Scientometrics (2024) 129:1493–1521
https://doi.org/10.1007/s11192-024-04942-3

Regional and sectoral variations in the ability to attract funding from the European Union's Seventh Framework Program and Horizon 2020

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Received: 19 April 2023 / Accepted: 9 January 2024 / Published online: 16 February 2024
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Abstract
The funding from the European Union's Framework Programs for Research and Innovation (EU FPs) is skewed across European countries and institutions. The goal of this article is to deepen our understanding of this skewness by incorporating a regional (NUTS-2) and a sectoral (higher education sector and private sector) perspective when studying the ability to attract 71.6 billion euros of research funding distributed by the EU Framework Programs between 2007 and 2020, and to explore how it changed from FP7 to Horizon 2020. We explore the ability to attract grant funding per unit of R&D personnel, and how it is affected by a region's volume of research personnel, R&D investments, research intensity, level of development, and mediated by the amount of funding requested. In the private sector, we find that several Southern European regions are highly capable of attracting funding, primarily through a high proposal intensity, e.g., large amounts of funding requested. In the higher education sector, regions in the so-called "blue banana" are particularly able to attract funding, due to high levels of R&D investments, strong research intensity, and a high amount of funding requested. From FP7 to Horizon 2020, we observe increasing divergence in the ability to attract funding in the private sector, in favor of peripheral regions, which aligns with the aims of the European Commission's cohesion policy.

Keywords European Framework Programs · Regions · Research funding · Sectoral funding variations · Convergence and divergence

Introduction

Public funding plays a significant role in shaping the development of science and technology (Wang et al., 2020). Being the world's largest funding program for research and innovation (Abbott, 2020), succeeding in the European Union's Framework Programs for

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Research and Innovation (EU FPs) is important to every European scientific community. With their massive budgets, the EU FPs serve to support and implement the EU's research and innovation policies, contributing to an integrated European Research Area (ERA) in an area with not only regional R&D differences (between countries), but also within countries (see e.g., Petrakos et al., 2005; Puga, 1999). Some studies have shown that the EU FPs have increasingly involved more peripheral parts of Europe, when looking at project participations (Neuländtner & Scherngell, 2020; Scherngell & Lata, 2013; Wang et al., 2017), but a different way of looking at the EU FP participation data may give different results.

The *goal of this article* is to complement current social network-based studies, by using budget data from funded projects in the 7th framework program for research and innovation (FP7) and Horizon 2020 (H2020), to explore how the distribution of European funding varies by regions and R&D performing sectors. In addition to a descriptive analysis of sectoral variations by regions, we also study how funding success at these two levels changed from FP7 to H2020, and how various regional R&D features may explain regional variations in funding success.

'Europe' in this context includes the EU member states (including the United Kingdom) and seven associated countries (Bosnia and Herzegovina, Iceland, Montenegro, North Macedonia, Norway, Serbia, and Switzerland).

In the next sections of the introduction, we first describe the role of cohesion in EU policies and highlight the possible trade-offs between integration and excellence in the European research area. Then, we look at the (rather limited) literature on regional and sectoral funding distribution in the EU FPs, where little research so far has paid attention to regional distribution of EU FP funding, and, to the best of our knowledge, no studies yet have explored funding success across both time and R&D performing sectors. Hence, our study aims to close a current knowledge gap.

Background: the European commission's efforts towards cohesion

Convergence of European regions is a high priority for EU policies (Boldrin et al., 2001; Breschi, 2004; Larraz Iribas & Pavia, 2010; Petrakos et al., 2011), with the EU's cohesion policy, including structural funds, accounting for one-third of the total EU budget (Crescenzi & Giua, 2020). EU's cohesion policy is about strengthening economic, social, and territorial cohesion in the EU. It aims to correct imbalances between regions,[1] trying to avoid regional disparities (Bachtler & Wren, 2006; Gänzle et al., 2019). The cohesion policy is not about an East–West or South-North divide, as there are within-country differences in the North-West of Europe as well (Abramo et al., 2015; Crespy et al., 2007; Kaufmann & Wagner, 2005). Among the regions at NUTS-2 level (Nomenclature of territorial units for statistics) classified by the European Commission (EC) as 'less developed' in 2021, however, there is a clear East-South focus, with 55 regions in Eastern European countries and 28 regions in Southern European Countries (in addition to one region in Belgium and four French overseas regions).

Whilst the main goals of the EU FPs are to improve the competitiveness of the EU and to promote high-quality research, they cannot be considered independently of the EU's cohesion policy. The EU FPs have traditionally not aspired to contribute to cohesion (Sharp, 1998), but the EU has sought to create synergies between its funding and policies, and for the program period 2021–2027 it aims at creating synergies "between Horizon

[1] https://ec.europa.eu/regional_policy/en/2021_2027/.

Europe and the structural funds for the purpose of 'sharing excellence', thereby enhancing regional R&D capacity and the ability of all regions to develop clusters of excellence" (Doussineau & Bachtrögler-Unger, 2021, p. 4). However, these may be conflicting issues, as excellence and cohesion may not be as collapsible as desired (Hoekman et al., 2009). After all, the funding allocation in the EU FPs is based on strong competition with little cohesion perspective in mind (Wanzenböck et al., 2020), thus possibly compromising the cohesion policies (Fratesi & Wishblade, 2017; Heraud, 2003; Hoekman et al., 2013), in so far that EU FP funding is more concentrated in urban/metropolitan areas with R&D intensive industries (e.g., Boix et al., 2016; Doussineau & Bachtrögler-Unger, 2021), possibly leading to increased regional inequality in Europe (Boldrin et al., 2001; Crescenzi & Giua, 2020; Hansen & Winther, 2011). Such agglomeration effects and uneven spatial concentrations of activities (e.g., Carlino & Kerr, 2015; Puga, 1999) represent an important driver of who the key performing regions in EU funded research are and may be an obstacle for the involvement of peripheral regions (Neuländtner & Scherngell, 2020).

Hoenig (2017) describes how EU science policy has shifted from economic, political, and social objectives to the "norm of scientific 'excellence'", foremost due to the establishment of the European Research Council (ERC). The ERC funding is highly concentrated in a few countries and institutions (thereby also regions) in Europe, not adding to convergence of EU FP funding (and admittedly: not intended to). Hoenig (2017) claims that ERC has strengthened the ERA's focus on excellence at the cost of mission-oriented and collaborative transnational research. Such a development has arguably been supported by leading countries, while less advanced countries have advocated that cohesion should be more emphasized (Hölzl, 2006). Yet, it has been argued that the EU FPs may be complementary to the structural funds in promoting cohesion, as collaboration projects in the EU FPs may help lagging regions in getting increasingly involved with leading research institutions from the North-West of Europe (Sharp, 1998).

Studying effects of EU cohesion policy on regional development has become a large field of research. Most of these studies use NUTS-2 regions (and some, NUTS-3) as their level of analysis, as the EU cohesion policy targets regions at this level (Fratesi & Wishblade, 2017). However, most of this literature is about economic growth in some respect (e.g., Gagliardi & Percoco, 2017), such as productivity growth (Basile et al., 2012), GDP per worker growth (Fiasci et al., 2017), income convergence (Farole et al., 2011) and even quality of life (Jewczak & Brudz, 2022). The effect of EU funds is mixed and considered a matter of controversy (Jagodka & Snarska, 2023). Mohl and Hagen (2010) concluded that Objective 1 payments (to NUTS-2 regions with PPP adjusted GDP per capita less than 75% of EU average) have promoted regional economic growth, but not Objectives 2 and 3. The lacking focus on R&D and the EU FPs in the literature related to EU cohesion policy is hardly surprising as the policy aims at reducing regional disparities and to stimulate economic growth. However, the EU FPs do channel a substantial amount of money across regions, possibly conflicting the cohesion policy, and one may thus ask, as Veugelers et al., (2015, p. 4): "Is Horizon 2020 right to ignore geographical considerations when allocating funding?".

Such considerations have not been completely ignored though. In assessing the Seventh Framework Program (FP7), the European Commission (2015) made several recommendations to increase the participation of new EU member states (EU-13) (where a large share of the Objective 1 regions is found), such as a better representation of their central themes and topics in Horizon 2020 (H2020). In FP7, the REGPOT program (Research Potential of

Converging Regions)[2] targeted member states underrepresented in the EU funding, while in H2020 the WIDESPREAD program (Spreading Excellence and Widening Participation) focused on "low R&I performing" or 'Widening' countries. WIDESPREAD included various actions dedicated to connecting research institutions in low performing regions with leading research institutions in Europe.

While national gaps are renowned, little is however known about how the excellence/cohesion tension has played out at regional level. Moreover, it is not known whether from FP7 to H2020, funds have been further concentrated in leading regions or distributed more evenly (Kaló et al., 2019). Here, we choose a regional approach rather than a country approach, because R&D systems are organized not only at a national level, but also, significantly, at regional levels and many regions display largely independent and peculiar R&D ecosystems (Asheim et al., 2011; Cooke & Leydesdorff, 2006; Danell & Persson, 2004; Schot & Steinmueller, 2018), e.g., with almost all European regions (NUTS-2) being shown to be highly specialized towards at least one thematic area of H2020 (Doussineau & Bachtrögler-Unger, 2021). Advanced regions have either a dominance of private R&D or relatively balanced structure between private and public R&D, while the opposite holds for lagging regions (Blazek & Kadlec, 2018). This is not just a between-country issue, as there are strong within-country variations as well. For example, in Norway the sectoral distribution of EU FP funding differs substantially at the regional level, with the three leading regions having completely different profiles.[3] Therefore, we argue that regional funding success in EU FPs should be analyzed separately for the different R&D performing sectors of a region.

Literature on grant success and distribution of funding in the EU FPs

The study of success in attracting research funding has been extensively explored at the individual level, in terms of the chances of an applicant to win. Studies have for example explored the effect of gender (Pohlhaus et al., 2011; van der Lee & Ellemers, 2015), quality of writing or clarity of proposals (Boyack et al., 2018), or the degree of interdisciplinarity (Bromham et al., 2016; Seeber et al., 2022a, 2022b). A few studies have explored more specifically EU funding, which we review in the following paragraphs and highlight the research gaps that we are going to address. The first strand of research on EU FPs is related to success, foremost at the institutional level; and mostly aimed at higher education institutions. Some studies stress the importance of prior participation (Enger & Castellaci, 2016), past coordination experience (Piro et al., 2020; Wanzenböck et al., 2020), a relative high volume of proposals (Piro et al., 2020), and that size and reputation of higher education institutions is decisive to overall participation (Lepori et al., 2015), which is in line with research funding studies in general that stress the 'Matthew effect', i.e. a strong concentration of funding in a limited share of the researchers/research institutions (e.g., Madsen & Aagard, 2020). Consequently, in some areas of the EU FPs there is a strong pre-selection

[2] REGPOT was introduced in FP7 on the background that "Europe needs to exploit its research potential, particularly in the less advanced regions that are remotely situated from the European core of research and industrial development".

[3] In *Oslo,* the funding is dominated by higher education institutions and public sector/other organizations. In *Trøndelag* more than half of the funding goes to the research institute sector, whereas in *Viken* more than half of the funding goes to private companies. Source: The Research Council of Norway (www.forskningsradet.no):

among potential applicants, foremost related to the ERC (Neufeld et al., 2013), where reputational strength matters more (Piro et al., 2020).

In the second strand of research, the general conclusion is that the EU FPs have substantially contributed to widening of the European research networks (Constantelou et al., 2004; Neuländtner & Scherngell, 2020; Scherngell & Lata, 2013; Wang et al., 2017), from being more concentrated in the former EU member states to also involving larger parts of Europe so that geographical distance and country border effects have gradually decreased (Neuländtner & Scherngell, 2020; Scherngell & Lata, 2013). Scherngell and Lata (2013) analyzed EU FP collaborative projects across 255 regions (NUTS-2) in the period 1999–2006 and found that geographical distance and country border effects on project participation in R&D collaboration networks had gradually decreased. Neuländtner and Scherngell (2020) examined KET (key enabling technology) projects at NUTS-3 level funded by the EU from FP1 up to H2020 (up to 2016) and found that negative border effects had diminished in the EU FPs but were still present.

Yet, other studies have argued that Europe remains largely a collection of (non-cooperating) networks (Chessa et al., 2013), and that distance (geographical economic, technological, social) still mattered in Europe since regions more similar to each other tend to collaborate the most, with lagging regions of Europe are struggling to enter persistent networks (Amoroso et al., 2018), still being dominated by a stable core of key institutions (Heringa et al., 2016).

Available analyses of *regional* success are almost exclusively provided for one country at the time, by national agencies (often available only in national language reports or web pages). For example, Vinnova (2020) examined Swedish participants in EU FPs by regions (number of project participations) and revealed a great disparity: the top 3 regions accounted for more than 70 per cent of the Swedish funding. Similar strong concentration has been observed in Denmark, with two thirds of the funding in H2020 obtained by the Copenhagen region.[4] In Norway, the concentration of funding is also highly skewed: 76 per cent the funding is channeled to three regions, while the remaining regions in Norway account for just 24 per cent of the funding.

Studies about regional distribution of funding programs are generally scarce. In the US, Walsh (2016) studied NIH funding (2004–2013) and found very large differences across US states in NIH funding *per capita.* In the United Kingdom, UKRI (2020) presented data at NUTS-1 level for UK government funding, adjusted e.g., for capita. The lacking regional focus in EU FP studies, beyond the social network approach, is surprising, given the many studies (using different approaches and output data) showing how R&D characteristics vary regionally (where such regional variations are targeted by the EC), not only between but also within countries. Regions have often distinct research profiles, developed over time (Heimeriks et al., 2019; Leydesdorff & Wagner, 2009), with variations in e.g., investments (Groenendijk, 2006), innovation capacity (European Innovation Scoreboard, 2021) and publication performance (Andersson et al., 2020; Hoekman et al., 2013), all of which must be expected to affect the capability to attract EU FP funding.

Studies about *sectoral* differences in EU FP funding success are lacking. Only Wanzenböck et al.'s (2020) study of consortia composition in the Societal Challenges of H2020 is with an outlook on sectors. They found that consortia dominated by private companies and research organizations had a higher probability of proposal success, arguing that this is not unexpected given H2020's focus on "application-oriented research with immediate societal

[4] https://ufm.dk/forskning-og-innovation/statistik-og-analyser/tilskud-til-forskning-og-innovation/eu-s-rammeprogram-for-forskning/deltagelse-i-h2020.

relevance". In fact, in their study, a high share of universities in the consortia was not ideal for the chance of success. However, no regional focus was applied in this study.

The only cross-country analysis of regional funding in the EU FPs that contrasts EU FP success with regional characteristics is in Anciaux et al.'s (2016) report on regional embeddedness of FP7's program for Nanoscience and Nanotechnologies, Materials, New Production Technologies, and Biotechnology (NMBP). Using NUTS-2 data, the authors visualized the realized vs. the expected participation rate—based on a set of criteria such as the technological strength of the region, the R&D intensity, the wealth of GDP, the population density, and other national and regional characteristics. This study covered 882 projects with 5,168 unique organizations, foremost Small Medium Enterprises (SMEs) and large enterprises. Most participants came from existing industrial hubs, especially in more central parts of Western Europe, with the most active regions being Catalonia (Spain), Lombardy (Italy) and Rhõne-Alpes (France). In general, they found that most regions were performing as expected, with some exceptions.

Our approach is motivated in line with the perspectives of the latter report, that is: funding success such as number of grants won (or being involved in) or volume of funding obtained, may look very differently if one studies the raw numbers or if one normalizes by size. The only published study that have done this is Sharp's (1998) analysis of regional variations in EU FP funding per R&D full-time equivalent (FTE) in the years 1987–1994 (FP3-FP4). Here, although there was a "catching up" of some southern countries (Greece and Portugal, but also Ireland), the cohesion countries (at that time) were still lagging in terms of funding per FTE. Sharp's (1998, p.586) conclusion was that: "Given their RTD capacities, the cohesion countries and regions have done quite well. While in absolute terms the richer countries and regions received more funding. When adjusted for population, the distribution was more equal, and when judged against numbers of R&D personnel or the cohesion countries/regions own RTD efforts, the distribution was biased in their direction". Hence, throughout an eight-year period, the distribution of funding became less concentrated, partly due to the cohesion regions becoming more active in collaborations, which is in line with results from social network studies.

Compared with existing research, this study presents three added values. First, Sharp's (1998) study is from a period where the EU only consisted of 12 countries, and most of today's lagging regions were not considered. Second, recent social network analyses are based on project counts; not accounting for the amount of funding received neglects a pivotal measure of their degree of involvement. Third, and most importantly, the sectoral approach has been missing so far. This is key to understand regional differences because the regions can vary substantially in the proportion of research conducted by higher education institutions, public research organizations and private companies. Hence, a region may be highly successful in its private sector and less so in its higher education sector (or vice versa). Our study thus explores variations across regions and R&D sectors *over time.*

Data and methods

Our study draws upon data from eCORDA, covering all projects from FP7 and H2020 in the period 2007–2020 (using the October 2020 edition of eCORDA). NUTS-2 information about project participants (and applicants) have been manually checked, and missing values completed based on information in the database (name of institution, address, city). The study covers 20,591 funded projects in FP7 (worth 29,1 billion euro) and 28,320 funded projects in H2020 (worth 42,5 billion euro). The FP7 projects originate from a total of 125,604 proposals, where a total of 138,7 billion euro was requested, while the H2020 projects are based on a total of 248,741 proposals, where a total of 389,4 billion euro was requested. The data has been manually cleaned to be consistent across sectors and regions; and only including R&D performing units that logically belongs to a region.

Sectors: choosing two main R&D sectors

We *explore variations between R&D performing sectors.* In eCORDA the project participants are classified by five sectors: i) Higher education institutions (HES): 34,1% of the project participations, and 40,4% of the funding. ii) Research institutions, non-profit (REC): 22,8% of the project participations, and 26,5% of the funding. iii) Private companies (PRC): 33,4% of the project participations, and 26,7% of the funding. iv) Public sector organizations, excluding research and higher education (PUB): 5,0% of the project participations, and 3,1% of the funding. v) Other, mostly organizations/networks/NGOs (OTH): 4,8% of the project participations, and 3,3% of the funding.

In this study, we focus on the two main sectors (HES and PRC), accounting for 67,1% of the funding. PUB and OTH do not carry out R&D tasks by funding and personnel that appears in national R&D statistics and are thus not studied. We also excluded the REC sector, because assigning REC's project funding to a specific region can be difficult or arbitrary. In fact, as many of the most important grant recipients in EU FPs are very large national research organizations, with laboratories and research centers spread all across their respective countries, but with all funding being assigned to the region of the headquarters (for example CNRS in France, Max Planck Institute in Germany, or the many national academies of sciences in Eastern Europe).

We explored in initial analyses of our study sample the correlations between sectors in the same regions, and whether there is a relationship at regional level in the efficiency of different sectors (based on the indicators described in the methods section). A correlation analysis revealed no relationship between HES and PRC (0.066),[5] which corroborates the relevance of analyzing the sectors separately.

Regional level: choosing NUTS-2 as level of analysis

There are three regional levels available at NUTS. In choosing NUTS-2 as level of analysis, three main criterions were considered. First, *data availability.* The higher level, the more data available (by year and sector), making NUTS-3 not feasible. Second, data's *fit to knowledge production unit*. There are some spatial delimitation problems in metropolitan areas like London and Paris at the NUTS-2 level since the borders may appear rather arbitrary with regards to knowledge production (Andersson et al., 2020; see also Boldrin et al., 2001; Isaksen & Onsager, 2010). Still, local R&D ecosystems, foremost observed in innovation studies (European Commission, 2021) point at strong variations at NUTS-2 level, which would be levelled out at NUTS-1 level. Third, *readability of the results vs sufficiently fine-grained results*. We believe that NUTS-2 regions represent a more optimal level of granularity, with population sizes in the range 0.8 – 3.9 million. By comparison NUTS-1 with 4–7 million people are too large (and few) for meaningful analyses

[5] At country level, there are just a few cases in which regional ability to attract funding in different sectors correlate: HES and PRC in Netherlands (.736**) and HES and PRC in Poland (.537*).

of regional variations; while NUTS-3 would produce too many regions with low or even missing values on granted projects (population ranges from 150.000 to 800.000), or too many artificial units whose independency is hard to establish (such as London, consisting of 32 NUTS-3 regions). We therefore conclude that NUTS-2 is the most optimal regional level for this study according to the three criterions, while acknowledging the non-optimal mix of strong knowledge hubs with more rural regions at NUTS-2, which has led Eurostat to produce a new typology of metropolitan regions (derived from NUTS-3 regions). Also, the RISIS-KNOWMAK project[6] has produced a more fine-grained classification based on NUTS-3 regions, to better capture the structure of knowledge production. However, such classifications could not be used because R&D data (FTEs and investments) are foremost available at NUTS-1 and NUTS-2, and do not have the same relevance from a cohesion perspective as NUTS-2 does, which is the regional level that European Commission is in fact targeting.

Normalizing data by number of researchers (FTEs)

The project participants' NUTS-2 codes (using the 2010 version of NUTS-2) and corresponding project information, have been matched with Eurostat data on number of researchers (FTEs), split by sectors, in order to create our dependent variable: funding received per FTE.

The number of FTEs serves two purposes in our analysis. First, in the descriptive analysis we normalize a region's received funding by FTEs to obtain a size-independent measure of funding success, which we explore geographically. Second, in multivariate analyses we treat FTEs as an independent variable in explaining the region's ability to attract funding in EU FPs. Other elements that may also explain R&D capacity used for our analyses are Eurostat-data on region's R&D investments per FTE and R&D intensity (R&D FTEs normalized by population), where the former two are considered the key components of an R&D system's size and its absorptive capacity in relation to R&D (Sharp, 1998).

In this paper we do not set out to include elements about the *quality* of the regional R&D systems, where choice of any such quality measures could be disputable,[7] but also potentially level out a large share of the regional differences, thus also removing exactly what we want to explore in this paper: regional differences.

In using Eurostat-data on FTEs (and investments and populations) by NUTS-2 regions a pragmatic choice had to be made, as Eurostat has incomplete information at NUTS-2 levels. Our baseline choice was to use average of available values for the period 2011–2015 where the coverage in Eurostat is most complete. For regions with no data in this period, we have used the closest year, or an average of the two closest years. One special case is the Netherlands, where FTEs by sector is only available for the years 2000–2002. The total numbers for Netherlands are, however, available in later years and based on the three sectors' percentages of FTEs in 2000–2002 we have estimated their values in 2011–2015 as similar percentages of national numbers. Regions where Eurostat does not produce R&D numbers have been excluded. In the appendix (Table 3) we show the data availability of NUTS-2 R&D data in Eurostat for the period 2011–2015 and use of other data in cases of missing information.

[6] knowmak.eu.

[7] R&D investments have been shown to be correlated with publication citation scores (King, 2004), and may thus be described as a quality dimensions.

In Eurostat, data on R&D personnel are split by the following sectors: HES (higher education sector), GOV (public sector), BES (business enterprise sector) and PNS (private non-profit sector). In matching eCORDA with Eurostat data, two sectors are directly comparable: HES (identical in both datasets) and BES which corresponds to PRC in eCORDA. Most countries (n = 28) are represented here with both two sectors in all regions. For two countries, the data availability in Eurostat is not complete and the countries are only to a limited extent included in our study (Belgium and Switzerland). R&D statistics for Albania, Kosovo, Liechtenstein, Moldova and Turkey is not available in Eurostat, and these countries are thus excluded from the analysis. Based on the data information above, we ran initial analysis of the relationship between a region's R&D personnel and its EU FP funding. Here, Cyprus was identified as an extreme outlier in both its HES and PRC sector. We therefore excluded Cyprus from the study. The sample thus consists of 268 NUTS-2 regions from 28 countries for the analysis of HES; and 276 regions from 29 countries in the analysis of PRC. In addition, Serbia and Bosnia-Herzegovina have been included at national levels.

Participation: budgets rather project counts

In comparing regions' (and sectors') project involvement we use real budget numbers rather than counts of project participations. For each region, and for each project, we have summed up the share of the funding from the EU (in euro) granted to a region, which is possible because eCORDA data specify the funding assigned to each project beneficiary (for whom we have NUTS-2 location). The main benefit of using detailed budget data compared to (a) project participation counts or (b) assigning all project participants with the project total budgets, is the fact that in a research consortium the distribution of money may vary considerably. For example, in a 5-million-euro project, neither (a) or (b) would be able to pick up that while the coordinator may receive 1 million, other partners are in the project with, say, 75 000 euro. Therefore, detailed budget data for each partner (and region) provides much more accurate information about project involvement.

Since the performance of beneficiaries in the EU FPs is typically measured by the number of granted proposals and funding received, it implicitly conceptualizing "success" in terms of efficacy—namely the absolute amount of money or projects attracted (for example in national statistics and R&D reports). However, such indicators are heavily size-dependent—meaning that large units will appear as very successful. Another common indicator of success is the *success rate,* given by the share of successful proposals. This indicator is independent from the size of a region. However, it makes no distinction of the amount of funding being attracted. To address such implicit distortion in the notion of success, we propose to conceptualize success in relation to a region's research capacity as expressed by its personnel in research and development (R&D personnel). This indicator provides a more accurate representation of how successful a region's R&D system is in attracting funds (output) vis-à-vis its research personnel (input). We choose R&D personnel (split by sectors) rather than e.g., number of inhabitants because it is not the people of a region who write research proposals and conduct research, but its research community. We also added the second most important component of an R&D system, namely R&D investments (per FTE) (Sharp, 1998), as a predictor in the regression analyses. Therefore, we measure success by considering the sum of funding received (€) divided by the region's number of R&D personnel (full-time equivalents, FTEs), thus expressing regional *funding attracted per FTE researcher*.

In the next sections we analyze the ability to attract EU FP funds per unit of personnel across regions and sectors, and over time (FP7 vs. H2020). The analysis is conducted in four separate parts.

The *first part* of the empirical analysis focuses on regional variations across sectors in FP7/H2020 combined, and how these differences descriptively vary by sector (Fig. 2). In Fig. 3 we visualize in maps, for each sector, how regional funding success varies across Europe.

In the *second part* of the analysis, we study how regional differences have changed from FP7 to H2020, i.e., we explore signs of convergence and divergence in the EU FPs (Table 1), before we visualize in maps *where* in Europe sectoral divergence and convergence has occurred (Figs. 4 and 5). In order to explore whether the differences between regions in their capability to attract funding have increased (divergence) or decreased (convergence), we select indicators by considering four important aspects of dispersion measures (e.g., Huisman et al., 2015; Litchfield, 1999): i) scale independence, ii) population independence, iii) the assumptions about the underlying distribution of the data, and the iv) consideration of the size of the units. *Scale independence* requires that ranges of values should not impact the estimate of dispersion. The indicator should satisfy this property when the scores have different ranges on an absolute scale. Namely, if the regions' funding per FTE in two periods displayed an identical distribution, they should score a similar value of dispersion, even if range in the H2020 period is greater than in the FP7 period due to an underlying increase in the amount of funding distributed. *Population independence* requires that the score of dispersion should not be affected by the number of units in the population. This is necessary to compare diversity in HES and PRC, due to some missing values in the first. The choice of the indicator also depends on the assumptions about the *distribution of data*. The standard deviation assumes a normal distribution, so it is not appropriate for skewed distributions – such as in the case of regions' funding per FTE. Finally, when the *size of the units* (regions) differs substantially, it might be desirable to take that into account, to avoid that the score of dispersion is unduly affected by very high score of few small regions.

Due to the skewness of the data, we consider three indicators of dispersion based on the Euclidean Distance:

- Euclidean Distance: average difference (distance) between each unit in the sample
- Euclidean Distance normalized: Euclidean Distance divided by the mean value of the sample.
- Euclidean Distance weighted and normalized: i) we compute the average of the distances between each unit weighted (multiplied) by the product of the units' size, ii) and normalize (divide) by the average distance in the sample weighed by the product of the average size of the units.

The indicators discussed satisfy the mentioned properties and conditions to a different extent:

	Scale independence	Population independence	Skewed distribution	Size of units
Standard Deviation	No	Yes	No	No
Euclidean Distance (ED)	No	Yes	Yes	No
ED normalized	Yes	Yes	Yes	No

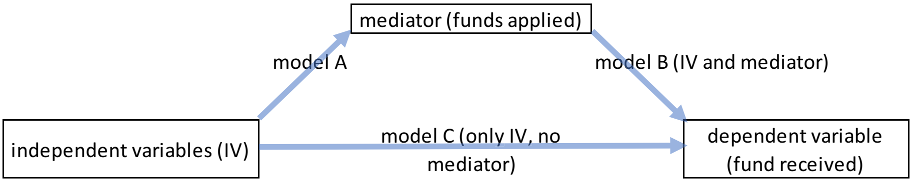


Fig. 1 Mediation model (adapted from MacKinnon, 2007)

	Scale independence	Population independence	Skewed distribution	Size of units
ED weighted and normalized	Yes	Yes	Yes	Yes

In the *third part* of the analysis, we investigate the development in funding success of the regions classified by the EC as 'less developed regions', thus also subject to the EC's cohesion policy.

Finally, in the *fourth part* of the analysis, we complement the descriptive analysis and explore via an inferential analysis what factors predict the amount of European research funding attracted per FTE researcher. We run four sets of models: two for HES (FP7 and H2020) and two for PRC (FP7 and H2020). The dependent variable is right skewed and the residuals of an ordinary least square (OLS) model do not satisfy the four conditions for a linear model. Hence, we employ a generalized linear model (GLM), which allows the response variable to have any arbitrary distribution. As predictors we test: the size of the region in terms of number of FTE researchers; the research intensity, namely the number of FTE researchers per 100 thousand inhabitants; the investments in R&D per FTE in HES and PRC sectors respectively; and whether the regions are classified as less developed regions, transition regions or more developed regions (as well as non-classified regions), by the European Commission.[8]

Importantly, the regression models explore a mediation effect of the amount of applied funding, namely the total value of the research funding for which a region applied and that would have been received if all the proposals in which it was involved were successful. Testing a mediation effect requires different regression models (MacKinnon, 2007; Fig. 1). First, a model with the mediator as the dependent variable (amount of funding asked/applied) since the mediation effect is present when the mediator is associated with the independent variables (model A). Second, a model where the dependent variable is the amount of funding received, and which includes both the independent variables and the mediator (model B). Third, a model where the dependent variable is the amount of funding received, which includes all the predictors except the mediator (model C).

In case of full mediation, the mediator completely absorbs the effect of the independent variables; in case of partial mediation, it reduces their effects: the coefficients remain significant, but the effect is smaller.

[8] Source: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021D1130.. Less developed regions: GDP per capita < 75% of the average GDP per capita of the EU-27; Transition regions: GDP per capita between 75 and 100%; More developed regions: GDP per capita > 100%. Source: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021R1060

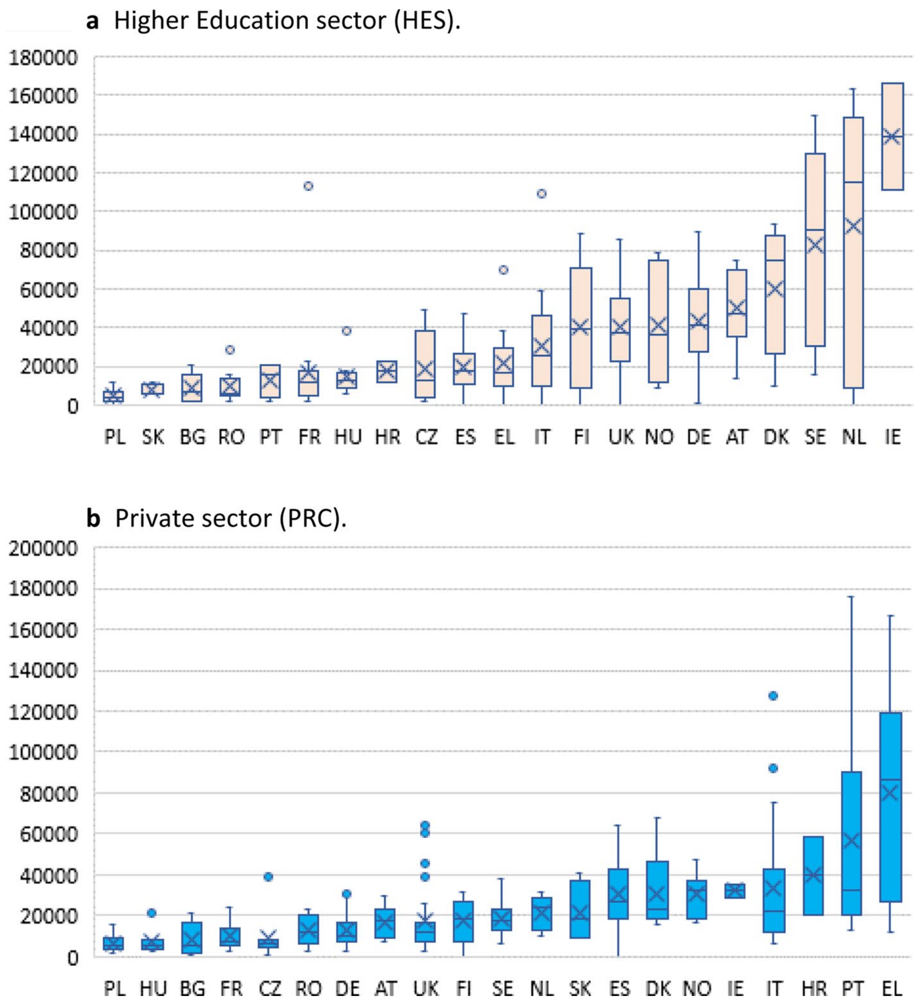


Fig. 2 Funds attracted per researcher FTE in NUTS-2 regions: variations between and within countries

Empirical analysis

Variation between regions

This section explores variations between regions in the amount of funding from EU FPs attracted per researcher (FTEs) in the two sectors. Figure 2 illustrates the variation in the regional ability to attract of EU FP funds per researcher in FTE by country,[9] for HES (2a) and PRC (2b). In HES there is rather clear divide, which reflects variations in wealth and R&D investments. Namely, regions from eastern and southern European countries display low

[9] Excluding countries with less than three NUTS-2 regions. The box plot ranges from the first to the third quartile, the line stretches to the minimum and maximum—dots represent outliers, the line identifies the mean while the x represents the median value.

ability to attract funding per capita, including France (except for the small region of Limoges). Central and northern European countries display much variability between regions, especially in the Scandinavian countries and in the Netherlands. Eastern European regions display lower ability to attract funding per capita also in PRC, whereas contrary to HES, southern European regions are the most attractive regions.[10] By comparison, in PRC, Nordic and central European countries are less able to attract funding; especially France and Germany.

Figure 3 reveals macro regions which cut across national boundaries.[11, 12] In HES (3a), along with Scandinavia and Ireland, the most successful regions occupy the central part of Europe—which is also known under the acronym of the 'Blue Banana', a geographical corridor of highly urbanized regions spreading over Western and Central Europe, from England until Northern Italy (Faludi, 2015). High performing regions in PRC (3b) are mostly located in the northern and southern parts of Europe: in Scandinavia, Ireland, and the Baltic region, as well as in the Mediterranean regions of Greece, Croatia, Italy, Portugal, and Spain.

Changes from FP7 to H2020

Table 1 explores for each sector how the ability to attract funding changed from FP7 to H2020.[13] Regional average funds per FTE increased remarkably from FP7 to H2020, especially in the private sector (PRC), where it almost doubled (Table 1). Due to the non-normal distribution of our data, we excluded the Standard Deviation and consider the three Euclidean Distances, as shown in Table 1.

In ED the dispersion increased from FP7 to H2020 due to the increase in the amount of funding distributed. ED normalized and ED weighted and normalized provide similar results. Dispersion is high but stable in HES. In PRC both measures show an increase in dispersion (10.8 and 9.0 per cent respectively). Comparing ED normalized vs. ED weighted and normalized reveals that in PRC there is less dispersion once the size of the regions is taken in consideration, which means that small regions have the most extreme values. For HES it is the opposite: dispersion is slightly greater for larger regions.

We further explore changes in regional ability to attract funding from FP7 to H2020, as illustrated in Fig. 4. The regions are colored depending on whether FP7 ability to attract funding and variation in the ability to attract funding from FP7 to H2020 are *above or below the median*.

[10] In Italy, Basilicata and Liguria (two relatively small regions) are outliers.

[11] In the maps, there are three cases where two regions have merged, so that data does not fit the maps. In the maps we have pragmatically used values for the largest region (by funding volume): In Lithuania, LT01 (Sostinės regionas) was used rather than LT02 (Vidurio ir vakaru Lietuvos regionas). In Poland, PL91 (Warszawski stoleczny) was used rather than PL92 (Mazowiecki regionalny). In Hungary, HU11 (Budapest) was used rather than HU12 (Pest)

[12] Since creative and talented people are often attracted to urban agglomerations, to densely populated and affluent areas (Florida, 2014; Musterd & Gritsai, 2013), we explored whether there is an association between the size of a sector in a region (in terms of number of researcher FTE) and the capability to attract funds per researcher. In HES there is a weak significant association (0.216**) at EU level. Within each country the correlation for HES is much stronger and significant, in the UK (0.694**), Poland (0.655**), Sweden (0.946**), Netherlands (0.850**), Finland (0.830*), Spain (0.587**), Germany (0.579**), and Bulgaria (0.880*). However, there is no relationship between size and the ability to attract funding per capita in PRC (-0.102).

[13] Bottom quartile regions in terms of FTEs are excluded for specific programs, to reduce the impact from some small regions with very high funding values per FTE.

a Higher Education Sector (HES).

b Private sector (PRC).

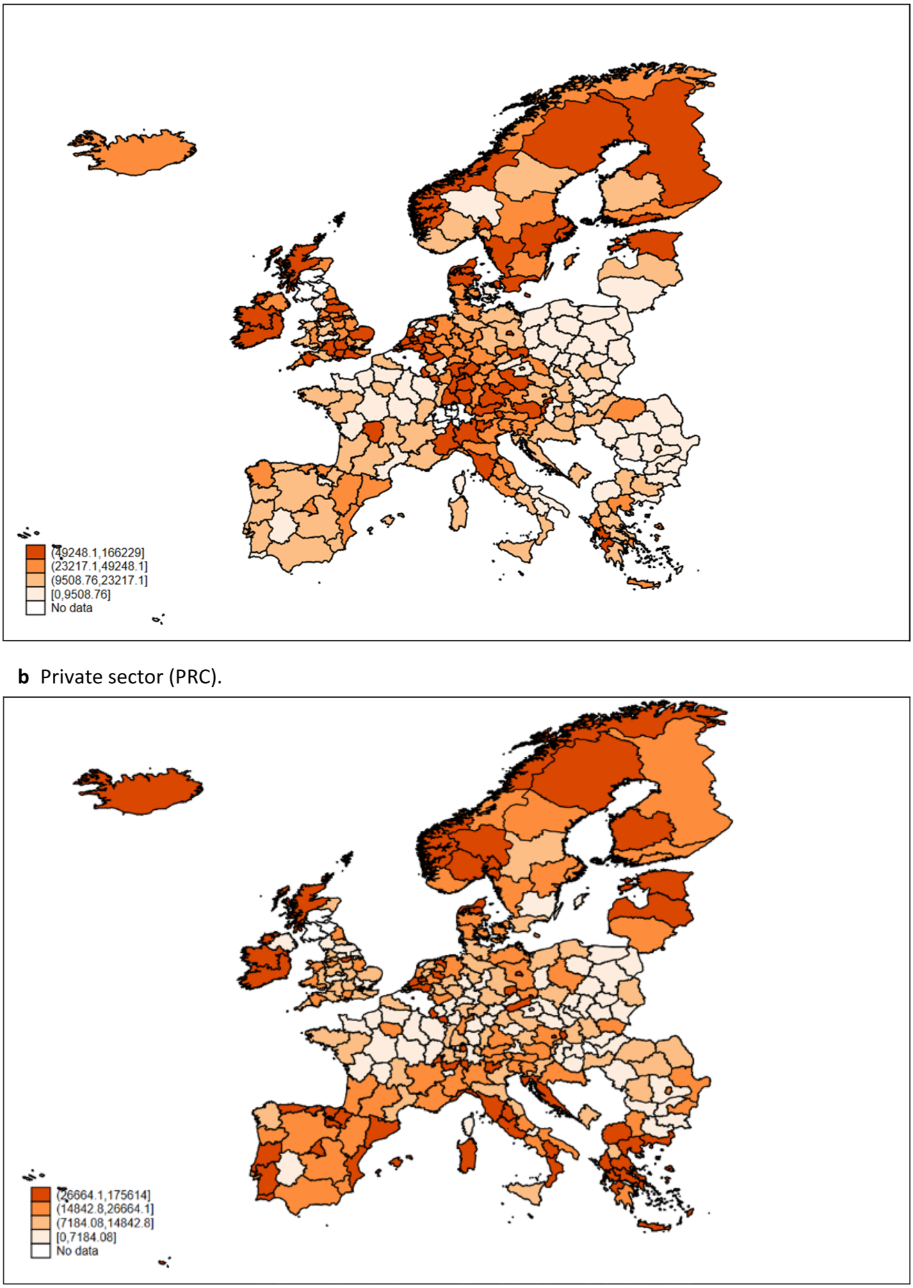


Fig. 3 Funds attracted per researcher FTE—NUTS-2 regions detail

Table 1 Regional ability to attract funding per FTE researcher in FP7 and H2020

	HES		PRC	
	FP7	H2020	FP7	H2020
Mean	14786	19253	7919	14848
ED	15442	19969	7411	15392
ED normalized*	1.04	1.04	0.94	1.04
ED weighted and normalized**	1.09	1.11	0.57	0.63

*Average distance

** ** Weighted: (size A*size B)*distance AB

(avg size * avg size)*avg distance

Brown colors indicate ‘convergence’, namely either: i) low attractiveness in FP7, but strong increase in H2020 (light brown) or ii) high attractiveness in FP7, but with no or weak increase in H2020 (dark brown). Grey colors indicate ‘divergence’, i.e.: iii) high ability to attract funding in FP7, and even higher ability in H2020 (dark grey) and iv) low ability to attract funding in FP7, and even less ability to do so in H2020 (light grey). In both sectors we observe mostly “grey”, i.e., diverging regions: 59 per cent of the regions in HES and 69 per cent of the regions in PRC.

In *HES*, negative divergence (i.e., low performing regions becoming even less able to attract funding) is concentrated in Eastern and Southern European regions and several French regions, whereas positive divergence (i.e., successful regions becoming even more able to attract funding) is in Scandinavian countries and the “blue banana” regions, stretching towards central Italy. Therefore, despite a stable overall dispersion in HES (Table 1), the geographical outlook shows a quite striking pattern.

In *PRC* there is a clear tendency of increased European divergence, both positive divergence for regions in the North and the South of Europe and negative divergence for regions in a central part of Europe, stretching from France to Poland.

Less developed regions

In Fig. 5 we explore the changes in funding success for a selected sample of regions, i.e., the 71 regions classified (2021) as ‘less developed’ by the EC. The purpose of this special outlook is to study how the funding development has been in those NUTS-2 regions that are specifically targeted under the EC’s cohesion policy, although we acknowledge that cohesion is not a key goal of the EU FPs. In Fig. 5 we observe two different patterns. In HES, most regions diverged negatively, i.e., they had low ability to attract funding in FP7 and became comparatively even less able to do so in H2020 (light grey color). In PRC, we see two sub dynamics. Most eastern regions had low ability to attract funding in FP7 and became comparatively even less able to do so in H2020 (light grey color), whereas most regions in the South strongly improved their funding capability (dark grey and light brown). Thus, the trend observed in HES is worrisome, both from the perspectives of EU FPs and cohesion policies, because of the negative divergence of less developed regions.

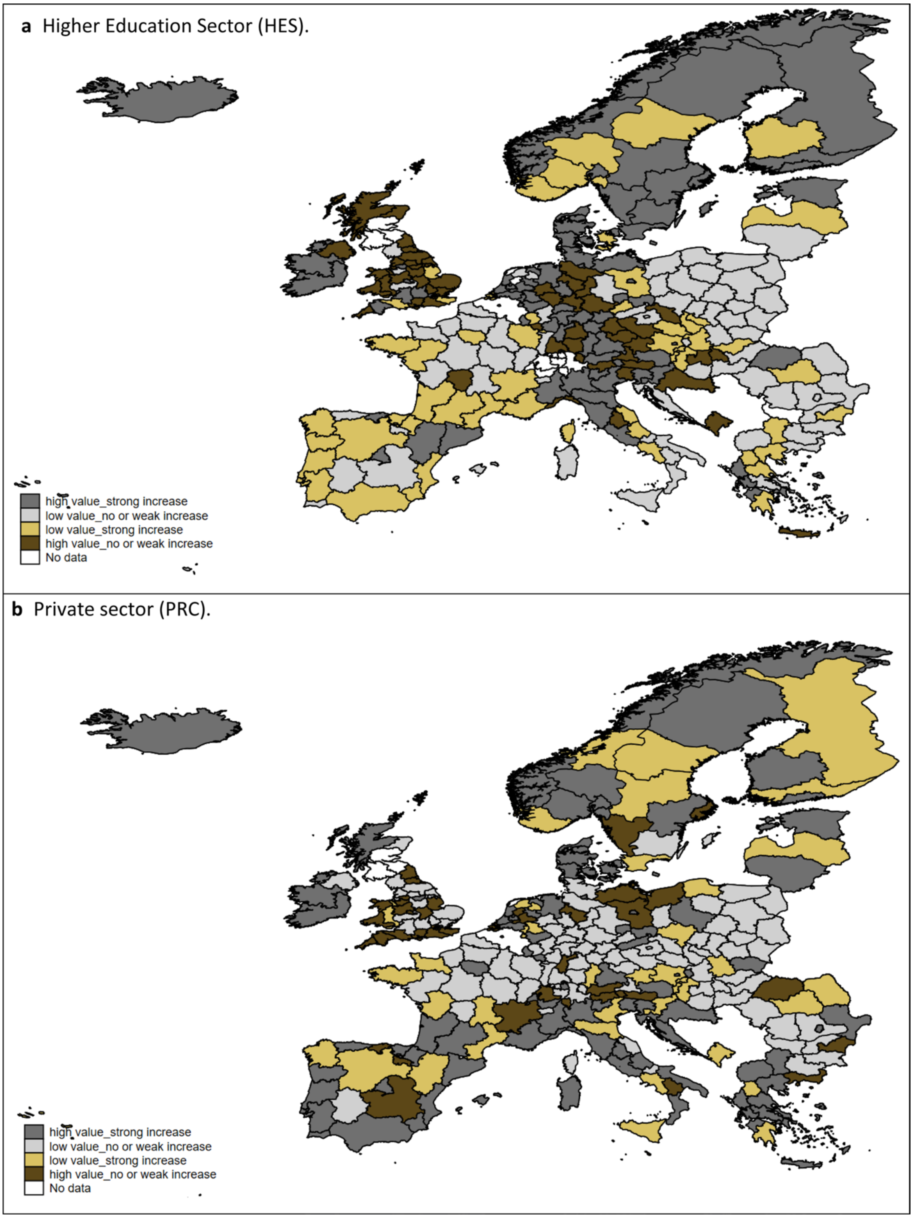
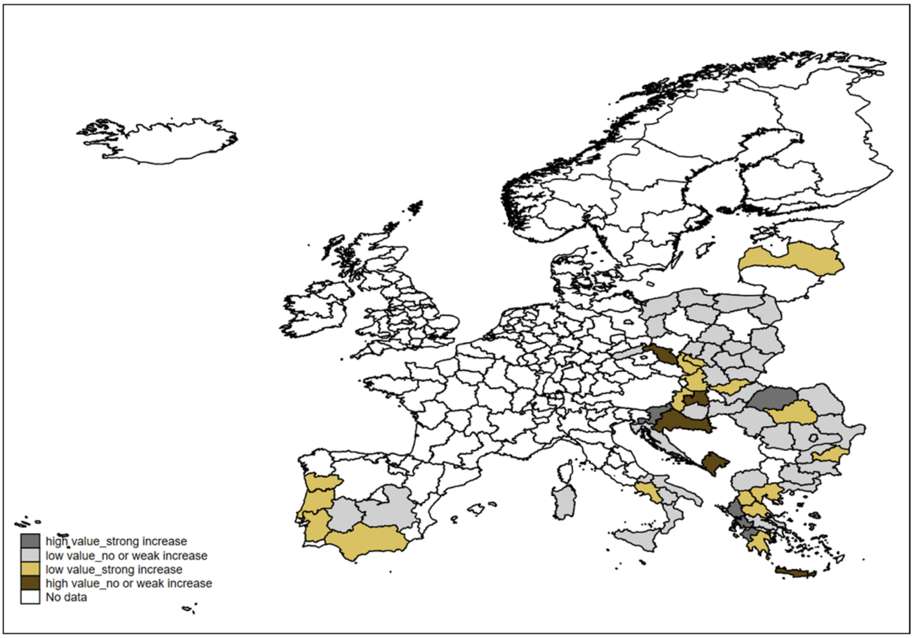


Fig. 4 Convergence (brown regions) and divergence (grey regions) in the funds attracted per researcher FTE from FP7 to H2020

Mediation effects of R&D investments, R&D intensity and proposal intensity

Table 2 reports the results of the Generalized Linear Models (GLM) for the Model A and the Model B of the mediation analysis (cf. data and methods section) for each

a Higher Education Sector (HES).



b Private sector (PRC).

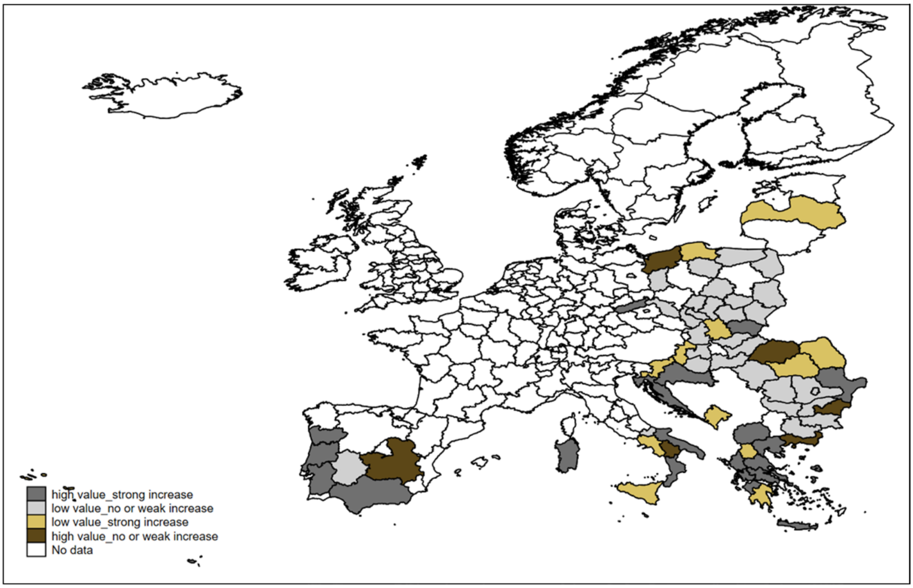


Fig. 5 Convergence (brown regions) and divergence (grey regions) in the funds attracted per researcher FTE from FP7 to H2020 in regions classified as 'less developed regions'

combination sector—program. Multicollinearity is not a major concern in our regression models because the greatest variance inflation factor is 1.61, well below the critical cut-off of ten.

Table 2 Regression analysis: mediation models and variations from FP7 to H2020

(a) Higher education sector (HES)	FP 7								H2020							
	FP7 –Funding applied				FP7-Funding received				H2020-Funding applied				H2020-Funding received			
	Coeff	S.E	Beta	Sig	Coeff	S.E	Beta	Sign	Coeff	S.E	Beta	Sign	Coeff	S.E	Beta	Sign
Funding applied per FTE					0.06	0.006	0.44	***					0.1	0.004	0.82	***
R&D FTEs	− 1.94	− 2.19	− 0.06		0.09	0.21	0.02	.	− 3.06	2.63	− 0.08		0.3	0.16	0.06	
R&D investments	453.21	204.55	0.15	*	36.53	20.21	0.09		637.05	245.39	0.16	**	7.88	14.98	0.02	
Research intensity	81.45	46.59	0.13	.	13.07	4.59	0.16	**	156.09	55.89	0.18	**	8.88	3.42	0.08	**
Region: low vs. high dev	− 78066	20471	− 0.29	***	− 11008	2059	− 0.32	***	− 155194	24559	− 0.44	***	− 5064	1591	− 0.11	**
Region: not classified vs. high dev	− 25330	21796	− 0.08		− 3463	2139	− 0.09		− 78258	26148	− 0.19	**	− 3096	1603	− 0.06	
Region: transition vs. high dev	− 62498	19154	− 0.22	**	− 9719	1913	− 0.26	***	− 136022	22977	− 0.36	***	− 2924	1476	− 0.06	*
Nagelkerke (Cragg and Uhler)	0.36				0.68				0.53				0.89			
(b) Private sector (PRC)																
Funding applied per FTE					0.03	0.0046	0.42	***					0.07	0.003	0.83	***
R&D FTEs	0.39	0.94	0.03		0.01	0.07	0.01		0.39	1.96	0.02		0.01	0.10	0.01	
R&D investments	− 389.03	222.00	− 0.12	.	13.86	16.81	0.05		− 505.23	462.92	− 0.07		− 19.63	22.96	− 0.04	

Table 2 (continued)

(a) Higher education sector (HES)	FP 7								H2020							
	FP7 –Funding applied				FP7-Funding received				H2020-Funding applied				H2020-Funding received			
	Coeff	S.E	Beta	Sig	Coeff	S.E	Beta	Sign	Coeff	S.E	Beta	Sign	Coeff	S.E	Beta	Sign
Research intensity	− 73.97	36.87	− 0.17	*	− 3.24	2.79	− 0.09		− 259.28	76.91	− 0.29	***	7.4	3.89	0.10	.
Nagelkerke (Cragg and Uhler)	0.14				0.25				0.19				0.68			

Sig. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

The analyses of HES and PRC reveals that different factors affect the funding capability in EU FPs. In HES (Table 2a), a region's level of development, amount of investment in R&D, and research intensity affect the level of resources received both directly and through the partial mediation of the amount of resources applied. In other words, developed, research-oriented regions attract more resources both because they apply for more resources (mediation effect) and directly, through more chances of obtaining them—ceteris paribus.

The private sector (PRC) (Table 2b) displays a different pattern. A region's research intensity negatively affects the amount of funds received through the full mediation of the amount of funding applied for.[14] The capability to attract funding is fully mediated by the amount of funding requested. In other words, the funding capabilities of Southern European regions is largely explained by a very active proposal activity of these regions.[15]

Discussion

Most analyses on European funding distribution examine success at an aggregate level, which hinders important information. To shed light on differences within each region, we explored variations between the two main R&D sectors (Higher education sector and private sector). Using the lenses of both a regional and a sectoral level enabled us to identify macro-regional patterns that cut across national boundaries or within national boundaries, and that could hardly be identified without considering the sectoral dimension. This element of the analysis is also important given that when defining which 'regions' should be targeted for cohesion policies, the European Commission (EC) has "defined NUTS-2 as the geographical level at which the persistence or disappearance of unacceptable inequalities should be measured" (Boldrin et al., 2001, p. 212). While we acknowledge the current debate and criticism raised towards using NUTS-2 to study European regional development (Fratesi & Wishblade, 2017), this level does serve a political purpose, and is also the level at which available and relevant R&D statistics are found.

The sectoral approach provides a better instrument to assess a region's performance, since a region may be performing well (or bad) in one sector only. The sectoral dimension is important from an intervention logic, as efforts to lift a region should arguably prioritize the sector in which it is underperforming.

The analysis revealed that variations in regional abilities to attract funding in Europe look very different depending on which sector is considered. To the best of our knowledge, no former study has addressed this on such a large-scale dataset as done here. In HES the 'expectation' of European variations in line with notions of scientific excellence was largely confirmed, with strong funding capability in the so-called "blue banana". This is in line with earlier studies about the distribution of publications and citations across Europe (e.g., Hoekman et al., 2013). This pattern has been stable across the two EU FPs.

[14] We ran Sobel Tests for both HES and PRC sectors to assess whether the reduction in the effect of the independent variable after including the mediator in the model was significant and therefore whether the mediation effect was statistically significant (MacKinnon et al., 2002). The mediation is indeed statistically significant for all the significant predictors (results available upon request).

[15] Note that for PRC we excluded the region development dummies as they absorb the other coefficients in the models. A model including the region development dummy and without the other predictors reveals that less developed regions receive more funds through the mediation of funds applied (results available upon request).

The inferential analysis shows that regions' ability to attract funding depends on the level of R&D investments, their research intensity, level of economic development, and the propensity to request funding.

In PRC we observed quite different results, which are easy to visually observe in the maps we have provided. Here, the effect of the level of investment in R&D and the research intensity is negatively associated with the level of funding applied and it is fully mediated by this variable. This implies that affluent, research-oriented regions in the North-West of Europe apply for lesser amount of funding. In other words, regions in for example Germany and south England may be persistently low in their ability to attract EU FP funds because the private sector is already very affluent, investing massive resources in R&D, or because there are good government or industry funding opportunities (Hoekman et al., 2013). In those contexts, going through the selective and time-consuming process of EU FP evaluation might not be worthwhile. In fact, it has been shown for the Nordic countries that R&D intensive (Børing et al., 2019) and highly productive firms (Gustafsson et al., 2020) are less likely to be involved in competitive project funding. Regions in the South of Europe are instead highly capable of attracting EU FP funding due to a very intensive proposal activity, arguably because EU funding is comparatively more desirable, due to both fewer domestic investments and higher purchasing power for the same amount of funds (Seeber et al., 2022a, 2022b). We also observed a negative divergence of Eastern European regions (Fig. 4b), suggesting a marginalized and increasingly peripheral position in PRC European R&D.

General measures of dispersion show that this is stable in HES while it has increased in PRC. At the same time, most of the regions are diverging, in both HES (59%) and PRC (69%).

This points to a crucial point of our study: funding of PRC has become increasingly channeled to regions in the South who already did well in FP7, so that a divergence in PRC, is in fact, through the lenses of the EC's cohesion policy, expressing a European *convergence* of R&D investment (cf. Hoekman, et al., 2013).

We have explored geographical variations in the capability to attract funds in EU FPs, by complementing existing studies in two regards. *First*, earlier studies have employed data on participation in the EU FPs and claimed an increasing involvement of peripheral regions in European research networks, which would contribute to the realization of ERA (Neuländtner & Scherngell, 2020; Scherngell & Lata, 2013; Wang et al., 2017). We have focused on the *depth* of participation and project involvement by using detailed budget numbers and found a more complex picture and mostly evidence of an increased divergence in funding success from FP7 to H2020. *Second,* earlier studies have not considered the sectoral dimension, while our analysis points at strong differences between regions' performance by sector. Funding to HES has remained concentrated in affluent parts of Europe (arguably in line with the excellence-orientation of the EU FPs), whereas funding to private companies has been increasingly channeled to the South of Europe, arguably in line with the cohesion policy of the EU, but the large majority of Eastern European regions have become increasingly less capable to attract funding.

Study limitations and further research

We acknowledge that a comparison of two time periods (2007–2013 and 2014–2020) may be insufficient for any accurate conclusions to be drawn about whether the EU FP funding over time is converging or diverging across regions but believe that comparing two seven-year periods with massive funding, makes a good enough case to at least imply that a diverging trend has taken place.

We have explored how R&D characteristics of a region may help understand its funding success across two EU FPs. There are numerous explanatory variables that could be entered into the analysis, in order to provide a better understanding of *why* regions perform as they do, and why the performance has changed over time. This would require a more in-depth study design on a more delimited set of EU FP thematic areas, compared to ours that spanned all subprograms of two very large and thematically broad areas of research.

It is fully possible that the research profiles of regions match differently with the thematic priorities of the EU FPs; in a similar vein, some regions might be more effective than others in lobbying their specific research priorities, resulting into a more appealing portfolio of EU FP calls. A structural shift in the EU FPs towards market innovation and societal impact (Kropp & Larsen, 2022) may have better fitted with the R&D profiles and capacities of already successful regions. To what extent regional changes in the ability to attract funding have been affected by shifted priorities and allocation criteria from FP7 to H2020, however, is an issue that we have not aspired to investigate in this analysis. In a similar vein, future research can investigate the role of regional specialization, which is an obvious factor in explaining not only funding success, but also funding opportunities. This issue has previously foremost been discussed in relation to the East–West divide of EU member states in EU FPs (Jurajda et al., 2017, p. 327), or that between old and new member states, thus also their regions, which can be understood among many different lines. The two clusters of countries/regions differ on thematic research prioritizations (Kovac et al., 2018; Moya-Anegon & Herrero-Solana, 2013; Pislyakov & Shuksina, 2014; Vinkler, 2018), which may influence on the ability to respond to EU FP calls. They also differ in their technological capability (Fagerberg et al., 2014), which is increasingly important in EU FPs given the strong emphasis on impact and technology readiness levels (TRLs). Technological leading nations and regions do not specialize in a few scientific fields but have highly diverse R&D systems (Cimini et al., 2014), with diversity across both performing sectors and the units in them (Piro, 2019). The clusters also differ in their abilities to be at the research front (Klavans & Boyack, 2008) and in their citation impact (Kozak et al., 2015; Prathap, 2018; Thelwall & Levitt, 2018). Yet, we cannot rule out the possibility that peripheral regions can be advantaged in the EU FPs, as far as the funding opportunities are well aligned to these regions' specializations (Hoekman et al., 2013, p.46). Furthermore, our study did not consider any characteristics of the *institutions* within a region. We do not know whether a region's funding obtained is primarily the result of a small group of leading institutions (prestigious universities, or large, R&D intensive companies), or whether it is more spread across different types of actors within the region. This will have implications for what type of institutions that should be targeted in the EU FPs, and future research should thus explore this by studying the characteristics of the proposal and project participants.

The excellence-cohesion dilemma is highly present in the allocation of EU FU funding. On the one hand, the EU FPs have acknowledged the need to increasingly involve the more peripheral countries and regions of Europe by specifically target such units in programs such as REGPOT and WIDESPREAD. However, such programs represent a very small share of the overall EU FP budgets, and our analyses have clearly demonstrated that more needs to be done to achieve such ambitions. Tensions will nevertheless remain when specific actions are taken to do so, as it would no doubt contrast key ambitions in EU FPs about excellence and economic competitiveness. To some extent, how ambitious instruments one would be willing to suggest launching, will depend on whether one chooses excellence over cohesion. In the former, actions should be taken to ensure that the most R&D intensive institutions and companies in the wealthy regions of Europe step up their interest in taking part in proposal writing (and consequently, EU funded projects). In the latter, efforts should target the involvement of Southern and Eastern European universities, and the PRC sector in Eastern Europe, and calls for funding should increasingly emphasize the involvement of participants from such parts of Europe. However, thinking separately about such priorities may exacerbate tensions and contradictions between them, whereas it could be more beneficial to incorporate a more 'holistic' mindset about the portfolio of instruments, where for example 'excellent' universities or private companies may be stimulated/motivated to include more peripheral partners that could benefit from such cooperation.

Appendix

See Table 3

Table 3 Number of regions per country and availability of Eurostat data at NUTS-2 level

Country (regions)	Eurostat availability: R&D personnel (HES and PRC)	Use of data/regions
AT (9)	Complete	All regions
BE (11)	Only sector numbers for BE10 (other regions only have total numbers)	BE10
BA (1)	Only at national level	National level
BG (6)	BG31 (HES missing)	All regions except BG31 (HES)
HR (2)	Complete	All regions
CY (1)	Complete	All regions
CZ (8)	Complete	All regions
DK (5)	Complete	All regions
EE (1)	Complete	All regions
FI (5)	Complete	All regions
FR (22)	FR10 (only data for 2011–2013)	All regions except overseas territories
DE (38)	Complete	All regions
EL (13)	Complete	All regions
HU (8)	Only 2017 data for HU11 and HU12	All regions
IS (1)	Complete	All regions
IT (21)	Complete	All regions
LV (1)	Complete	All regions
LT (2)	Complete	All regions
LU (1)	Complete	All regions
MK (1)	Complete	All regions
MT (1)	Complete	All regions
ME (1)	Complete	All regions
NL (12)	Available years 2000–2002	All regions
NO (7)	Complete	All regions
PL (17)	PL71, PL72, PL81, PL82, PL84, PL91, PL92 (Only for 2016 and 2017)	All regions
PT (7)	Complete	All regions

Table 3 (continued)

Country (regions)	Eurostat availability: R&D personnel (HES and PRC)	Use of data/regions
RO (8)	Complete	All regions
RS (1)	Only at national level	National level
SK (4)	Complete	All regions
SI (2)	Complete	All regions
ES (19)	Complete	All regions
SE (8)	Complete	All regions
CH (7)	Only data for PRC	Only PRC
UK (38)	Complete	All regions

Funding This paper was supported by the Research Council of Norway (R-QUEST Grant 256223).

Declarations

Conflict of interest The authors declare no conflicts of interest/competing interests.

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