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European R&D networks: A snapshot from the 7th EU Framework Programme

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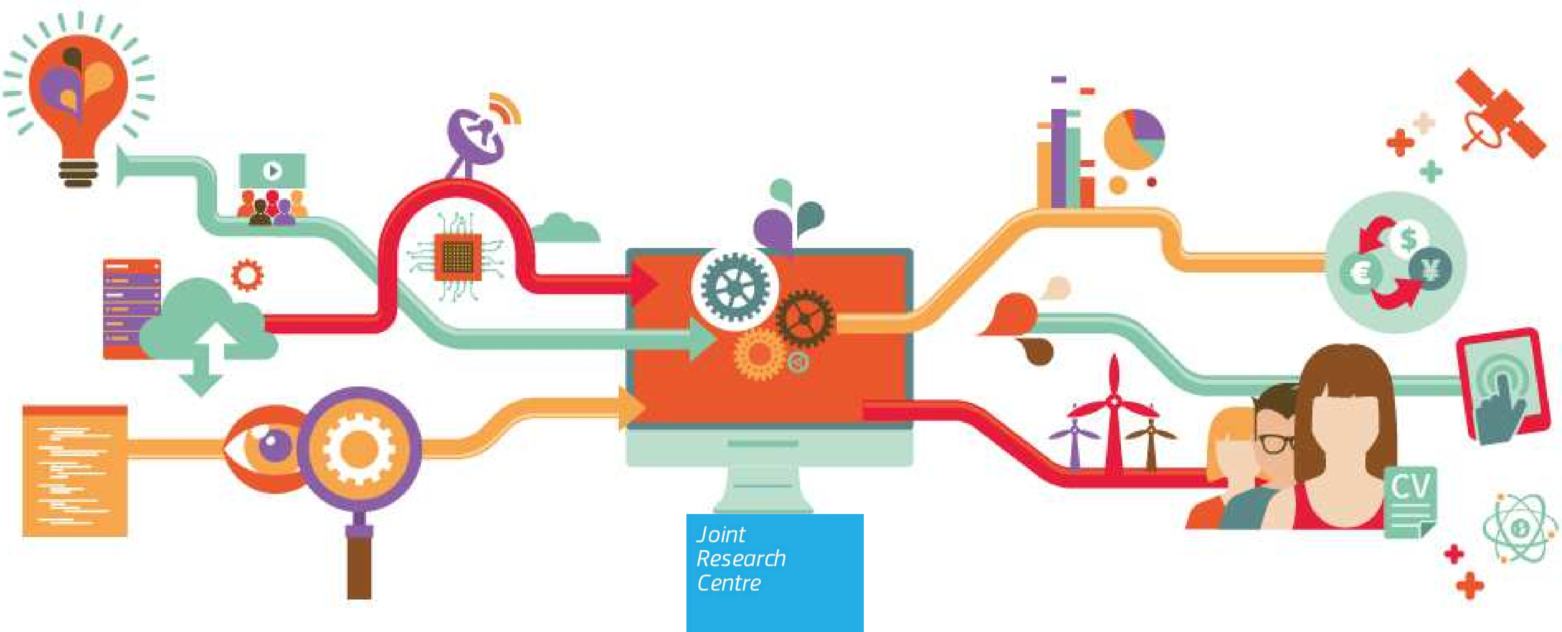

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European R&D networks: A snapshot from the 7th EU Framework Programme

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Abstract

Recent empirical studies have investigated the territorial impact of Europe's research policies, in particular the contribution of the European Framework Programmes to the integration of a European Research Area. This paper deepens the analysis on the integration and participation of peripheral regions, by focusing on the differences in intensity and determinants of inter-regional collaborations across three groups of collaborations. We consider collaborations among more developed regions, between more and less developed regions, and among less developed regions. Building on the recent spatial interaction literature, this paper investigates the effects of physical, institutional, social and technological proximity on the intensity of inter-regional research collaboration across heterogenous European regions. We find that the impact of disparities in human capital and technological proximity on regional R&D cooperation is relevant and differs across subgroups of collaborations. Moreover, despite the efforts of integrating marginal actors, peripheral regions have lower rates of collaborations.

Keywords: European Research Area, spatial interaction modelling, R&D collaboration, regional integration

JEL classification: O38, L14, F15, R15

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1 Introduction

Cooperative agreements for innovation have an important role to play in terms of facilitating specialization across Europe, because they can bring together distant partners and provide them with opportunities to further develop capabilities in their areas of specialization (Hagedoorn et al., 2000). The promotion of consortia between firms, universities, research centres and public entities has gained prospects for further development of Science and Technology Policy in Europe. In particular, cooperative research has been extensively supported through European Framework Programmes.

The Framework Programmes for Research and Technological Development (FP1 through FP7 and Horizon 2020, since 1984) are the European Commission's medium-term planning instruments for research and innovation. In the early 1980s, the first cooperative programmes focussed mainly on ICT and energy, as these were the fields where Europe was losing competitiveness compared to the US and Japan. Over time, the priority of gathering resources and strengthening the capabilities in high-tech fields meshed with the policy objective of achieving economic, social and territorial cohesion. This resulted in the progressive integration of lagging regions to the European research network. Concerns have been raised regarding possible conflicts between the two policy objectives. In fact, supporting the competitiveness by strengthening research and innovation capacities may generate disproportionate benefits for richer regions, given that R&D funds are concentrated in advanced regions as they have a higher density of researchers as a share of employment.[1] In fact, despite the efforts deployed at national and European level, there are still significant internal disparities in terms of research and innovation performance. This is largely due to the lack of industrial, technological and scientific resources needed to achieve critical mass and to develop the sufficient absorptive capacity to participate in the dynamics of innovation in Europe (Cassi et al., 2015).

The European Commission has changed approach to reinvigorate the European research infrastructure and to reflect the most recent theoretical and empirical debate about R&D networks (Breschi and Cusmano, 2004). Since FP6, policy actions are devoted to creation of crucial "centres of excellence", that would act as catalysts for marginal actors within a policy framework aimed at increasing cooperation and bettering knowledge transfer mechanisms. In fact, empirical studies show that the diffusion of knowledge created in centres of excellence may either remain confined to neighbouring territories or prescind from geographical contiguity through relational networks

[1] Eurostat, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=rd_p_persreg&lang=en

(Bresnahan et al., 2001; Maggioni et al., 2007).

However, the instruments introduced in the FP6 —Networks of Excellence (NoE) and Integrated Projects (IP)— were the subject of much attention as they increased the bias towards large consortia (Marimon, 2004) mainly located in the North-West of Europe. On the one hand, Muldur et al. (2007) identify the lack of clarity in the definition of critical mass of human, technological and financial resources as one of the structural weaknesses of the FP6, which might have led to artificial pressure to set up big projects. On the other hand, traditionally it has been argued that when knowledge is tacit, innovation networks are more likely to be geographically bounded (Audretsch and Feldman, 1996; Storper and Venables, 2004), and the propensity for innovative activities to cluster spatially may favour core regions rather than integrating peripheral ones.

The concern regarding the role of large scale agglomerations in regional economic convergence (i.e. the decrease in regional inequalities) has raised substantial interest in the last 20 years, both in academic and political arenas. Much empirical research in this direction has focused on the effect of cohesion policies on inter-regional income convergence (López-Bazo et al., 1999; Ramajo et al., 2008) rather than on the territorial impact of Europe's research policies. More recently, scholars have started investigating the territorial impact of Europe's research policies, in particular the contribution of the FPs to the integration of a European research area (Breschi and Cusmano, 2004; Hoekman et al., 2013; Chessa et al., 2013; Scherngell and Lata, 2013). This new strand of research looks at the impact of European research integration policies from two methodological perspectives. The first is a network analysis perspective (Breschi and Cusmano, 2004; Roediger-Schluga and Barber, 2008; Heller-Schuh et al., 2011; Fracasso et al., 2015). This approach is mainly descriptive and maps the geographical distribution of organizations' joint participation in FP projects, often overlapping the collaboration networks constructed from patent and publication data. Alongside, a growing number of empirical studies has relied on spatial interaction models to address the role of heterogeneity among cooperating partners[2] on the intensity of inter-regional research collaboration across Europe.[3] The existing literature on research integration, however, look at the role of geographical and technological characteristics on the overall collaboration intensity, without delving into the differences across groups of regions.

[2]Networking and cooperation usually involves heterogeneous actors, bringing together their particular knowledge bases, and complementing each other's strengths and capabilities. Cooperating partners will differ in many ways, according to a number of dimensions of distance, such as geographical, institutional, and technological.

[3]See Scherngell, 2013 for a thorough review of the studies.

The main contribution of this paper consists in filling this gap in the literature by dissecting the determinants of inter-regional collaborations across three groups of collaborations, namely, collaborations among more developed regions, between more and less advanced regions, and among less developed regions. Our results show that there is a high degree of persistency in cooperations among close and similar regions. Indeed, not only has the percentage of collaborations involving a lagging region reached a plateau in recent years (between FP6 and FP7), but we also find that the participation of a peripheral region generally hinders the collaboration intensity. These findings play a central role in the discourse on the existing obstacles to the participation of peripheral regions and the challenges for their future integration.

Second, we consider a wider range of determinants of regional R&D cooperation. In addition to the previously considered institutional, cultural and spatial proximity, we include economic and human capital characteristics, and knowledge network proximity. The inclusion of these additional factors may be crucial because, on the one hand, the ability to create joint knowledge depends on innovative capacity and knowledge endowment (skills, level of education, business R&D intensity, etc). Moreover, as innovation increasingly relies on global knowledge flows, territorial aspects of innovation and learning capacity have become a key resource in regional competitive advantage (Autant-Bernard et al., 2007). Griffith et al. (2004) find that human capital has an important effect on rates of both innovation and technology transfer, and stress the key role of regional disparities in innovation, entrepreneurship and human capital. On the other hand, macroeconomic indicators such as GDP per capita allow us to control for regional income disparities. Additionally, geographical proximity between organizations "is neither a necessary nor a sufficient condition for learning to take place: at most, it facilitates interactive learning, most likely by strengthening the other dimensions of proximity" (Boschma, 2005, pp.62). In many cases, other forms of proximity may be more relevant. The capacity of organizations to learn and innovate may be influenced by e.g. social proximity (the degree of personal acquaintance between two actors), as it may stimulate interactive learning due to trust and commitment.

Third, we provide further results on European R&D networks using recent data on the FP7. There are only few publications that analyse FP7 data. Some qualitative studies focus on a specific subset of research projects funded by FP7, i.e. 'COST' networking actions (Rakhmatullin and Brennan, 2014), or on the experiences of specific countries (Albrecht, 2013; Kučera et al., 2013 on the Czech Republic, and Mataković and Novak, 2013 on Croatia). Muldur et al. (2007) provide an ex ante assessment of the FP7 programme. Also, our current analysis complements previous work on the structure of cooperative networks, as our data covers all FP7 projects, and for each project the response rate is almost 100% (whereas other studies have a response rate of only "about 80%"; Scherngell and Barber, 2009).

The remainder of this paper is organized as follows. Section 2 reviews the studies on regional cooperation using FPs data. Section 3 describes the empirical model of regional R&D collaborations. In Section 4, we report detailed information on the data and on the variables' construction. In Section 5, we present and discuss the results. We draw our conclusions in Section 6.

2 Background literature on regional cooperation using FP data

For many years now, the relationship between technological innovation, R&D cooperation and performance has been an important topic in more than one strand of research.

A large part of the empirical literature on innovation cooperation relies on firm-level survey data such as the Community Innovation Surveys (Becker and Dietz, 2004; Veugelers and Cassiman, 2005; Okamuro, 2007), and it had provided evidence on the importance of R&D partnerships and its variation across firms, industries and countries (Audretsch and Link, 2006). Innovation cooperation is measured as a binary variable indicating whether a firm has participated in joint R&D and other innovation projects with other organisations.

Other indicators to measure R&D collaboration are co-publishing, co-patenting and cooperative R&D agreements.[4]

A number of studies analysing collaborative knowledge networks at the regional and national level has focused on co-patenting and co-publishing (Katz, 1994; Ponds et al., 2007; Hoekman et al., 2009) and highlighted the role of geographical and cultural proximity (Boschma, 2005). Studies analyzing collaborative innovation projects at the regional level have been mostly limited to particular countries. Katz (1994) analysed co-publications for UK regions, Liang and Zhu (2002) for Chinese regions, Danell and Persson (2003) for Swedish regions, and Ponds et al. (2007) for Dutch regions. At the European level, a growing empirical literature is confirming the relevance of geograph-

[4] An interesting and alternative approach to the study of cooperative networks can be found in Kauffeld-Monz and Fritsch (2013), who use questionnaire data to get several insights into the patterns and structures of cooperative networks. They discuss "public research's gatekeeper function" and observe that "public research organizations, especially universities, are profoundly involved in knowledge-exchange processes and possess more central (broker) positions within their regional innovation networks than private firms" (p. 669).

ical and institutional distance and finding evidence of heterogeneity between regions and countries in their propensity to collaborate (Hoekman et al., 2010; Maggioni et al., 2007; Hoekman et al., 2009, 2010; Coad et al., 2017).

An ever-growing number of empirical studies investigates the geography of knowledge diffusion relying on the structural characteristics of different European Framework Programme networks.

Framework Programmes are medium-term funding instruments to support scientific research in Europe. The first Framework Programme (FP1) started in 1984 and had a budget of about €4 billion. The succeeding FP's had increasingly larger budgets, reaching over €50 billion for FP7 (2007-2013) and €80 billion for FP8 (Horizon 2020 or H2020, for the period 2014-2020) (Rodríguez et al., 2013).

Collaborative research constitutes by far the largest component of the Framework Programmes. The medium/large collaborative research projects last for 3-5 years and have a minimum of 3-6 participants from different Member States, countries of the European Neighbourhood policy, associated countries or countries with international agreements on Science & Technology [5] and are implemented by transnational consortia composed of firms, universities, and research institutes. Under the various FPs, collaborative research projects in both basic research and applied science have been organised under broad thematic areas, such as Energy, ICT, Health, covering a wide range of S&T priorities.

FP5 received attention from several perspectives. A special issue of 'Science and Public Policy' focused on the evaluation of FP5 (see Arnold et al., 2005; Polt and Streicher, 2005; Guy et al., 2005). The economic geography literature has analysed FP5 data to investigate themes such as international cooperation, the relative strength of geographical versus technological proximity for knowledge transfer, and the potentially deterring role of distance, culture and other barriers (Maggioni et al., 2007; Scherngell and Barber, 2009, 2011; de Clairfontaine et al., 2015). Taking an alternative approach based on economic complexity or 'econophysics', Almendral et al. (2007) contains an advanced statistical analysis of the network of cooperative projects using FP5 data (see also Barber et al., 2006, for advanced 'econophysics'-type statistical analysis on FP1-FP4 data). Finally, Bruce et al. (2004) investigate interdisciplinarity of FP5 projects

[5] Associated Countries: Albania, Croatia, Iceland Israel, Liechtenstein, the Former Yugoslav Republic of Macedonia, Montenegro, Norway, Serbia, Switzerland and Turkey. Countries with EC international agreement on Science & Technology: Argentina, Australia, Brazil, Canada, China, Egypt, India, Japan, Republic of Korea, Mexico, Morocco, New Zealand, Russia, South Africa, Tunisia, Ukraine and the United State of America. Countries of the European Neighbourhood policy: Algeria, Armenia, Azerbaijan, Belarus, Georgia, Jordan, Moldova, Palestinian-administrated areas, Syrian Arab Republic. *Source*: http://www.fp7peoplenetwork.eu/

by taking a qualitative approach based on interviews, questionnaires and case studies.

While most studies have focused on a single FP, other projects have been able to link data from successive Framework Programmes to explore longer term trends. Scherngell and Lata (2013) emphasize the need to investigate dynamic effects, and focus on the period 1999-2006 which includes FP5 and FP6 projects. Rodríguez et al. (2013) investigate the trends relating to the integration of scientific activities with broader societal concerns by analysing project-level solicitations in FP5-FP7 data (up to 2010 only). Other research has shown that participants have higher chances of receiving FP funding when they have already participated in previous FPs (Arnold et al., 2005; Paier and Scherngell, 2011). Some scholars have investigated the effectiveness of FP participation when some participating regions are further from the scientific frontier than others, and the evidence suggests that the returns to FP funding are highest when projects involve some scientifically lagging regions (Hoekman et al., 2013).

Other studies have focused on specific sectors within the Framework Programmes. Pandza et al. (2011) focus on collaborative diversity in the nanotechnology thematic area of FP6, while Barber et al. (2011) perform a network analysis on FP5's main thematic areas. Breschi et al. (2009) focus instead on Information and Communication Technology (i.e. FP6's Information Society Priority).

To obtain information on innovation performance, some scholars have combined FP data with performance data from other sources, such as matching FP5 data with EPO co-patent applications (Maggioni et al., 2007; Sebestyén and Varga, 2013; Varga et al., 2014), or matching FP data with data on enterprises balance sheet information (Caloghirou et al., 2001; Hernán et al., 2003; Kastelli et al., 2004; Protogerou et al., 2012). An interesting contribution that analyses data on Spanish firms (1995-2005) involves investigating the determinants of firm-level participation in FP-funded projects (Barajas and Huergo, 2010), as well as the effects of FP participation on technological capacity and productivity (Barajas et al., 2012). What they found is that R&D cooperation has a positive impact on the technological capacity of firms, which is in turn positively related to their productivity.

3 Empirical framework

3.1 Model of inter-regional R&D collaborations

We model the number of collaborations between pairs of regions as a negative binomial gravity process, using data on joint participation to FP7 projects (LeSage and Pace, 2008).

Let $Y_{ij\tau}$ denote the number of joint participations to an R&D project funded by the FP7 of regions i and j during the time period τ which is the 2007-2013 time interval. The basic spatial interaction (or gravity) regression model takes the form of

$$Y_{ij\tau} = e^{\beta_0} X_{i\tau}^{\beta_1} X_{j\tau}^{\beta_2} \prod_{k=1}^{K} D_{(k)ij\tau-1}^{\delta_k} \epsilon_{ij\tau}, \tag{1}$$

where $X_{i\tau}$ and $X_{j\tau}$ are the origin and destination factors of the interaction. $X_{i\tau}$ is proxied by the aggregate number of collaborations in region i at time τ. Similarly, $X_{j\tau}$ is proxied by the aggregate number of collaborations in region j at time τ. $D_{ij\tau-1}$ is a set of K measures of distance between region i and j during the period $\tau - 1$ referring to the years 2000-2006. $\epsilon_{ij\tau} \sim \Gamma(\alpha)$ is a Gamma distributed disturbance term, where α is an ancillary parameter indicating the degree of overdispersion of the data.

As we are dealing with overly dispersed count data, ordinary least squares estimation approach is not appropriate (Silva and Tenreyro, 2006). Most often, a Poisson model specification is applied (Scherngell and Barber, 2009; Hoekman et al., 2013). However, many regions did not collaborate and the amount of zeros in the dependent variable is larger than assumed for a Poisson distribution. As a result, the conditional variance may be higher than the conditional mean, $Var[Y_{ij}|\cdot] = exp(\alpha)E[Y_{ij}|\cdot]$, which violates the equidispersion property of the Poisson distribution. A common approach to deal with overdispersed data is the negative binomial regression model. Note that, when $\alpha = 0$ the data is equidispersed and a Poisson model is more adequate. We test the hypothesis $\alpha = 0$ using a likelihood ratio test.

We assume that the number of inter-regional R&D collaborations follows a negative binomial distribution, and we can rewrite eq. (1) as the conditional expectation of Y_{ij} as

$$E[Y_{ij\tau}|X_{i\tau}, X_{j\tau}, D_{ij\tau-1}, \epsilon_{ij\tau}] = exp\left[\beta_0 + \beta_1 x_{i\tau} \beta_2 x_{j\tau} + \sum_{i=1}^{K} d_{(k)ij\tau-1}^{\delta_k} + \xi_{ij\tau}\right], \tag{2}$$

where the lower case letters indicate logs, and $\xi = log(\epsilon)$.

While it seems plausible to assume a lack of simultaneity between the set of lagged control variables and the dependent variable, there might still be potential endogeneity deriving from the correlation between the control and omitted variables, say z, that affect the (log-)number of inter-regional collaborations. Our identification strategy rests on the assumption that the information contained in z_τ with respect to $Y_{ij\tau}$ is already contained in $Y_{ij\tau-1}$, i.e. in the number of past collaborations.

3.2 Data and descriptive statistics

For our analysis, we focus on all the collaborative research projects among $i = 1, \ldots, n = 270$ NUTS 2 regions[6] of the EU28 Member States financed during the period 2007-2013 under FP7. To obtain additional information of regional characteristics, we merge the aggregate number of collaborations per region (NUTS 2) from FP7 data [7] with Eurostat NUTS 2-level data to assess how regional measures of centrality and proximity are related to the participation to FP7 projects.

Inter-regional collaboration

To construct our dependent variable, i.e. inter-regional collaboration, we follow previous studies (e.g. Scherngell and Lata, 2013) and fill in the n–by–n matrix of regional collaborations by counting as regional links all the possible links between participants to a project. For example, if a project has three participants from three different regions —i, j and k— we count three inter-regional links (i and j, j and k, i and k). If, within the same projects, there are two participants from region i and one from region j, this counts as two collaborations between i and j, that is, we do not account for intra-regional collaboration. The matrix $\mathbf{C}$ of regional collaborations is constructed as

$$\mathbf{C} = \begin{pmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ y_{n1} & y_{n2} & \cdots & y_{nn} \end{pmatrix}$$

where the diagonal elements of $\mathbf{C}$, y_{ii}, represent the intra-regional collaborations, whereas the off-diagonal elements $y_{ij}, i \neq j$ contain the number of inter-regional R&D collaborations between region i and region j for all region pairs. To give an example, if region 1 corresponds to Burgenland (AT11 in NUTS 2) and region 2 corresponds to Lower Austria (AT12), then the matrix element y_{12} (or y_{21}) represents the number of times that organizations from these two regions participated to the same R&D projects (in this example, y_{12}=2).

The matrix $\mathbf{C}$ has a total of 270×270 (72900) elements. For our analysis, we consider

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[6] We refer to the Nomenclature of territorial units for statistics (NUTS) adopted till 2010 (EUROSTAT, 2011)

[7] We access the FP7 project database through CORDA — the common research data warehouse. CORDA is the FP's central repository of data collected and/or derived during the course of FP implementation. It is managed by DG RTD J5 as the system owner and DG RTD J4 as the IT system supplier. It is publicly available at https://data.europa.eu/euodp/en/data/dataset.

only the off-diagonal elements of the lower triangular matrix, as these represent the inter-regional R&D collaborations. The resulting number of matrix elements is then $\frac{270\times 270-270}{2} = 36315$.

In contrast to the previous empirical literature, we distinguish inter-regional collaboration according to the different level of development of the regions. Similarly to the definition adopted by the European Commission, we name a region "more developed" (labelled "More") if its level of GDP per capita is higher than 90% of the EU average, and "less developed" (labelled "Less") if its GDP per capita is below this GDP threshold. This distinction yields 150 more developed regions and 120 less developed regions.[8]

Table 1: R&D collaboration among European regions (2007-2013)

All regional links	Matrix elements †	Total number of collaborations	Mean	Median	SD	Min	Max
More/More	11175	485985 (76%)	43	11	122	0	3310
More/Less	18000	142249 (22%)	7.9	2	20	0	536
Less/Less	7140	13574 (2%)	1.9	0	4.9	0	93
All regions	36315	641808 (100%)	18	2	71	0	3310
Non-zero links							
More/More	9566	485985	51	15	130	1	3310
More/Less	11752	142249	12	5	23	1	536
Less/Less	3064	13574	4.4	2	6.7	1	93
All regions	24382	641808	26	6	85	1	3310

† The number of matrix elements refers to the off-diagonal lower triangular matrix. The total number of intra-collaborations, not reported in the table, is 164208.

Table 1 reports some descriptive statistics for our dependent variable. 80% of all collaborations are inter-regional collaborations (i.e., 20% of cooperations are within the same regions). The majority of inter-regional collaborations take place among more developed regions, although there is also a significant share of collaborative research agreements established between more and less developed regions (22% of the total).

[8] The 90% threshold is the same used by the European Commission to define different priorities of the EU's regional policy. For this priority setting, a further distinction is done between 'transition" (between 75% and 90%) or "less developed" (less than 75%) regions, resulting in 49 transition regions and 71 less developed regions. Further differentiating between transition and less developed regions may lead to important dynamic considerations in terms of their rates of development, as well as their improvement in innovation capability over time, and will be an avenue for future research.

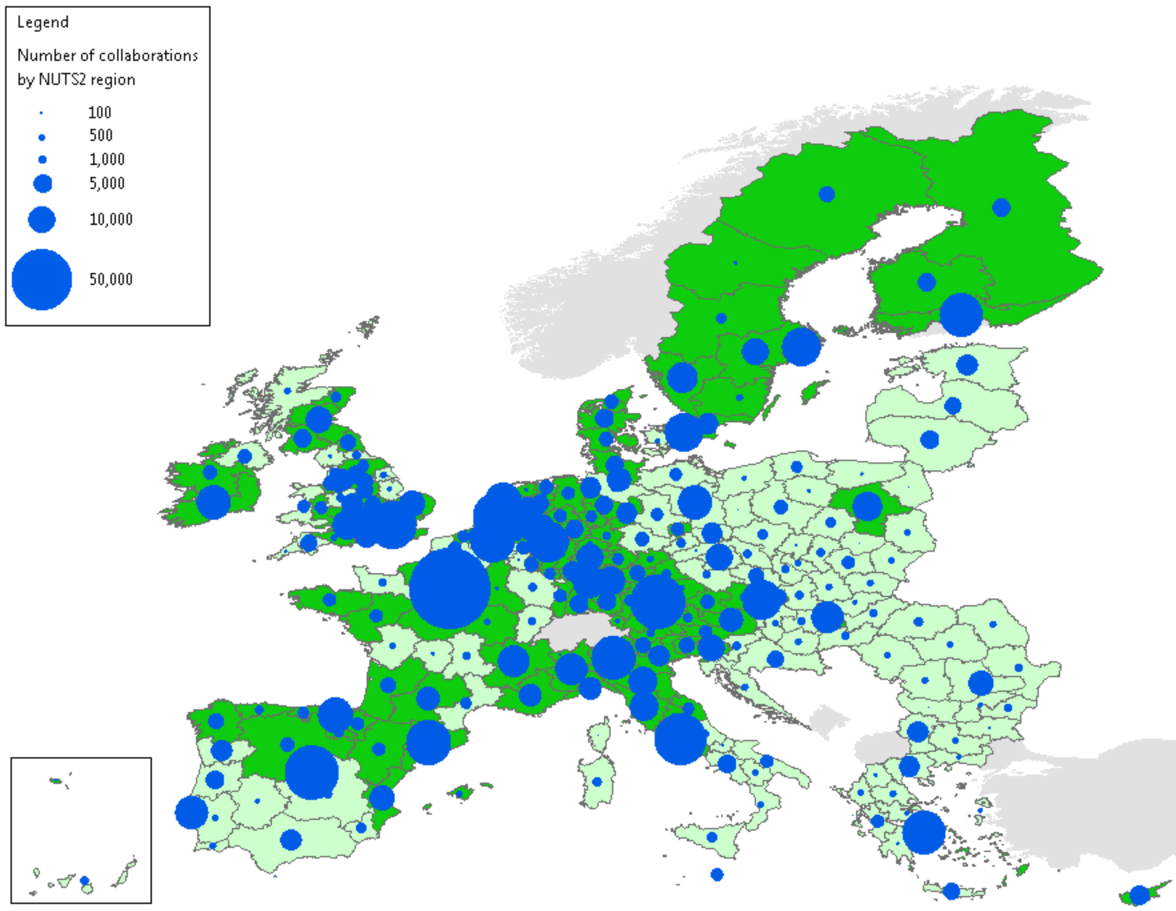

Figure 1: Distribution of R&D collaboration intensity across European regions (2007-2013, more developed regions are in dark green)

Fig. 1 displays the geographical distribution of the intensity of inter-regional collaborations. The two levels of economic development are reported as different-colored areas (light and dark green), while the intensity of collaborations is portrayed as circles with size that is proportional to the number of collaborations per region. The number of R&D joint projects is concentrated mainly in more developed regions.

Independent variables

Among the determinants of R&D collaborations, we considered three sets of variables.

The first group of determinants falls under the category of geographical effects and include the geographical distance between two regions, and the peripherality of the cooperating regions. The geographical distance (GEO_{dist}) is constructed taking the Euclidean distance between the regions' centroids in thousands of kilometers. To control for existence of a polarised 'core-periphery' structure of the European innovation system, we adopt a different approach from previous studies,[9] and use the aggregate number of patents per region to control for marginality in a scientific sense (Evangelista et al., 2017). In particular, the dummy *periphery* takes value 1 if at least one of the regions has a number of patents smaller than the 75^{th} percentile.[10]

Table 2: Summary statistics (all regions)

	Variables	mean	sd	min	max
Geographical Effects	GEO_{dist}	1.41	1.34	0.01	13.42
	periphery	0.94	0.24	0	1
Institutional & Economic Effects	GDP_{dist}	9.14	8.03	0.00	67.35
	neighbour	0.02	0.12	0	1
	international	0.93	0.26	0	1
Knowledge & Social Effects	$TECH_{dist}$	0.78	0.23	0.03	1.41
	HC_{dist}	7.98	5.89	0.00	36.74
	$COOP_{FP6}$	14.23	57.18	0	2997

The second set of determinants aims at controlling for institutional, economic, and cultural effects. In particular, to proxy the distance in terms of economic development, GDP_{dist}, we use the log of the difference in the GDP levels of two regions, taking data from the EUROSTAT database for the period 2000-2006 and used for each region the average GDP per capita in PPP of the period. To account for institutional and language barriers, as well as the possible clashes between national policy schemes, we take two dummy variables, *international*, that takes value 1 if the two regions are not in the same country, and *neighbour*, which takes value 1 if there is a common border between regions [11].

The third set of determinants accounts for a wide range of knowledge proximity

[9]Scherngell and Lata (2013) define the marginality in a geographic sense, where a region is defined peripheral if it is not the location of the capital city of a country. Maggioni et al. (2007) consider the distance from Brussels, arguing that regions that are far from Brussels are disadvantaged.

[10]For robustness, in appendix we report additional estimates from two alternative measures of periphery. The dummy periphery_{PUBS} takes value 1 if at least one of the two regions has a number of scientific publications smaller than the 75^{th} percentile. The dummy $\text{periphery}_{CAPITAL}$ is defined as in Scherngell and Lata (2013), where the dummy takes value 1 if at least one of the regions does not host the capital city of the country.

[11]In an early specification of the model we included also a dummy for common language between two regions. We finally decided to take it out because it was not significant once we put in the dummy *neighbour* in.

Table 3: Averages by regional group

	Variables	More/More	More/Less	Less/Less
Geographical Effects	GEO_{dist}	1.02	1.52	1.76
	periphery	0.83	0.99	1.00
Institutional & Economic Effects	GDP_{dist}	6.54	12.18	5.52
	neighbour	0.02	0.01	0.02
	international	0.90	0.95	0.93
Knowledge & Social Effects	$TECH_{dist}$	0.76	0.78	0.81
	HC_{dist}	6.46	9.66	6.24
	$COOP_{FP6}$	34.28	6.73	1.77

Note: All averages across regional groups are statistically different from each other at the 1%-level, apart from the difference between More/More and Less/Less in the percentage of collaborating regions that are neighbours.

measures, as we consider both technological and human capital proximity, as well as social proximity. The technological proximity among regions, $TECH_{dist}$ is calculated using patent data for the period 2000-2006 taken from the OECD Patstat database. For each region, we first calculated its technological profile as the share of patent applications filed at International Patent Office (IPO) by inventors located in each NUTS2 region for each technological subclass (International Patent Classification, IPC). We then took the correlations between pairs of technological profiles. We obtain an index, ρ, that goes from 1 (strongly positively correlated technological profile) to -1 (strongly negatively correlated technological profile), with a value of 0 if two regions have uncorrelated technological profiles. The technological distance is then calculated as $1 - \rho$ to obtain a measure of distance that goes from 0 (positively related technological profiles) to 2 (negatively related technological profiles). The human capital distance, HC_{dist}, is the difference in percentage of population with tertiary education employed in science and technology. We took the data from the EUROSTAT database for the period 2000-2006 and used for each region the average of the period. Finally, to proxy social proximity, i.e. the degree of personal acquaintance between two regions (Balland et al., 2015), we use the number of previous collaborations between two regions in the previous round of the framework program (FP6)[12], $COOP_{FP6}$.

Table 2 shows the summary statistics for all the independent variables. For example,

[12] The participation to FP6 was open also to actors based in candidate countries that would have entered the EU in 2004 or 2007

the average geographical distance between two partnering regions is 1410 kilometers, and 94 percent of collaborations included at least one peripheral region. On average, only 2 percent of the collaborations was among regions that shared a border, while 93 percent of regional cooperation was international. Table 3 reports the averages of our sets of control variables by regional group. On average, the distance among more developed regions is smaller than the distance between more and less, or between less and less developed regions. The GDP distance (in logs), the human capital distance, and the percentage of international collaborations are the highest between the mixed group of collaborating regions (More/Less). The technology distance gradually increases from 0.76 (More/More) to 0.81 (Less/Less), indicating that less developed regions are less technologically related both to the more advanced region and among them. Finally, the average number of previous collaborations is also decreasing with the number of participating less developed regions (34 for More/More, 7 for More/Less, and 2 for Less/Less, approximately). Compared to the average numbers of collaborations during FP7 (Table 1), we see that, while the average number of collaborations increased (from 34 to 43) between more advanced regions, it remained fairly stable for the other two groups of regions (8 and 2 during FP7 and 7 and 2 during FP6 for More/Less and Less/Less, respectively).

4 Estimation results and discussion

Results from the spatial interaction model described in Section 3 confirm the importance of geographical, institutional, technological, and social proximities on research collaboration.

Table 4 reports the estimated coefficients for the entire sample of regional collaborations. The table is organized in three columns. The first column displays the estimation results from a specification similar to other studies that have used previous FP data (Scherngell and Barber, 2011; Scherngell and Lata, 2013; de Clairfontaine et al., 2015 to name a few). In line with these studies, we find a negative effect of geographical distance and institutional/language barriers. Also, economic distance and technological similarity have the expected negative and positive signs, respectively. The larger the distance in terms of log-GDP per capita, the lower the expected count of collaborations, while the more technologically similar two regions, the higher the expected number of collaborations. The regression coefficients can be interpreted as elasticities or semi-elasticities if the control variable is measured in levels. For example, in column 1, for an additional thousand kilometers distance, the expected number of collaborations decreases by 29.1 percent; an increase by 1% in the distance in log-GDP corresponds to a 2.4% decrease in collaborations. The interpretation for the coefficients of dummies (periphery, international, and neighbour) is however different. In this case, exponentiating the coefficients yields the incidence rate ratios (IRR), which give interpretable coefficients for dummy variables. For example, peripheral regions are expected to have 30% ($1-exp(-0.356) = 0.299$) fewer collaborations than central regions. Collaborating with a region located in another country results in 14.3% ($1 - exp(-0.154) = 0.143$) fewer collaborations than collaborating with a region that is located in the same country. Finally, partnering regions that share a border have 52.5% ($exp(0.422) = 1.525$) more collaborations than regions that do not.

When introducing human capital distance (column (2)), the impact of geographical distance significantly drops from 29.1 to 12.1 percent. This may be due to the presence of geographical clusters that have similar availability of human capital. The distance in the share of population with a tertiary degree and/or employed in science and technology is significant and negative. In particular, a one percentage point increase in this distance corresponds to a decrease in inter-regional cooperations by 1%. The effect of social proximity (column (3)) is quite relevant, as for every additional ten projects in the past, the expected log number of regional cooperations increases by four percent. This could be due to the fact that previous cooperation between pairs of regions increases the trust, reduces the uncertainty and some of the initial fixed costs to set up a pre-competitive cooperative agreement.

Table 5 reports the results for the three subsamples of collaborations among pairs of regions. At first glance, one can see heterogeneity in the determinants of cooperation across the subsamples.

The negative coefficients of the geographical and GDP distance confirm that the closer two regions are —both in geographic and economic terms— the higher the number of collaboration links they share, especially for cooperations among less developed regions.

The relation between the participation of a peripheral region and the collaboration intensity is negative for cooperations among more developed regions, and between more and less developed regions. In particular, teaming up with a peripheral participating region decrease the average number of collaborations by 27% for pairs of more developed regions (23% for cooperations between a more and a less developed region). However, when collaborating among less developed regions, the inclusion of a peripheral region increase the collaboration intensity by 468%, approximately 4.7 times more collaborations than without a peripheral region.

Table 4: Negative binomial estimation results (all regions)

Dep.var.: number of collaborations	(1)	(2)	(3)
$o_i = d_i$	0.138***	0.135***	0.122***
	(0.001)	(0.001)	(0.001)
GEO_{dist}	-0.291***	-0.121***	-0.115***
	(0.006)	(0.008)	(0.008)
periphery	-0.356***	-0.396***	-0.354***
	(0.021)	(0.020)	(0.020)
GDP_{dist}	-0.024***	-0.021***	-0.020***
	(0.001)	(0.001)	(0.001)
international	-0.154***	-0.263***	-0.267***
	(0.021)	(0.021)	(0.021)
neighbour	0.422***	0.465***	0.433***
	(0.040)	(0.040)	(0.040)
TECH_{dist}	-0.165***	-0.139***	-0.142***
	(0.022)	(0.022)	(0.022)
HC_{dist}		-0.010***	-0.009***
		(0.001)	(0.001)
COOP_{FP6}			0.005***
			(0.000)
constant	1.473***	1.503***	1.507***
	(0.032)	(0.032)	(0.032)
$ln\alpha$	0.390***	0.339***	0.329***
	(0.007)	(0.007)	(0.007)
Observations	71,584	64,317	64,317
ll	-197950	-186127	-185974
Pseudo R2	0.139	0.135	0.135

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Negative binomial estimation results by collaboration groups

Dep. var.: number of collaborations	More/More	More/Less	Less/Less
$o_i = d_i$	0.095***	0.068***	0.355***
	(0.001)	(0.001)	(0.010)
GEO_{dist}	-0.104***	-0.033***	-0.125***
	(0.012)	(0.011)	(0.020)
periphery	-0.316***	-0.256***	1.544***
	(0.019)	(0.061)	(0.523)
GDP_{dist}	-0.004***	-0.015***	-0.012***
	(0.001)	(0.001)	(0.004)
international	-0.106***	-0.330***	-0.698***
	(0.027)	(0.032)	(0.057)
neighbour	0.424***	0.365***	0.681***
	(0.050)	(0.074)	(0.076)
TECH_{dist}	0.006	-0.100***	-0.173***
	(0.030)	(0.030)	(0.063)
HC_{dist}	-0.011***	-0.003**	-0.003
	(0.002)	(0.001)	(0.003)
COOP_{FP6}	0.002***	0.052***	0.071***
	(0.000)	(0.001)	(0.004)
constant	1.797***	1.270***	-1.696***
	(0.038)	(0.069)	(0.524)
$ln\alpha$	-0.006	0.190***	0.056*
	(0.011)	(0.011)	(0.029)
Observations	21,904	31,367	11,046
ll	-84473	-79224	-16590
Pseudo R2	0.122	0.120	0.145

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Cultural/institutional barriers hamper the collaborations, especially among pairs of less developed regions, which seem to be more susceptible to cultural, institutional, political barriers, as coefficients of 'international' and 'neighbour' are the highest (in absolute value) in this group.

Technological distance has a significant and negative effect only for cooperations among more/less and less/less developed regions, while it has a neutral effect on the cooperation among more developed areas. This might be in part because pairs of regions with a higher level of development have already a more similar technological profile (see Table 2). Conversely, the distance in human capital matters the most for pairs of more developed regions, while has no effect on pairs of less developed ones. Finally, the social proximity plays a bigger role for the cooperative projects among less developed regions (an increase in cooperations by 71% for every ten past additional projects).

In further robustness analysis, we explored the sensitivity of our results to alternative indicator for peripheral regions, based on either the performance of the region in terms of number of scientific publications, or the presence of a capital city in the region. Both of these indicators — in terms of number of scientific publications (Table 6) or presence of a capital city (Table 7) — show that peripheral regions have fewer collaborations (and the coefficients are highly statistically significant). The coefficients for the other variables are barely affected by the change of periphery indicator. We also repeated the baseline analysis of collaboration groups (in Table 5) with these two alternative indicators of peripheral regions (see Tables 8 and 9), and the results are overall similar.

5 Conclusions

The more recent EU policy approach encourages regional actors to identify their competitive advantages (i.e. to pursue a smart specialisation strategy) in an international setting and to network in order to tap into knowledge sources located outside of the region (Foray et al., 2009; McCann and Ortega-Argilés, 2015; Kyriakou et al., 2016). In this context, this paper contributes to the debate on the engagement of peripheral regions into collaborative research networks and factors that promote or hamper their participation. We used a series of proxies to estimate the impact of different kinds of distances on the probability of two regions to establish an R&D collaboration.

Our analysis suggests that all the distances considered —geographical, economic, technological, social and human capital— matter. Finding that 'distance matters' is not a surprising result and is in line with previous empirical studies (Ghemawat, 2001; Olson and Olson, 2003; Maggioni and Uberti, 2009). What is remarkable is that distances still matter. Despite more than 30 years of Framework Programmes, an integrated European Research Area is still far from been reached. The results provide us a scenario where regions collaborate more among them if they are similar. There appears to exist a certain path dependency when it comes to regional R&D collaborations. FP programs have created a dense network of regional partnerships, but this is a network mainly among close and similar regions, with a high degree of persistence over time. Essentially the network is getting deeper rather than broader.

Splitting the sample according to the level of economic development of the regions gave us two further insights. First, distance matters differently for different regions. The number of collaborations among less developed regions is the most affected by distance. Only a quarter of all collaborations established under FP7 involve at least one lagging region. This percentage has not significantly changed compared to FP6. Moreover, for collaborations including at least one developed region, FP7 does not seem to have succeeded in stimulating the participation of marginal regions, as we find that the participation of a peripheral region hinders the collaboration intensity. Second, technological similarity does not affect the number of collaborations among more developed regions, while it does when the regions collaborating are one more/one less or both less developed. This can be interpreted as seeking technological complementarity when two developed regions are involved, looking for similarity otherwise.

Future research could complement our focus on pan-European FP7 research funding by examining national research funding schemes for collaborative research, and investigating how country-level schemes (or their absence) may interact with EU-level schemes such as FP7, particularly with regards to the inclusion of peripheral regions. Furthermore, inter-regional collaborations are not independent from intra-regional collaborations (Sun and Cao, 2015), and future work could better investigate their coevolution. Another promising line for future research would be to complement the insights from the empirical literature (which has mainly focused on quantitative analysis of large datasets) with insights from interviews of stakeholders such as project managers, to get new perspectives into why peripheral regions have low participation rates.[13] Finally, the difference we observed in the collaboration patterns according to the level of development of the regions involved calls for more targeted policies in the future (Foray and Steinmueller, 2003).

There is a potential tension between the policy goals of promoting excellence among

[13]We are grateful to an anonymous reviewer for these interesting suggestions.

leading regions, on the one hand, and integrating peripheral regions, on the other. Researchers and policy-makers need to have a better understanding of how to make these two policy goals better coordinated and mutually supportive. A clear policy implication emerging from our analysis is the need to reorient Framework Programmes in the future in order to promote collaborations among actors who would not have collaborated otherwise. If the goal is still to widen the European research area, including actors and regions that are peripheral, we suggest that future FPs should seek to create collaborations among regions that did not collaborate in the past, rather than further strengthening existing ties.

References

Albrecht, V. (2013). The Czech Republic in FP7: Low participation with high collaborative excellence. *Ergo*, 8(1):3–8.

Almendral, J. A., Oliveira, J., López, L., Sanjuán, M. A., and Mendes, J. (2007). The interplay of universities and industry through the FP5 network. *New Journal of Physics*, 9(6):183.

Arnold, E., Clark, J., and Muscio, A. (2005). What the evaluation record tells us about European Union Framework Programme performance. *Science and Public Policy*, 32(5):385–397.

Audretsch, D. B. and Feldman, M. P. (1996). R&D Spillovers and the Geography of Innovation and Production. *The American Economic Review*, 86(3):630–640.

Audretsch, D. B. and Link, A. N. (2006). Empirical evidence on knowledge flows from research collaborations: Introduction to the special issue. *Economics of Innovation and New Technology*, 15(1):1–3.

Autant-Bernard, C., Mairesse, J., and Massard, N. (2007). Spatial knowledge diffusion through collaborative networks. *Papers in Regional Science*, 86(3):341–350.

Balland, P.-A., Boschma, R., and Frenken, K. (2015). Proximity and innovation: From statics to dynamics. *Regional Studies*, 49(6):907–920.

Barajas, A. and Huergo, E. (2010). International R&D cooperation within the EU Framework Programme: empirical evidence for Spanish firms. *Economics of Innovation and New Technology*, 19(1):87–111.

Barajas, A., Huergo, E., and Moreno, L. (2012). Measuring the economic impact of research joint ventures supported by the EU Framework Programme. *The Journal of Technology Transfer*, 37(6):917–942.

Barber, M. J., Fischer, M. M., and Scherngell, T. (2011). The community structure of research and development cooperation in Europe: evidence from a social network perspective. *Geographical Analysis*, 43(4):415–432.

Becker, W. and Dietz, J. (2004). R&D cooperation and innovation activities of firms Evidence for the German manufacturing industry. *Research policy*, 33(2):209–223.

Boschma, R. (2005). Proximity and Innovation: A Critical Assessment. *Regional Studies*, 39(1):61–74.

Breschi, S., Cassi, L., Malerba, F., and Vonortas, N. S. (2009). Networked research: European policy intervention in ICTs. *Technology Analysis & Strategic Management*, 21(7):833–857.

Breschi, S. and Cusmano, L. (2004). Unveiling the texture of a European Research Area: emergence of oligarchic networks under EU Framework Programmes. *International Journal of Technology Management*, 27(8):747–772.

Bresnahan, T., Gambardella, A., and Saxenian, A. (2001). 'Old Economy' Inputs for 'New Economy' Outcomes: Cluster Formation in the New Silicon Valleys. *Industrial and Corporate Change*, 10(4):835.

Bruce, A., Lyall, C., Tait, J., and Williams, R. (2004). Interdisciplinary integration in Europe: the case of the Fifth Framework programme. *Futures*, 36(4):457 – 470.

Caloghirou, Y., Tsakanikas, A., and Vonortas, N. S. (2001). University-industry cooperation in the context of the European framework programmes. *The Journal of Technology Transfer*, 26(1-2):153–161.

Cassi, L., Gallié, E.-P., and Merindol, V. (2015). Core and periphery in scientific networks: Evidence from european inter-regional collaborations, 2000-2011. Technical report, DRUID.

Chessa, A., Morescalchi, A., Pammolli, F., Penner, O., Petersen, A. M., and Riccaboni, M. (2013). Is Europe evolving toward an integrated research area? *Science*, 339(6120):650–651.

Coad, A., Amoroso, S., and Grassano, N. (2017). Diversity in one dimension alongside greater similarity in others: evidence from fp7 cooperative research teams. *The Journal of Technology Transfer*, pages 1–14.

Danell, R. and Persson, O. (2003). Regional R&D activities and interactions in the Swedish Triple Helix. *Scientometrics*, 58(2):203–218.

de Clairfontaine, A. F., Fischer, M. M., Lata, R., and Paier, M. (2015). Barriers to cross-region research and development collaborations in Europe: evidence from the fifth European Framework Programme. *The Annals of Regional Science*, 54(2):577–590.

EUROSTAT (2011). Regions in the European Union. Nomenclature of territorial units for statistics. NUTS 2010/EU-27.

Evangelista, R., Meliciani, V., and Vezzani, A. (2017). Specialisation in key enabling technologies and regional growth in europe. *Economics of Innovation and New Technology*, 0(0):1–17.

Foray, D., David, P. A., and Hall, B. (2009). Smart specialisation–the concept. *Knowledge economists policy brief*, 9(85):100.

Foray, D. and Steinmueller, E. (2003). On the economics of R&D and technological collaborations: Insights and results from the project colline. *Economics of Innovation and New Technology*, 12(1):77–91.

Fracasso, A., Grassano, N., and Vittucci Marzetti, G. (2015). The Gravity of Foreign News Coverage in the EU: Does the Euro Matter? *JCMS: Journal of Common Market Studies*, 53(2):274–291.

Ghemawat, P. (2001). Distance still matters. *Harvard business review*, 79(8):137–147.

Griffith, R., Redding, S., and Van Reenen, J. (2004). Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries. *The Review of Economics and Statistics*, 86(4):883–895.

Guy, K., Amanatidou, E., and Psarra, F. (2005). Framework Programme 5 (FP5) impact assessment: A survey conducted as part of the five-year assessment of European Union research activities (19992003). *Science and Public Policy*, 32(5):349–366.

Hagedoorn, J., Link, A. N., and Vonortas, N. S. (2000). Research partnerships. *Research Policy*, 29(4):567–586.

Heller-Schuh, B., Barber, M., Henriques, L. M., Paier, M., Pontikakis, D., Scherngell, T., Veltri, G., Weber, M., et al. (2011). Analysis of Networks in European Framework Programmes (1984-2006). Technical report, Institute for Prospective and Technological Studies, Joint Research Centre.

Hernán, R., Marín, P. L., and Siotis, G. (2003). An empirical evaluation of the determinants of Research Joint Venture Formation. *The Journal of Industrial Economics*, 51(1):75–89.

Hoekman, J., Frenken, K., and Tijssen, R. J. (2010). Research collaboration at a distance: Changing spatial patterns of scientific collaboration within Europe. *Research Policy*, 39(5):662–673.

Hoekman, J., Frenken, K., and van Oort, F. (2009). The geography of collaborative knowledge production in Europe. *The Annals of Regional Science*, 43(3):721–738.

Hoekman, J., Scherngell, T., Frenken, K., and Tijssen, R. (2013). Acquisition of European research funds and its effect on international scientific collaboration. *Journal of Economic Geography*, 13(1):23–52.

Kastelli, I., Caloghirou, Y., and Ioannides, S. (2004). Cooperative R&D as a means for knowledge creation. Experience from European publicly funded partnerships. *International Journal of Technology Management*, 27(8):712–730.

Katz, J. (1994). Geographical proximity and scientific collaboration. *Scientometrics*, 31(1):31–43.

Kauffeld-Monz, M. and Fritsch, M. (2013). Who Are the Knowledge Brokers in Regional Systems of Innovation? A Multi-Actor Network Analysis. *Regional Studies*, 47(5):669–685.

Kučera, Z., Vondrák, T., and Frank, D. (2013). R&D collaboration of the EU countries with partners beyond the EU group. *Ergo*, 8(1):9–16.

Kyriakou, D., Martínez, M. P., Periáñez-Forte, I., and Rainoldi, A. (2016). *Governing Smart Specialisation*. Routledge.

LeSage, J. P. and Pace, R. K. (2008). Spatial econometric modeling of origin-destination flows. *Journal of Regional Science*, 48(5):941–967.

Liang, L. and Zhu, L. (2002). Major factors affecting China's inter-regional research collaboration: Regional scientific productivity and geographical proximity. *Scientometrics*, 55(2):287–316.

López-Bazo, E., Vayá, E., Mora, J. A., and Suriñach, J. (1999). Regional economic dynamics and convergence in the European Union. *The Annals of Regional Science*, 33(3):343–370.

Maggioni, M. A., Nosvelli, M., and Uberti, T. E. (2007). Space versus networks in the geography of innovation: A European analysis. *Papers in Regional Science*, 86(3):471–493.

Maggioni, M. A. and Uberti, T. E. (2009). Knowledge networks across Europe: which distance matters? *The Annals of Regional Science*, 43(3):691–720.

Marimon, R. (2004). Evaluation of the effectiveness of the New Instruments of Framework Programme VI. High-level expert panel reports, European Commission.

Mataković, H. and Novak, I. R. (2013). Croatia's participation in the Seventh Framework Programme: a Moderate Success? *Business Systems Research*, 4(2):126–143.

McCann, P. and Ortega-Argilés, R. (2015). Smart specialization, regional growth and applications to European Union cohesion policy. *Regional Studies*, 49(8):1291–1302.

Muldur, U., Corvers, F., Delanghe, H., Dratwa, J., Heimberger, D., Sloan, B., and Vanslembrouck, S. (2007). *A new deal for an effective European research policy: The design and impacts of the 7th framework programme*. Springer Science & Business Media.

Okamuro, H. (2007). Determinants of successful R&D cooperation in Japanese small businesses: The impact of organizational and contractual characteristics. *Research Policy*, 36(10):1529–1544.

Olson, G. and Olson, J. (2003). Mitigating the effects of distance on collaborative intellectual work. *Economics of Innovation and New Technology*, 12(1):27–42.

Paier, M. and Scherngell, T. (2011). Determinants of collaboration in European R&D networks: Empirical evidence from a discrete choice model. *Industry and Innovation*, 18(1):89–104.

Pandza, K., Wilkins, T. A., and Alfoldi, E. A. (2011). Collaborative diversity in a nanotechnology innovation system: Evidence from the EU Framework Programme. *Technovation*, 31(9):476–489.

Polt, W. and Streicher, G. (2005). Trying to capture additionality in Framework Programme 5 main findings. *Science and Public Policy*, 32(5):367–373.

Ponds, R., Van Oort, F., and Frenken, K. (2007). The geographical and institutional proximity of research collaboration. *Papers in regional science*, 86(3):423–443.

Protogerou, A., Caloghirou, Y., and Siokas, E. (2012). Twenty-five years of science-industry collaboration: the emergence and evolution of policy-driven research networks across Europe. *The Journal of Technology Transfer*, 38(6):873–895.

Rakhmatullin, R. and Brennan, L. (2014). Facilitating innovation in European research area through pre-competitive EU-funded COST Actions. *Journal of Innovation and Entrepreneurship*, 3(1):1–20.

Ramajo, J., Márquez, M. A., Hewings, G. J., and Salinas, M. M. (2008). Spatial heterogeneity and interregional spillovers in the European Union: Do cohesion policies encourage convergence across regions? *European Economic Review*, 52(3):551–567.

Rodríguez, H., Fisher, E., and Schuurbiers, D. (2013). Integrating science and society in European Framework Programmes: Trends in project-level solicitations. *Research Policy*, 42(5):1126–1137.

Roediger-Schluga, T. and Barber, M. J. (2008). R&D collaboration networks in the European Framework Programmes: Data processing, network construction and selected results. *International Journal of Foresight and Innovation Policy*, 4(3-4):321–347.

Scherngell, T. (2013). *The geography of networks and R&D collaborations*. Springer.

Scherngell, T. and Barber, M. J. (2009). Spatial interaction modelling of cross-region R&D collaborations: Empirical evidence from the 5th EU Framework Programme. *Papers in Regional Science*, 88(3):531–546.

Scherngell, T. and Barber, M. J. (2011). Distinct spatial characteristics of industrial and public research collaborations: evidence from the fifth EU Framework Programme. *The Annals of Regional Science*, 46(2):247–266.

Scherngell, T. and Lata, R. (2013). Towards an integrated European Research Area? Findings from Eigenvector spatially filtered spatial interaction models using European Framework Programme data. *Papers in Regional Science*, 92(3):555–577.

Sebestyén, T. and Varga, A. (2013). Research productivity and the quality of interregional knowledge networks. *The Annals of Regional Science*, 51(1):155–189.

Silva, J. S. and Tenreyro, S. (2006). The log of gravity. *The Review of Economics and statistics*, 88(4):641–658.

Storper, M. and Venables, A. J. (2004). Buzz: face-to-face contact and the urban economy. *Journal of Economic Geography*, 4(4):351–370.

Varga, A., Pontikakis, D., and Chorafakis, G. (2014). Metropolitan Edison and cosmopolitan Pasteur? Agglomeration and interregional research network effects on European R&D productivity. *Journal of Economic Geography*, 14(2):229–263.

Veugelers, R. and Cassiman, B. (2005). R&D cooperation between firms and universities. Some empirical evidence from Belgian manufacturing. *International Journal of Industrial Organization*, 23(5):355–379.

Alternative measures of periphery

Table 6: Negative binomial estimation results (all regions). Repeating Table 4 using an alternative indicator for peripheral regions, based on number of publications.

Dep.var.: number of collaborations	(1)	(2)	(3)
$o_i = d_i$	0.138***	0.135***	0.122***
	(0.001)	(0.001)	(0.001)
GEO_{dist}	-0.308***	-0.139***	-0.132***
	(0.006)	(0.008)	(0.008)
periphery_{PUBS}	-0.536***	-0.596***	-0.573***
	(0.019)	(0.020)	(0.020)
GDP_{dist}	-0.026***	-0.024***	-0.023***
	(0.001)	(0.001)	(0.001)
international	-0.191***	-0.312***	-0.310***
	(0.021)	(0.021)	(0.021)
neighbour	0.372***	0.411***	0.384***
	(0.040)	(0.040)	(0.040)
TECH_{dist}	-0.182***	-0.158***	-0.160***
	(0.022)	(0.022)	(0.022)
HC_{dist}		-0.008***	-0.007***
		(0.001)	(0.001)
COOP_{FP6}			0.005***
			(0.000)
constant	1.729***	1.779***	1.793***
	(0.033)	(0.034)	(0.033)
$ln\alpha$	0.380***	0.327***	0.316***
	(0.007)	(0.007)	(0.007)
Observations	71,584	64,317	64,317
ll	-197950	-186127	-185974
Pseudo R2	0.140	0.136	0.137

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Negative binomial estimation results (all regions). Repeating Table 4 using an alternative indicator for peripheral regions, based on whether a region includes a capital city.

Dep.var.: number of collaborations	(1)	(2)	(3)
$o_i = d_i$	0.139***	0.137***	0.126***
	(0.001)	(0.001)	(0.001)
GEO$_{dist}$	-0.308***	-0.155***	-0.147***
	(0.006)	(0.008)	(0.008)
periphery$_{CAPITAL}$	-1.092***	-1.028***	-0.909***
	(0.046)	(0.045)	(0.045)
GDP$_{dist}$	-0.027***	-0.025***	-0.024***
	(0.001)	(0.001)	(0.001)
international	-0.208***	-0.313***	-0.308***
	(0.021)	(0.021)	(0.021)
neighbour	0.387***	0.421***	0.401***
	(0.040)	(0.040)	(0.040)
TECH$_{dist}$	-0.176***	-0.148***	-0.147***
	(0.021)	(0.022)	(0.022)
HC$_{dist}$		-0.009***	-0.009***
		(0.001)	(0.001)
COOP$_{FP6}$			0.004***
			(0.000)
constant	2.146***	2.108***	2.012***
	(0.007)	(0.007)	(0.051)
$ln\alpha$	0.382***	0.333***	0.326***
	(0.051)	(0.051)	(0.007)
Observations	71,584	64,317	64,317
ll	-197715	-185973	-185879
Pseudo R2	0.140	0.135	0.136

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Negative binomial estimation results by collaboration groups. Repeating Table 5 using an alternative indicator for peripheral regions, based on number of publications.

Dep. var.: number of collaborations	More/More	More/Less	Less/Less
$o_i = d_i$	0.096***	0.069***	0.353***
	(0.001)	(0.001)	(0.010)
GEO_{dist}	-0.137***	-0.043***	-0.121***
	(0.012)	(0.011)	(0.020)
periphery_{PUBS}	-0.373***	-0.445***	0.553***
	(0.020)	(0.042)	(0.201)
GDP_{dist}	-0.008***	-0.016***	-0.012***
	(0.001)	(0.001)	(0.004)
international	-0.143***	-0.349***	-0.690***
	(0.027)	(0.032)	(0.056)
neighbour	0.379***	0.348***	0.686***
	(0.050)	(0.073)	(0.076)
TECH_{dist}	-0.009	-0.112***	-0.168***
	(0.030)	(0.030)	(0.063)
HC_{dist}	-0.010***	-0.001	-0.003
	(0.002)	(0.001)	(0.003)
COOP_{FP6}	0.002***	0.051***	0.073***
	(0.000)	(0.001)	(0.004)
constant	1.937***	1.490***	-0.722***
	(0.040)	(0.058)	(0.218)
$ln\alpha$	-0.011	0.184***	0.056*
	(0.011)	(0.011)	(0.029)
Observations	21,904	31,367	11,046
ll	-84425	-79172	-16590
Pseudo R2	0.122	0.120	0.145

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9: Negative binomial estimation results by collaboration groups. Repeating Table 5 using an alternative indicator for peripheral regions, based on whether a region includes a capital city.

Dep. var.: number of collaborations	More/More	More/Less	Less/Less
$o_i = d_i$	0.099***	0.069***	0.354***
	(0.001)	(0.001)	(0.010)
GEO_{dist}	-0.156***	-0.039***	-0.125***
	(0.012)	(0.011)	(0.020)
$\text{periphery}_{CAPITAL}$	-0.429***	-0.361***	-0.073
	(0.051)	(0.073)	(0.204)
GDP_{dist}	-0.007***	-0.016***	-0.012***
	(0.001)	(0.001)	(0.004)
international	-0.139***	-0.346***	-0.688***
	(0.027)	(0.032)	(0.056)
neighbor	0.408***	0.361***	0.688***
	(0.051)	(0.073)	(0.076)
TECH_{dist}	0.008	-0.098***	-0.174***
	(0.030)	(0.030)	(0.063)
HC_{dist}	-0.012***	-0.003**	-0.003
	(0.002)	(0.001)	(0.003)
COOP_{FP6}	0.002***	0.051***	0.071***
	(0.000)	(0.001)	(0.004)
Constant	2.040***	1.306***	-0.261
	(0.059)	(0.082)	(0.029)
$ln\alpha$	0.005	0.189***	0.057**
	(0.011)	(0.011)	(0.214)
Observations	21,904	31,367	11,046
ll	-84574	-79220	-16593
Pseudo R2	0.121	0.120	0.145

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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