Eurostat data
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Since the crisis, the innovation-inducing effort has tended to follow, to a far greater extent than before, efficiency criteria at the expense of nurturing new innovation poles and creating the right ecosystems for innovation to thrive outside the traditional innovation hubs. With the exception of Sweden and Finland (which still ranked first and fifth, respectively, in R&D intensity in the EU28 league in 2016), a certain polarisation in the R&D effort has ensued. In spite of significant improvements in a handful of some of the less-developed EU countries – and, especially in Slovenia, Czechia, Greece, and Poland – most less-developed countries and regions lag well behind the core of Europe in terms of both capacity to invest in R&D and innovation. Today, as is the case in other parts of the world (Carlino and Kerr, 2015) the innovation divide in the EU remains far larger than the gap for most other basic economic indicators, such as GDP per capita, employment or productivity. Such an R&D gap signals that addressing inequalities in wealth, employment or productivity may be made harder by the low innovation capacity of many of Europe's less-developed areas.

This panorama derives mainly from the clash between conflicting principles at the heart of the EU. The pursuit of excellence in innovation is at odds with the objectives of delivering harmonious development and territorial cohesion (Article 174 of the Treaty). This represents an important conundrum for the EU. On the one hand, invention and innovation today increasingly demand larger, more complex projects, involving top research centres and firms and a critical mass of scientists that are mostly found in a limited number of areas (Buzard et al., 2017). Thus, greater efficiency is regularly achieved via the territorial concentration of investment. On the other hand, innovation polarisation may imply that considerable talent for innovation and ample research potential is being left untapped. It can also lead to brain and firm drain that can leave many areas of the EU increasingly vulnerable and incapable of facing competition (De Noni et al., 2018). Worse still, the lack of innovation in less-developed areas can render many of them dependent on government assistance and brewing social and economic tensions. Thus, the R&I divide may be contributing to a geography of discontent that threatens to undermine the very system on which the pursuit of excellence in innovation is based (McCann, 2019; Rodríguez-Pose, 2018).

This contribution to the Science, Research and Innovation Performance of the EU (SRIP) Report looks at the economic consequences of the R&I divide across EU regions and highlights the policy challenge this represents by considering the opportunities and risks that the concentration of the innovation effort and of innovative outcomes entail for Europe's future position in the world. First, this contribution will review the theoretical factors behind current levels of territorial polarisation in innovation. It will then present the evidence and highlight how the geographical gaps in R&D investment and in innovation affect both the production of innovation and economic growth for the EU as a whole and across its different types of regions, according to the level of development. The final section develops some policy implications and general recommendations.

2. Why does innovation tend to concentrate geographically?

A somewhat oversimplified version of the linear model of innovation (Bush, 1945; Maclaurin, 1950) assumes that innovation is a direct consequence of investment in R&D (Balconi et al., 2010). Places that invest more in R&D innovate more and, as a result, experience increases in productivity and greater economic dynamism and growth. From this point of view, the logical policy for achieving greater innovation and economic growth is increasing investment in R&D. This is precisely what the EU and most countries within it have done until recently.

However, more recent theoretical developments suggest that R&D investment alone does not trigger the same returns on investment everywhere. There are several reasons for this.

First, technology is not equally and ubiquitously accessible at similar costs. Moreover, investment in technology does not necessarily benefit from constant or decreasing returns to scale, as assumed by the neoclassical growth theory (Swan, 1956; Solow, 1957). This implies that, whereas in certain areas investment in R&D

may make a lot of sense in order to achieve innovation, in others, similar investments may yield much lower returns or simply be wasted. According to the endogenous growth theory (Romer, 1986: Lucas, 1988), investment aimed at triggering greater innovation can produce increasing returns to scale, especially in places with better endowments in basic factors, such as infrastructure (which facilitates accessibility) and labour skills. Consequently, one additional euro in locations with good physical and human capital would result in greater innovation than in areas where those endowments are far weaker.

Second, many lagging-behind areas cannot make the most of any additional investment in R&D because they are too far away from the technological frontier (Aghion and Griffith, 2008). Distance from the technological frontier reduces the capacity of territories to develop and host innovative activity as they not only lack the necessary critical mass but are also far less likely to have sufficient endowment in human capital and the adequate 'economic fabric' to transform R&D into innovation. Such often economically lagging-behind areas are regarded as less able to generate, import and absorb knowledge and, consequently, to make the leap from investment to innovation, meaning that most investment in R&D would just be money wasted (Rodríguez-Pose, 2001).

Third, larger and denser regions provide – according to the new economic geography approach (Ottaviano and Puga, 1998; Fujita, Krugman and Venables, 2001) and to urban economics (Glaeser, 2012) – the positive externalities that facilitate the interaction and networking behind the exchange of knowledge. Large and dense urban agglomerations contain the suitably skilled human capital and knowledge infrastructure and the economies of scale, specialisation and diversification that facilitate the generation and circulation of new knowledge. By having a large number of innovative actors co-located in one place, the right environment is created for the formation and diffusion of new knowledge. Most of this new knowledge is in the form of 'tacit' knowledge which is knowledge that is distributed through non-codified channels which benefit from the co-location of economic actors and the proximity to innovation that large and densely agglomerated environments afford (Feldman and Florida, 1994; Gertler, 1995). This is what Marshall (1895) described as 'something is in the air' and what Storper and Venables (2004) called the 'buzz' of the city. Smaller and less-dense cities and regions lack these favourable ecosystems, making the field of innovation an uneven one.

Furthermore, the quality of local institutions also plays an important role in defining the capacity of different places to innovate. Larger cities and metropolises tend to innovate more and not only because they benefit from considerable positive externalities. They also enjoy, as a whole, better institutional quality. As indicated by Rodríguez-Pose and Di Cataldo (2015: 693), 'knowledge production structures in lagging regions are massively affected by quality of government': the lower the quality of government, the smaller the chances to innovate. Quality of government thresholds often prevent investment in R&D in lagging-behind regions from yielding significant economic returns.

Finally, knowledge tends to be 'sticky' and travels with great difficulty (Moreno et al., 2005; Rodríguez-Pose and Crescenzi, 2008; Sonn and Storper, 2008). Thus, physical proximity becomes a fundamental driver of R&I. Agglomeration externalities and the co-location of innovative actors can result in the creation of geographically bounded networks or systems characterised by high degrees of trust, collaboration and cooperation within which knowledge may be exchanged and shared. Physical agglomeration is considered to be at the root of frequent and repeated transfers of information and knowledge, enabling the emergence of new ideas and their rapid transformation into economically viable activities (Duranton and Puga, 2001; Storper and Venables, 2004). This knowledge transfer takes place in both a codified and tacit way (Storper and Venables, 2004; Leamer and Storper, 2014), facilitated by the frequent face-to-face interactions that the high density of innovative actors in core areas affords (McCann, 2007). The key role played by physical proximity can, therefore, justify an increasing concentration of the R&I effort in core areas.

Wrapping up, it has often been argued that large and densely populated core areas provide the most adequate ecosystems for new knowledge to come to fruition and for innovation to take hold (Duranton and Puga, 2001; Puga, 2010). They have a considerable advantage in R&I endowments vis-à-vis less-developed regions, as they concentrate both the largest knowledge infrastructure, ranging from public research centres, laboratories and universities to firms with the greatest capacity to invest in and conduct R&I activities. These facilities, in turn, generate and attract large numbers of researchers and skilled individuals.

In contrast, there is a dearth of innovative resources in less-developed areas which, in addition to their distance to the technological frontier (Aghion and Griffith, 2008), can represent an insuperable barrier for the creation of new knowledge, its circulation, and its transformation into viable and sustainable economic activity. As a consequence, smaller and/or less-developed cities and regions are generally perceived to be less capable of hosting innovative activity.

To summarise, in the pursuit of R&I excellence and maximisation of the returns of R&D and innovation investment, core areas are not only generally thought to be in a better position to attract more resources because of the sheer concentration of innovative actors, but they are also perceived as more likely to offer considerably higher returns than when investment takes place in peripheral areas.

3. The innovation input and output divide in the EU

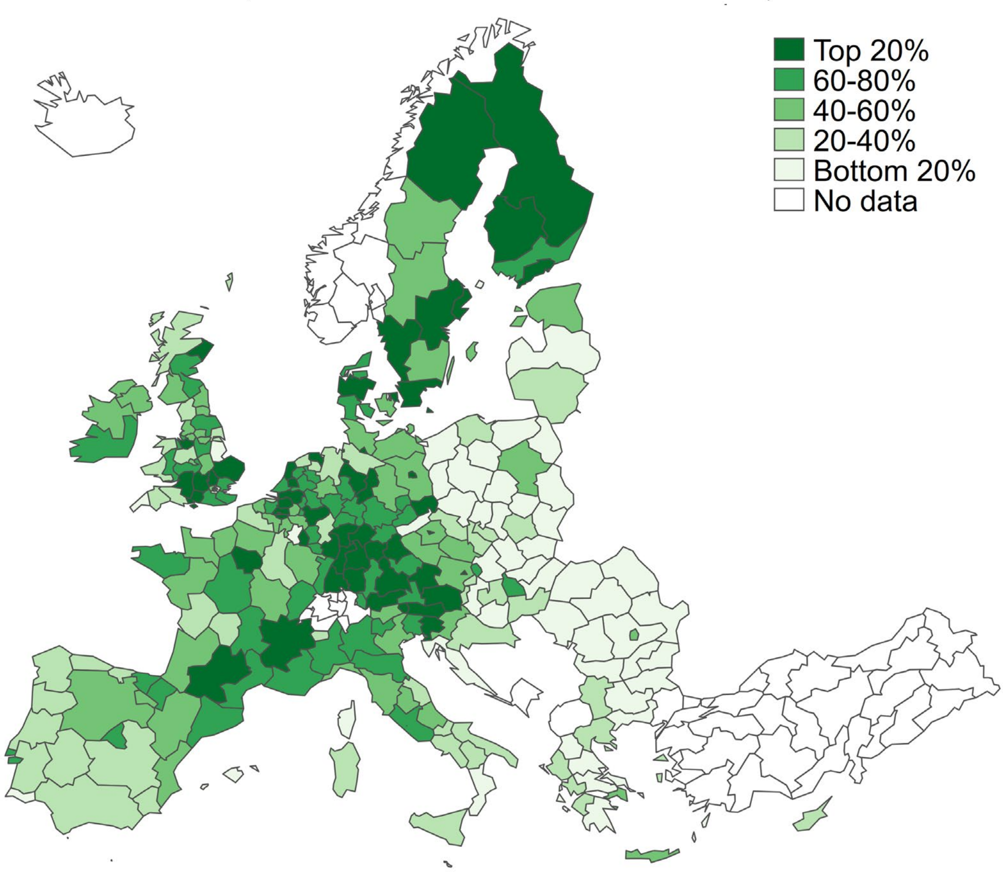
To what extent has Europe followed the dominant trend? Are innovation inputs geographically concentrated in order to potentially deliver higher economic returns? Figure 12-2 portrays the geographical distribution of total R&D investment (in 2005, euros) for the NUTS 2 regions of the EU28 during the period 2000 to 2016. The different levels of expenditure by region are expressed in quintiles.

Three groups of regions can be distinguished among the top spenders on R&D. As expected from the theory, the first group comprises some of the largest agglomerations in the EU. Inner London, Paris, Madrid, the Randstad, Berlin, Copenhagen, Stockholm and Helsinki belong to this category. Agglomerations of innovative firms, skilled individuals and public research centres and leading universities are behind the high levels of R&D expenditure in these regions. The second group follows the so-called 'Blue Banana': a set of regions stretching from the northern Alps in Austria and Germany, along the Rhine Valley into the southern and western

Netherlands and northern Belgium, to the south of England. This is the traditional industrial and economic motor of the EU. The third set of regions has its centre in the Nordic countries – involving the whole of Finland, numerous regions in Sweden and, to a lesser extent, Denmark. These regions have the greatest degree of R&D expenditure in the EU (Figure 12-2).

At the opposite end of the spectrum, very limited R&D investment took place in that same period in many central and eastern European countries outside the national capitals and largest agglomerations. That was the case for Bulgaria, Romania and Slovakia and, with limited exceptions, Hungary and Poland. In 2016, Latvia had the lowest R&D investment intensity in Europe, with just 0.44% of GDP.

Figure 12-2 Total intramural R&D expenditure in PPS per inhabitant, average 2000-2016 (EUR)



Source: Author's elaboration using Eurostat data
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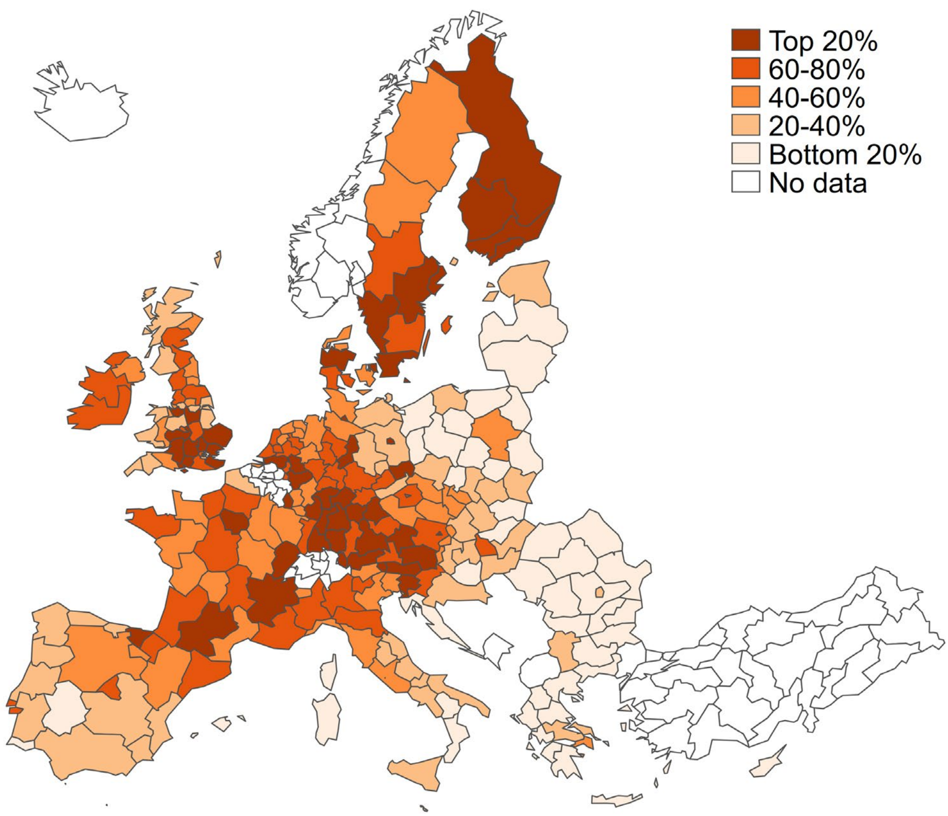
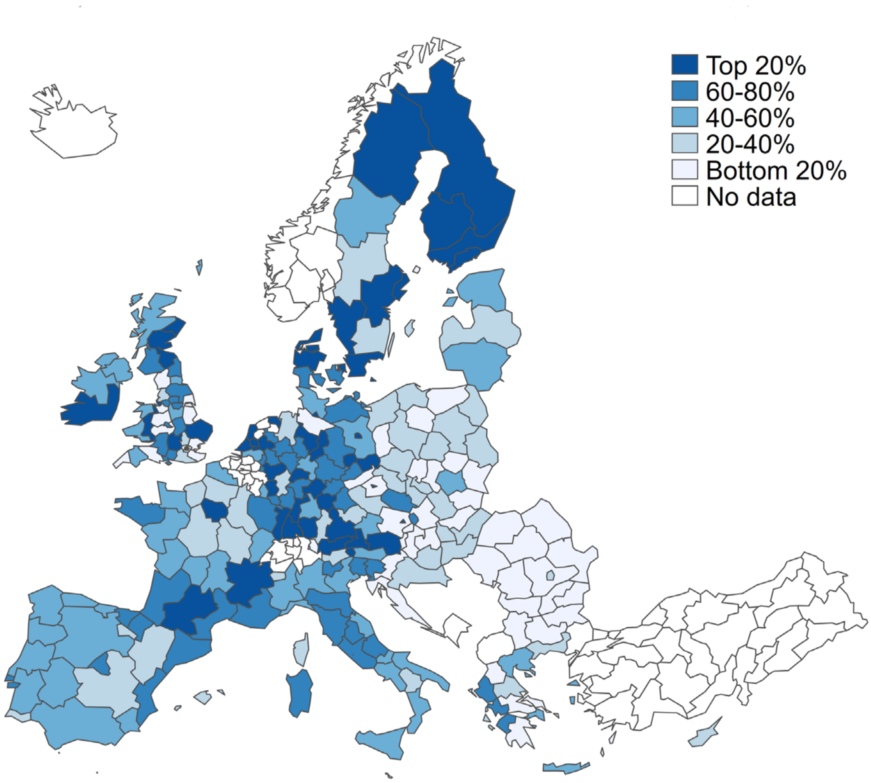
Are there differences in this distribution between the R&D effort in the private and the public sectors? Figure 12-3 maps this difference by focusing on R&D investment by region in the business sector and in higher education. The map for the business sector follows closely that of total R&D expenditure, as business-sector expenditure represents roughly two thirds of all R&D efforts in the EU. The three types of regions identified in Figure 12-2 are still very much in evidence: large metropolises, Blue Banana, and Nordic regions.

The panorama is somewhat different when considering the higher education sector. While the big spending regions still coincide with those with the greatest agglomeration, and most eastern European regions remain at the bottom of the investment ladder, this is not so likely to be the case in many southern European regions. Investment in higher education in a number of southern French regions, most regions in Spain and Portugal, areas of central and southern Italy, or Western Slovenia is higher than their overall level of R&D investment might suggest. In many of these cases – as in Andalusia and Extremadura in Spain, Centro and Alentejo in Portugal, or Campania and Puglia in Italy – the government and higher education sectors compensate for the absence of a private sector capable of pursuing R&D activities.

Figure 12-3 Total intramural R&D expenditure in PPS per inhabitant, average 2000-2016, in the business (first map) and the higher education (second map) sectors (in euros)





Source: Author's elaboration using Eurostat data
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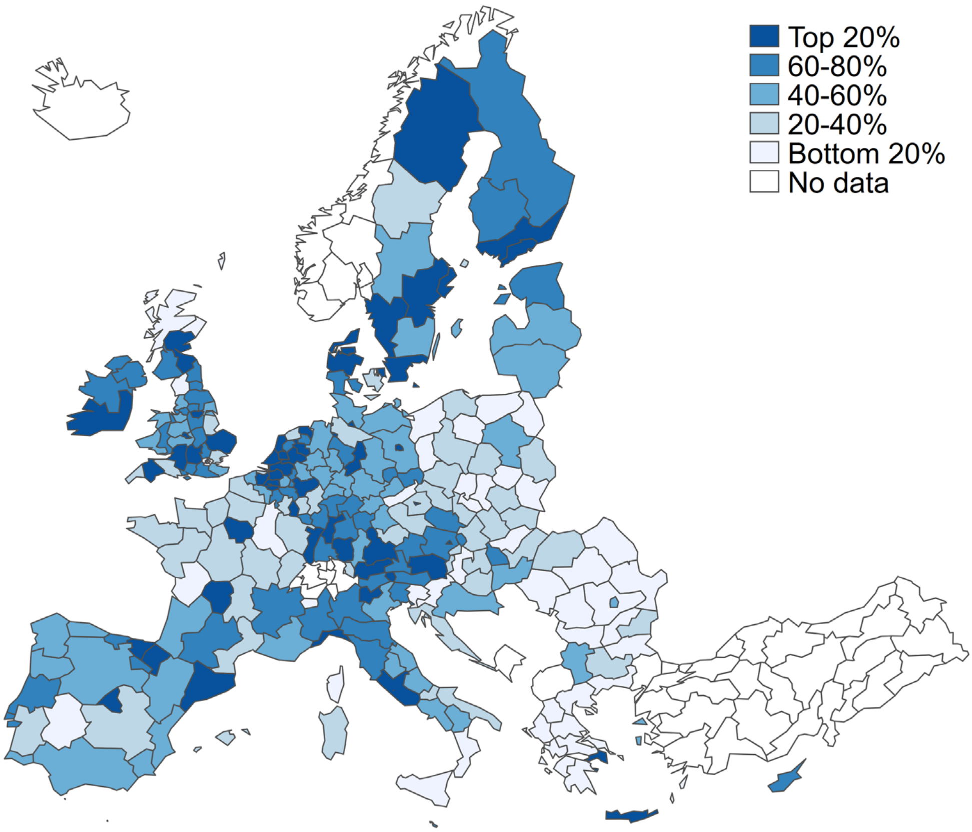
The concentration of innovation-leading inputs is not limited to R&D. The EU has set up a number of flagship research programmes whose main aim is the pursuit of excellence in research. This implies funding the best proposals by the best researchers and the best research teams, regardless of location. As research capabilities are unevenly distributed across the geography of the EU, the territorial allocation of research funding under these programmes is equally uneven. Figure 12-4 presents the distribution of EU research funding within the Seventh Framework Programme (FP7) (2007-2013).

Figure 12-4 Seventh Framework Programme (2007-2013) expenditure per head



Science, research and innovation performance of the EU 2020

Source: Author's elaboration based on DG Research and Innovation, Corda data

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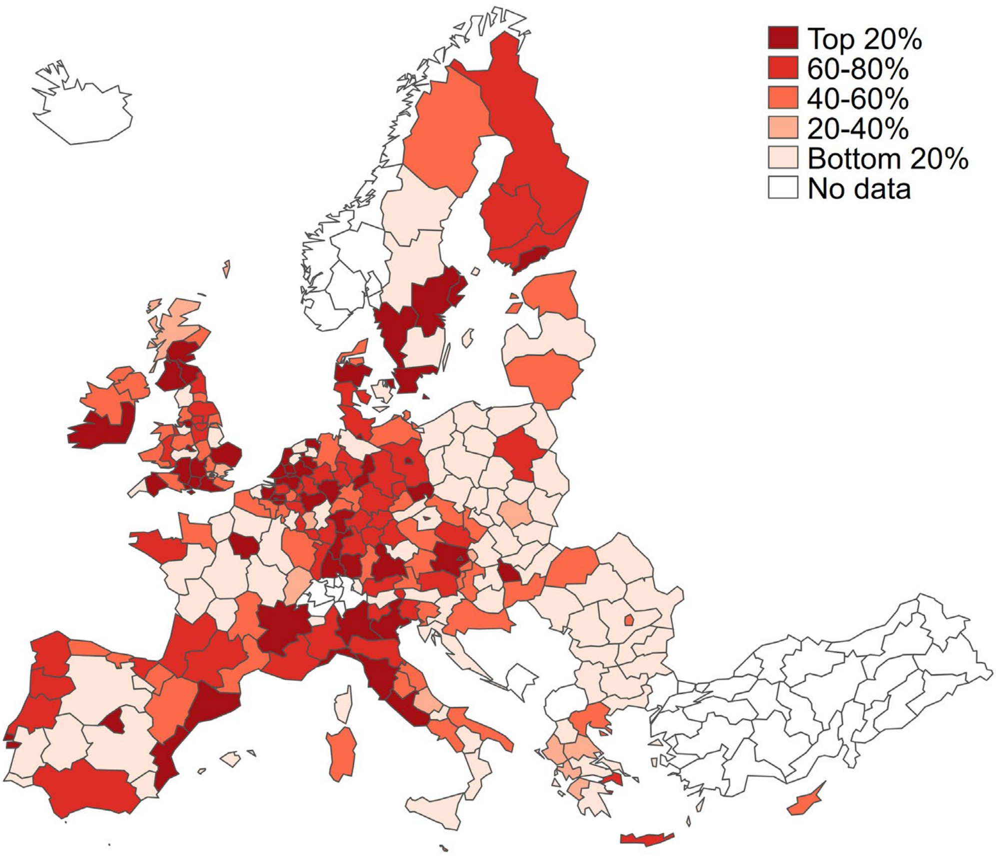
Although there is less concentration of FP7 research funding than when considering overall R&D expenditure, the top areas attracting European research funds follow relatively familiar patterns. Capital cities and large agglomerations (with the exception of London), regions around the Alps and along the Rhine (e.g. Upper Bavaria, Karlsruhe, Alsace, Cologne, Antwerp), and a number of Nordic regions attract the bulk of the funding. Despite some exceptions in central and eastern Europe, such as Athens, Bratislava, Crete, Estonia and Prague, the lowest share of funding per capita is found when moving eastwards. Most of Romania, the whole of Greece outside Athens and Crete, and 9 out of 17 regions in Poland are in the bottom 20% in terms of FP7 expenditure per capita.

This pattern is reproduced when only considering the resources disbursed by the European Research Council (ERC) during the period 2014-2018 (Figure 12-5). With some exceptions (Athens, Crete, Estonia, Limousin), the regions in the top 20% expenditure category reproduced what has already been highlighted for R&D and the overall FP7 expenditure. Core regions or large urban agglomerations, strongly endowed with human capital, research facilities, and some of

Figure 12-5 European Research Council payments per capita per region (2014-2018)



Source: Author's elaboration based on DG Research and Innovation, Corda data
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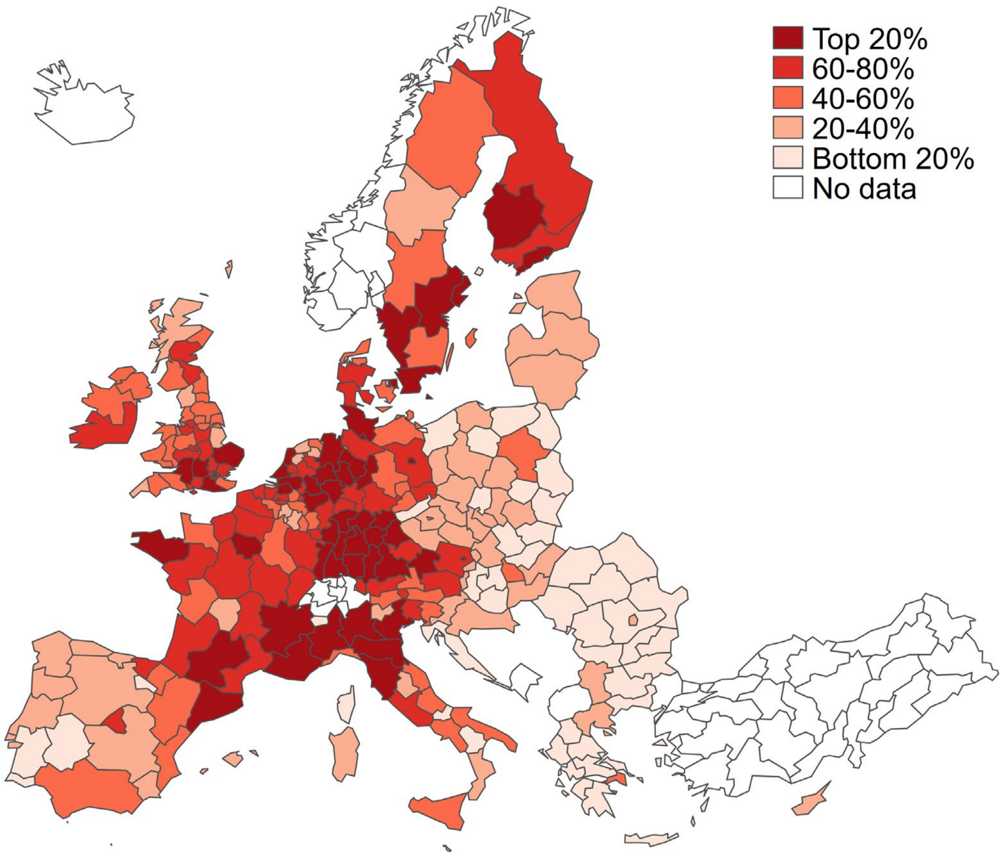
the best universities in Europe are the greatest beneficiaries of this European-wide scheme.

The regional differences in innovation inputs are reproduced to a considerable extent in terms of innovation outputs. When mapping the only innovation output that is available over a considerable period of time for the whole of the EU at a regional level – patent applications[1] – a very uneven geography of innovation emerges.

1 Patent applications are, however, a highly imperfect measure of innovation outputs. Patents tend to reflect more invention and radical product innovation than process, organisational, marketing or incremental product innovation. They also boost the innovative capacity of areas specialising in manufacturing, relative to those whose economic structure is more reliant on services. And, within manufacturing, they favour those areas specialising in sectors such as chemicals or pharmaceuticals that routinely rely on patenting as a way of appropriating the returns on their innovation.

Figure 12-6 Patent applications to the European Patent Office (EPO), per million of active population (2000-2012)



Source: Author's elaboration based on Eurostat data
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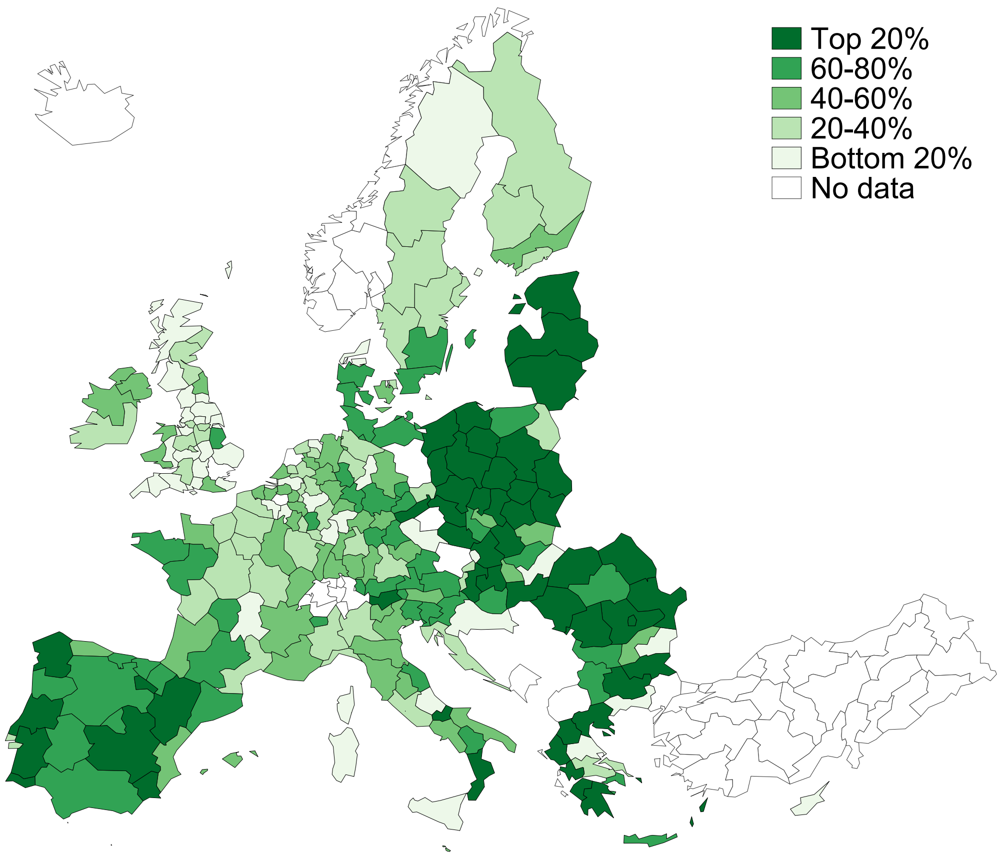
There are some minor differences between the geographical distribution of the groups of regions in terms of patenting and that derived from the innovation input maps. Both Germany and the north of Italy, the two areas in the EU with the largest manufacturing sectors, score well. The top 20% of patenting regions are populated by southern German and northern Italian regions. Most capital cities in the EU's economic core, from Paris to London, Stockholm, Helsinki and Copenhagen, to Amsterdam, Berlin and Vienna are also over-represented in the top category. However, the former Iron Curtain is still very much in evidence. With very few exceptions (Budapest, Warsaw), regions in central and eastern Europe cluster in the bottom 40% of EU regions in terms of patenting. From Estonia to Crete, from western Slovenia to north-east Romania, patent applications have remained well below those found in most western European regions. Only some regions in the Italian Mezzogiorno and the least-developed areas of the Iberian Peninsula have comparable low levels of patent applications to those found in most central and eastern European regions.

However, the patenting divide across EU regions has been gradually declining since the turn of the century. Regions in the Baltics, the Visegrád countries, Romania, Bulgaria, Greece, southern Italy and the Iberian Peninsula have been catching up, albeit starting from very low levels in some cases, compared to the core of the EU. Outside this group, only the Italian region of Alto Adige is in the top 20% of catching-up regions. In contrast, some of the lowest growth in patenting took place in regions in the United Kingdom, Wallonia in Belgium, Brunswick, Cologne, Darmstadt and Rhine-Hesse-Palatinate in Germany, or North Brabant in the Netherlands. However, not all regions in areas lagging-behind in innovation have caught up. Abruzzo, Sardinia and Sicily in Italy, Eastern Macedonia and Thrace and Thessaly in Greece, North-eastern Bulgaria, the Northern Great Plain in Hungary, the South-west of Czechia and Continental Croatia were stuck in the bottom category of patent application growth, which means these regions achieved much lower innovation progress than the EU average.

Figure 12-7 Patent application growth (2000-2012)



Source: Author's elaboration based on Eurostat data
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4. The R&D divide, innovation and economic performance

What are the consequences of the R&D and innovation divide for innovation and economic growth, respectively, in Europe? Does the innovation divide in the EU affect its overall economic prospects? Are the regions at the bottom of the innovation scale particularly disadvantaged? This section of the paper focuses on these questions. Following the basic logic of the linear model of innovation, which has articulated the majority of innovation policies in Europe to date, the first question concerns the extent to which regional differences in innovation efforts affect innovation across EU regions. This is then followed by an analysis of how regional differences in innovation capacity in the EU impinge on economic growth. Two econometric models reflecting these two stages are proposed. The model for innovation adopts the following form:

$$Ln\ Pat_{i,t} = \alpha + \beta_1 GDPpc_{i,t-1} + \beta_2 R\&D_{i,t-1} + \delta_1 X_{i,t-1} + \varepsilon_{i,t}$$

and

$\varepsilon_{i,t} = v_t + v_e$

where:

Pat depicts patent applications in region i per million active population;

GDPpc is the gross domestic product (GDP) per capita;

R&D represents total R&D investment in euros per person in region i during period t. Particular attention is devoted to the R&D effort in the less-developed regions, both in central and eastern Europe as well as southern Europe;

X is a vector of the key factors which – according to the endogenous growth, new economic geography, and urban economics theories – should affect innovation. These include the region's total population, representing agglomeration externalities; the population density; and the share of the adult population (25-64 years) with tertiary education; plus the overall government quality index at a regional level, as measured by the Quality of Government Institute at the University of Gothenburg (Charron et al., 2014). This latter variable is also interacted with the share of R&D investment, as local government quality may affect the returns on R&D policy;

v_t, v_e v_t capture time fixed effects; and v_e the error term;

i,t depict region and time, respectively. Depending on the regression, t can cover either 1991-2012 – for regression (1) with no controls, or 2000-2012, as the human capital control has only been available since 2000.

For the second stage of the linear model, assessing the connection between innovation and economic growth, the regression adopts the following form:

$$Ln\ GDP_{i,t} = \alpha + \beta_1 PAT_{i,t-1} + \delta_1 X_{i,t-1} + \varepsilon_{i,t}$$

and

$\varepsilon_{i,t} = v_t + v_e$

where:

GDP represents GDP per capita in a given EU region;

Pat depicts the change in patent applications per million active population;

X is a vector of the key factors which, according to the main theories of economic growth, are bound to shape regional growth. These include the four controls considered in equation (1), as well as the interaction term involving regional quality of government and R&D investment;

v_t, v_e v_t capture time fixed effects; and v_e the error term.

The econometric analysis is conducted using a static panel data estimation with fixed effects (FE), including interaction effects to explore potential differences in the association of the R&D and patenting variables on innovation outputs and economic growth, respectively, in less-developed regions, in general, and in the less-developed regions in central and eastern Europe and southern Europe, in particular. The use of panel data analysis with FE requires the use of levels in both depending variables to assess change in patenting and economic growth. The standard errors are clustered in order to control for arbitrary heterogeneity and autocorrelation.

The results for the innovation equation [Model (1)] are presented in Figure 12-8.

Figure 12-8 From regional R&D investment to patenting in the EU

Dep. variable: change in regional patent applications	1991-2012 (1) FE	2000-2012 (2) FE	(3) FE	(4) FE	(5) FE
GDP per capita (ln)	-25.3613 (15.966)	-11.1401 (11.849)	-32.9371 (25.121)	-25.0009 (24.257)	-26.2811 (23.392)
Investment in R&D	2.03058*** (0.202)	1.97186*** (0.213)	2.59703*** (0.398)	2.61802*** (0.402)	2.61378*** (0.405)
Less-developed regions				-0.9484*** (0.253)	
Less-developed regions (eastern Europe)					-0.8133* (0.479)
Less-developed regions (southern Europe)					-0.8133* (0.479)
Population			-0.00002 (0.000)	-0.00002 (0.000)	-0.00002 (0.000)
Population density			0.06164*** (0.017)	0.06106*** (0.017)	0.06144*** (0.017)
Share of adults with higher education			2.03352** (0.876)	2.21038** (0.880)	2.15108** (0.895)
Government quality			28.0973* (15.051)	27.0416* (14.996)	27.9861* (15.022)
Interaction R&D inv.*government quality			-0.59242* (0.306)	-0.59752* (0.308)	-0.60771* (0.312)
Observations	4227	3345	3022	3022	3022
Number of regions	273	273	253	253	253
R^2	0.617	0.648	0.666	0.670	0.667
Adjusted R^2	0.615	0.646	0.664	0.668	0.664
F test	14.54	18.14	19.05	19.33	19.38

Science, research and innovation performance of the EU 2020

Source: Author's own calculations

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/partii/chapter12/figure_12-8.xlsx

The results highlight that innovation – proxied by patent applications to the EPO per million of active population – in the EU regions is fundamentally linked to four factors: investment in R&D, population density, a higher share of population with tertiary education, and government quality (Figure 12-8, equation 3). Regions in the EU that have invested the most in R&D have, by and large, managed to transform said investment into patents. This is valid for analyses covering both the period starting in 1991 (equation 1) and that since 2000 (equation 2). However, the transformation of R&D into innovation has been far more problematic in the less-developed regions of the EU[2]. In the latter regions, the returns in terms of patenting of additional investment in R&D were far lower than in more-developed areas (see also Sterlacchini, 2008). And the greater difficulty to transform the science and technology effort into innovation affected less-developed regions in central and eastern and in southern Europe in a similar way (Figure 12-8, equation 5). Investment in R&D in these regions yielded lower innovation returns.

Education also emerges as an important driver of innovation. Regions with greater educational endowment – proxied by the share of the adult population with higher education – innovated more that those with weaker human capital (Rodríguez-Pose and Crescenzi, 2008; Marrocu et al., 2013; Faggian et al., 2017). Density – generally considered to be a fundamental factor in the transfer of knowledge (Duranton and Puga, 2001; Storper and Venables, 2004; Glaeser, 2012) – also played an important role in the generation of patents, relative to the contribution of sheer agglomeration (Figure 12-8, equations 4 and 5).

Finally, government quality has a profound association with innovation, which is both direct and indirect. Directly, poor quality government discourages innovation (Rodríguez-Pose and Ketterer, 2019). Indirectly, marginal improvements in R&D yield higher returns in terms of innovation in regions with better government quality. In addition, the benefits from increases in the R&D effort linked to more efficient government institutions accrue, to a greater extent, to regions with initially poor government quality on the periphery of Europe than to regions in the core that already enjoy far better government institutions (Rodríguez-Pose and Di Cataldo, 2015).

However, the transition from innovation into greater economic activity and growth in the EU has been less evident. Figure 12-9 presents the results of estimating the growth model, using an FE approach [Model (2)]. The coefficients for patent applications show the link between patenting over the last three decades and regional economic growth in the EU. These coefficients indicate that there has been no evidence of a link between patenting and regional economic performance in the EU since the early 1990s (Figure 12-9, equations 1 to 3). Regions that have patented the most have not grown faster. In contrast, the endowment of human capital and the institutional quality at a regional level are strongly and significantly connected to regional economic growth. Regions with the best human capital and government institutions have grown considerably more rapidly than those with greater shortages in these two domains. Both agglomeration and density are negatively connected with economic growth (Figure 12-9, equation 3).

2 Defined here as all those regions that qualified as less developed (Objective 1) during the programming period 2000-2006.

Figure 12-9 From patenting to economic growth in the EU

Dep. variable: change in GDP per head	**1991-2012**	**2000-2012**			
	(1) FE	**(2) FE**	**(3) FE**	**(4) FE**	**(5) FE**
Patent applications	0.00004 (0.000)	0.00006 (0.000)	0.00017 (0.000)	0.00015 (0.000)	0.00002 (0.000)
Less-developed regions				0.00094*** (0.000)	
Less-developed regions (eastern Europe)					0.01026*** (0.002)
Less-developed regions (southern Europe)					0.00011 (0.001)
Population			-0.0000*** (0.000)	-0.0000*** (0.000)	-0.0000*** (0.000)
Population density			-0.0001*** (0.000)	-0.0001*** (0.000)	-0.0001*** (0.000)
Share of adults with higher education			0.00338** (0.002)	0.00318** (0.002)	0.00242* (0.001)
Government quality			0.07304*** (0.025)	0.07351*** (0.025)	0.06641*** (0.023)
Interaction R&D inv.*government quality			-0.00017 (0.000)	-0.00016 (0.000)	-0.00004 (0.000)
Observations	4 227	3 345	3 022	3 022	3 022
Number of regions	273	273	253	253	253
R^2	0.612	0.434	0.511	0.519	0.553
Adjusted R^2	0.610	0.432	0.508	0.512	0.550
F test	82.80	103.3	77.74	76.15	66.99

Science, research and innovation performance of the EU 2020

Source: Author's own calculations

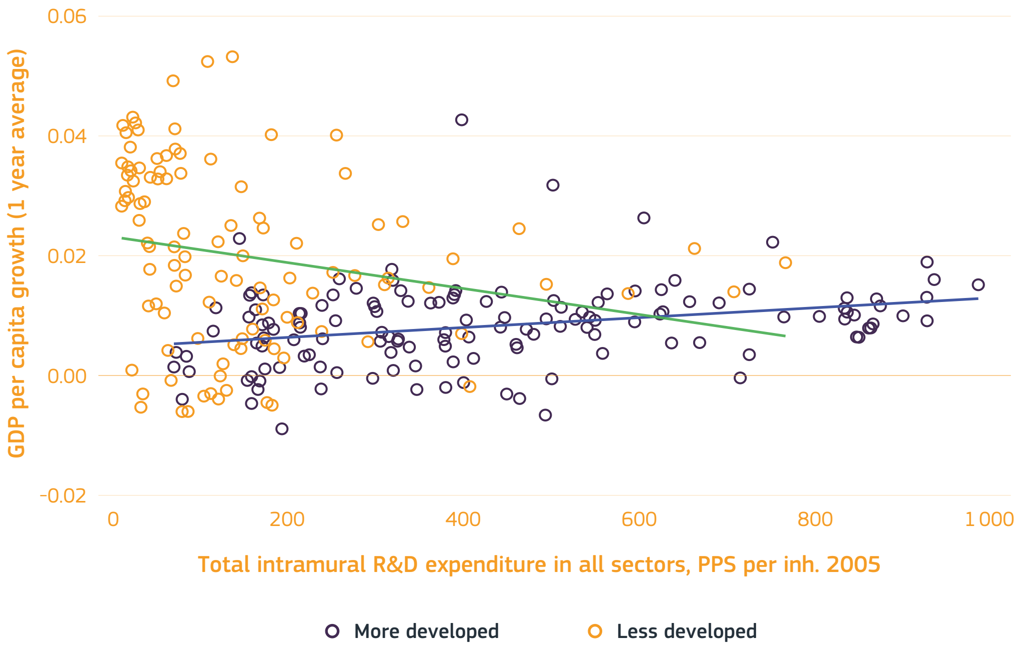
Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/partii/chapter12/figure_12-9.xlsx

As indicated in Figure 12-8, although less-developed regions have had greater difficulties in transforming R&D into innovation, innovation outputs in these areas seem to be more connected to economic growth than in more-developed EU regions (Figure 12-9, equation 4). This process, however, is entirely driven by the less-developed regions of central and eastern Europe, whereas those in southern Europe suffer from the same problems of converting innovation into economic growth as the average European region (Figure 12.9, equation 5),

Overall, across the EU regions, there is a positive connection between R&D activities and innovation, measured by patenting. However, translating innovation into economic growth is far less forthcoming (e.g. Bilbao-Osorio and Rodríguez-Pose, 2004). Likewise, Europe's less-developed regions are less capable of generating innovation from R&D inputs which, in turn, may curtail their capacity to grow in the medium to long term. Hence, the basic tenet of the linear model of innovation – that R&D investment leads to greater innovation and, in turn, innovation leads to growth – is challenged in the EU, in particular across most of its less-developed regions. This evidence is graphically represented in Figure 12-10 which traces the transition from R&D investment in 2000 (measured in constant (2005) euros per capita) and regional economic growth between 2000 and 2012.

Figure 12-10 From investment in R&D to economic growth in both less- and more-developed regions

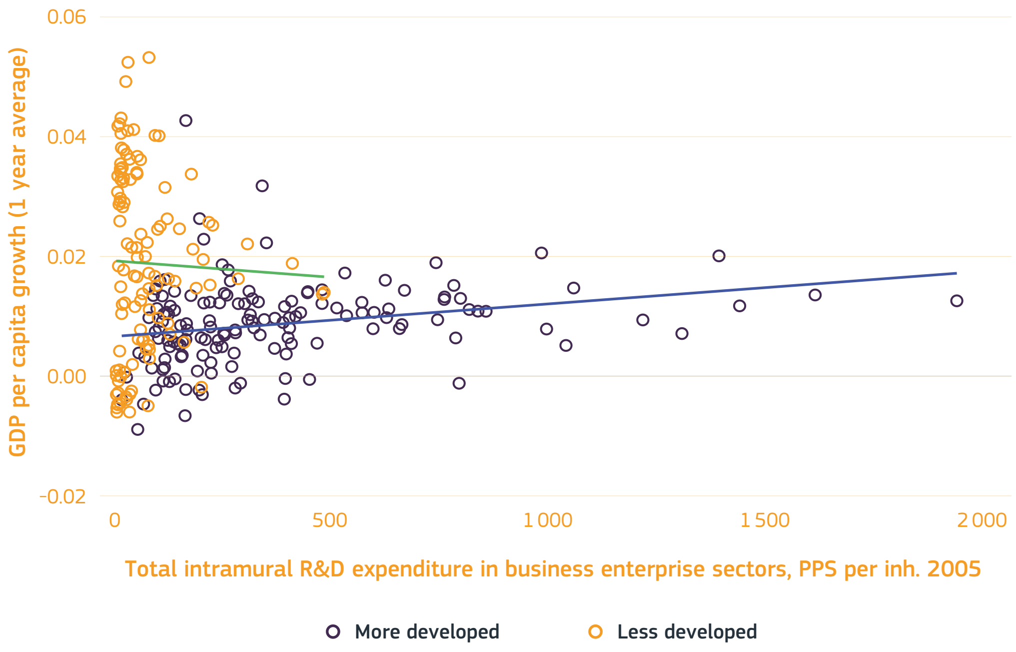


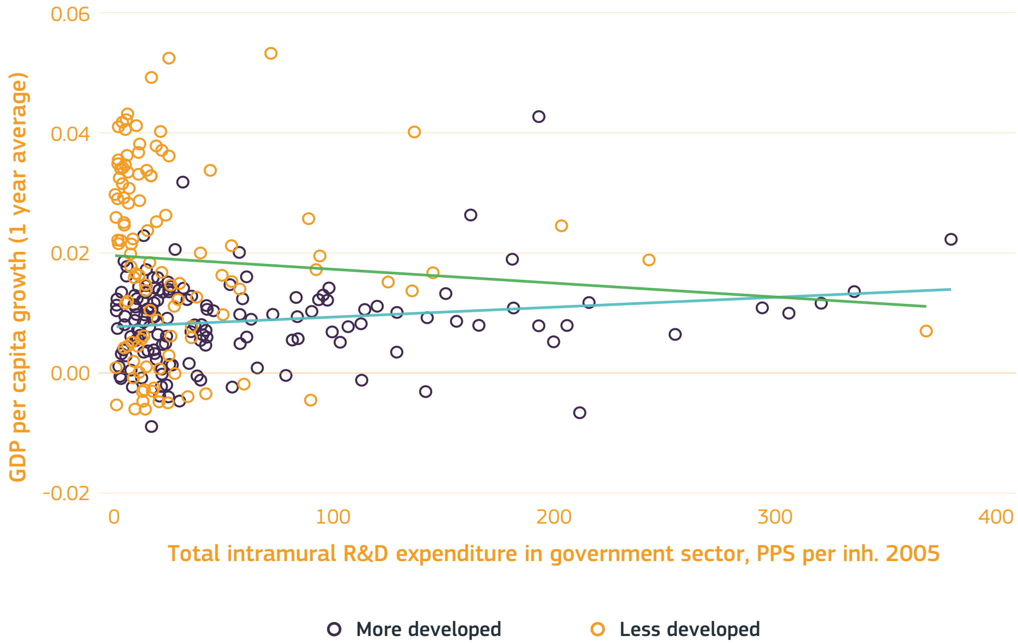
Source: Author's own elaboration
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/partii/chapter12/figure_12-10.xlsx

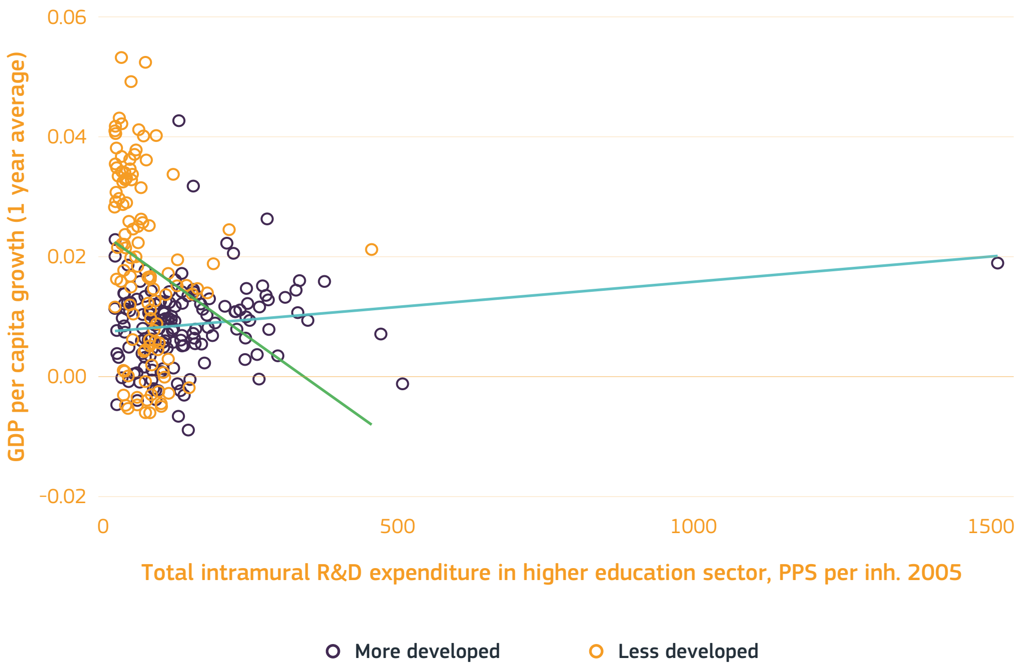
As indicated in the econometric analysis, more investment in R&D has resulted in virtually no additional growth. There is, however, an important difference between the connection between R&D and economic growth in both more- and less-developed regions. In more-developed regions, the regression line between R&D expenditure and economic growth has a slightly positive slope. Regions in the core of Europe with a higher initial level of investment in R&D have achieved a marginally greater degree of economic growth. However, this is not the case in the less-developed regions. A negative regression line reinforces the idea that, in many of these areas, the effort to generate greater innovation has not delivered on the final objective of unleashing greater economic activity and growth.

To what extent is this a consequence of the different types of R&D investment being carried out in both less- and more-developed parts of the EU? Figure 12-11 looks at the connection between R&D investment in the three main sectors – business, government and higher education and economic growth – during the period of analysis.

Figure 12-11 From investment in R&D to economic growth in less- and more-developed regions, by sector of R&D investment







Source: Author's elaboration based on Eurostat data
Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/partii/chapter12/figure_12-11.xlsx

While in more developed regions, R&D investment in the business, government, and higher education sector is connected to slightly higher growth, this is far from being the case for less developed regions. All the regression slopes are negative for the less developed category, meaning that the lagging-behind regions that invested the most in R&D have encountered considerable difficulties in transforming this type of innovation input into economic growth. The greatest mismatch concerns the higher education sector. As many less-developed regions lack the advanced business fabric capable of churning out new knowledge generation activities (Rodríguez-Pose, 2001), universities and higher education institutions have acted as substitutes. Indeed, the majority of the growth in R&D investment in the less-developed regions of the EU has taken place in the higher education sector. This additional investment has contributed to an increase in the scientific output in these regions. Both central and eastern Europe and southern Europe have considerably narrowed the gap in scholarly publications relative to the scientific leaders in Europe. Whereas the countries in central and eastern Europe produced only 16% of the articles of the three European scientific leaders (the UK, Germany and France) in 2000, this share had risen to almost 27% by 2018 (Figure 12-12). A similar improvement in scientific output was witnessed across southern Europe, where the shift was from 34% in 2000 to 52% in 2018 (Figure 12-12). But, as highlighted by Figure 12-11, this considerable leap forward in scientific publications has not resulted in substantial improvements in economic outcomes. Most regions at the economic fringes of the EU have little to show for the increased R&D effort conducted mainly before the crisis.

Figure 12-12 Scientific production in central and eastern and southern Europe relative to the scientific leaders in Europe (%) (2000-2018)

	2000	2010	2018
Scientific leaders[1]	100	100.	100
Central and eastern Europe[2]	16.29	22.57	26.76
Southern Europe[3]	33.87	45.37	51.89

Science, research and innovation performance of the EU 2020

Source: Author's own calculations

Notes: Documents published in journals indexed in the Scimago country rankings. (1)United Kingdom, Germany, France. (2)Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia. (3)Cyprus, Greece, Italy, Malta, Portugal, Spain.

Stat. link: https://ec.europa.eu/info/sites/info/files/srip/2020/partii/chapter12/figure_12-12.xlsx

Three key factors may explain this mismatch. First and foremost, a large share of the universities in less-developed regions are far from being knowledge-generation leaders, which means it is often difficult for them to make the most of R&D investment. Second, those university departments in less-developed regions that do manage to produce frontier research often find that they have no viable business partners in the local economy. The structural composition of the economies in these lagging-behind regions is key to this. The lack of a critical mass of innovative firms in most eastern and southern European regions represents a fundamental barrier for the development of networks between universities and public research centres, on the one hand, and firms, on the other. Consequently, new knowledge being generated in these areas does either not percolate locally or, in the worst-case scenario, is lost from an economic point of view. Therefore, the most successful research centres and departments in the EU's less-developed regions are pushed to reach out to business partners in distant locations. Finally, a large share of the research conducted by universities is basic in nature which – although fundamental in leading to innovation further down the road – has less immediate direct impact than the more applied research generally performed by the business sector. Weaker universities and business fabrics in the economic periphery of Europe thus prevent higher education institutions from fulfilling the same role as catalysts of innovation and economic growth as they accomplish, for example, in North America (Rodríguez-Pose and Wilkie, 2019).

Hence, a very modest transformation of R&D into innovation and economic activity in the EU's less-developed regions contributes to what has been called the 'European innovation paradox': the lower capacity of the EU as a whole, relative to, most notably, the United States but also to the Asian Tigers, to convert innovation inputs into greater economic dynamism (Dosi et al., 2006; Argyropoulou et al., 2019). This is possibly because too much attention – especially in the less-developed regions of the EU – has been put on the 'supply-side' of innovation (knowledge generation) at the expense of the capacities of different territories to absorb knowledge and innovation. Similarly, the focus has been on the R (research-side) of R&D rather than on the D (development-side). While more investment in research and the development of the physical scientific infrastructure for it contributed to addressing an investment gap in the first instance, overlooking the D side has contributed to the generation of a significant bottleneck that prevents Europe from making the most, relative to other economies, of its considerable innovation effort (Dosi et al., 2006; Rodríguez-Pose and Wilkie, 2019; Bianchini et al., 2019).

5. Towards a different innovation policy for the EU's less-developed regions

Overall, the EU as a whole, and its economic periphery, in particular, have failed to make the most of policies that follow the linear model of innovation (see also Camagni and Capello, 2013). Low levels of investment but, above all, structural bottlenecks – including deficits in human capital endowments, brain drain, weak economic fabrics, and inadequate institutional ecosystems – have resulted in a low capacity in the EU's less-developed regions to produce new knowledge. But, more fundamentally, this has led to a pervasive inability to translate knowledge into economically feasible innovation. This raises questions about the wisdom of pursing a policy where the main focus is on one aspect of the supply-side of innovation effort: R&D.

Moreover, the incapacity of less-developed European regions to transform new knowledge into viable economic activity is undermining the economic potential of these regions and can lead to an exacerbation of the already significant inequalities in GDP, employment and productivity further down the line. It also limits overall innovation in the EU, as considerable innovation potential remains untapped. But the consequences go well beyond unexploited potential and spill over into the social and political realms. Lack of opportunities and capacity to exploit innovation and, consequently, limited economic growth is a source of tension and discontent on a continent that is naturally averse to inequalities. The outcome is growing social and political tensions, increasingly manifested through the ballot box and the occasional outbursts of violence (e.g. the rise of the '*gilets jaunes*' in France), which threaten the economic and political stability of the EU and which can ultimately also challenge innovation in core areas. Brexit has the potential to be a fundamental example of this (through the flight of innovative firms, brain drain, reduction of investment in R&D, and greater social and political uncertainty) (Rodríguez-Pose, 2018).

Hence, a change in politics in order to promote economically viable innovation in the EU's less-developed regions is on order, as the innovative deficit in less-developed areas of the EU is not necessarily a consequence of limited R&D investment or one of a lack of new scientific knowledge production. Many less-developed regions in the EU have levels of expenditure in R&D which – although still with margins of improvement – are broadly in line with their degree of economic development. Although the emphasis on the research side of R&D has expanded knowledge creation, the benefits in terms of greater economic growth, higher productivity and employment generation have been well below par.

There is therefore a need to go beyond R&D – without neglecting progress in this respect over the last three decades – and to tackle head-on the bottlenecks related to these areas' limited innovative capacity. This implies, at the very least, considering the following areas of intervention:

1. ***Complementing the pursuit of excellence in R&I needs with a greater emphasis on promoting innovation in the EU's less-developed areas***: Although excellence should remain at the heart of the R&I effort, it should be acknowledged that the territorial polarisation of R&I limits the overall innovation potential of the EU. This would imply that unveiling and tapping into R&I potential specifically in the EU's less-developed regions may need to become an explicit and complementary policy objective.

2. ***Putting innovation at centre stage in less-developed regions***: So far, the R&D effort in less-developed regions has been dedicated mainly to improving research outcomes. As shown in Table 12.3, the less-developed countries of the EU periphery have multiplied their scientific output and – at least in number of outputs – closed the scientific gap with the core of the EU. However, improvements in research have not been matched by similar progress in terms of innovation. With a few exceptions, less-developed regions in the EU struggle to transform research into new processes and products developed by local firms – or, often, elsewhere in the EU as well – which means that the impact of the greater research effort on the prosperity and well-being of society is limited.

   This requires an innovation policy that goes well beyond the simple funding of R&D or subsidies to firms in support of R&D and concentrates on: a) enhancing the innovation capacity of firms in the region; and b) creating an adequate ecosystem for innovation to emerge and thrive. More focus on the role of production networks and value chains, as well as on triple and quadruple helix strategies is thus warranted to cement the foundations of favourable innovation systems (Carayannis and Campbell, 2012).

3. ***Promoting pan-European and international networks involving innovation actors***: Recent research has emphasised the importance of extra-local connectivity

as a source of innovation and change. Innovative actors which branch out to other innovative actors outside the local territory not only become more capable of creating new knowledge and innovating themselves, but also turn into catalysts of innovation in their local environments. According to the literature, the results are greatest when these connections are international – the so-called innovation 'pipelines' (Bathelt et al., 2004). Such pipelines facilitate the circulation of new knowledge and reduce the risk of lock-in. There is increasing evidence – from research in Sweden, Norway, Finland, Austria, Portugal and Canada – that dynamic firms in peripheral locations innovate in a different way from those in more innovation-prone environments (Shearmur, 2017; Eder, 2019; Eder and Trippl, 2019). Frequently, innovation is essentially achieved by compensating for the lack of critical mass and for the distance to the technological frontier by engaging in international interaction (Doloreux and Dionne, 2008; Fitjar and Rodríguez-Pose, 2011; Tödtling et al., 2012; Grillitsch and Nilsson, 2015).

Yet the formation of networks for R&I in European policy has fundamentally been limited to the promotion of research consortia within the different Framework Programmes with very limited protagonism for firms. Putting companies at centre stage of the formation of innovation partnerships, first, and networks, later, can represent a huge boost in the innovation capacity of many less-developed regions.

4. ***Aligning EU policies with their potential effects on R&I and territorial inequalities (and better coordination with national innovation policies)***: Lack of an adequate horizontal alignment between the European policies that affect research innovation and territorial inequalities is limiting the impact on investment in innovation. This is not only reducing the returns on the European R&I policy and European Cohesion Policy, but also concerns all efforts to improve education and skills across the EU.

   In addition to these improvements in horizontal coordination, there is also a need for better vertical coordination between European and national R&I policies.

5. ***Tackling poor institutions***: Weak institutions, in general, and poor governance quality, in particular, are important barriers to R&I (Rodríguez-Pose and Di Cataldo, 2015). R&I policies in areas with weak governance are often misguided and almost always lead to significant waste of limited resources. Therefore, improvements in institutional quality must become essential components of any R&I strategy. Interventions targeting institutional bottlenecks, especially in terms of improving efficiency in delivering innovation programmes, increasing transparency and accountability, and combatting corruption will improve the outcomes of any intervention to promote innovation, particularly in the less-developed regions that tend to endure the worst of institutional bottlenecks.

Putting all these factors together requires the development of new, place-sensitive policies: That means policies that are based on strong theory and solid empirical analyses, but which are sensitive to the conditions and problems of specific groups of regions across Europe (Capello and Camagni, 2015; Crescenzi and Giua, 2016; Iammarino et al., 2019). Only in this way can research and innovation policies become versatile enough to make sure that the contrasting objectives of pursuing excellence and maximising the returns on R&I investment, on the one hand, and of mobilising as much innovation potential as possible and achieving more territorially harmonious development, on the other, can be reconciled.

6. Conclusions

The EU suffers from an important innovation divide that is curtailing its capacity to increase its competiveness and economic presence on the world stage, while also undermining the goal of improving the welfare of Europeans regardless of where they live. The tendency of economically viable innovation to concentrate in the more-developed areas is also having considerable consequences on the EU's capacity to close the gap between its economic core and its periphery, further sponsoring a social and political discontent that can have serious consequences – economic and otherwise – for the future of Europe. And the dominant innovation policy emanating from both the Lisbon Strategy (2000-2010) and Europe 2020 of raising the R&D effort to 3% of GDP – despite non-negligible improvements in new knowledge generation – has, so far, failed to trigger the economic dynamism to both increase the competitiveness of the EU as a whole and to close the innovation divide between its more- and less-developed areas.

This demands a thorough re-examination of European innovation policy, especially in the EU's less-developed areas. The R&D-oriented one-size-fits-all, European-wide policies of the past have not led – and, in all likelihood – will not lead to improvements in competitiveness. Nor are they likely to yield significant improvements in economic growth, sustainable employment, and welfare in the EU's less-developed regions. As Sterlacchini emphasises: 'simply investing more public and private resources in the fields of knowledge and education does not guarantee equal growth opportunities among EU regions' (Sterlacchini, 2008: 1106). There is a need, therefore, to go beyond the focus on R&D and adapt policies to the specific characteristics of different territories: a place-sensitive innovation policy for the EU. Such approach must put innovation and innovation absorption at its core, focusing on the mechanisms that would facilitate the generation and absorption of innovation by individual economic actors and firms and contribute to the inclusion of these actors in innovation-generating and diffusing value chains and knowledge, often extending well beyond the local environment (Miguélez and Moreno, 2015).

Recent steps have been taken in this direction at both the EU and national level. In particular, since the reform of the European Cohesion Policy in 2014, the implementation of smart specialisation strategies represents an important step in the right direction. But changes should become bolder and more daring in order to better realise the innovation potential of the whole of Europe and to narrow the innovation and social and economic divide within the EU. The stakes are high as, without better use of the talent and potential for innovation across the entire EU, we will not only be giving up on significant capacities to generate new knowledge, but will also be putting at risk the economic and social stability which has been at the heart of making Europe one of the most prosperous and – despite appearances – equal societies in the world.

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