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Exploring European-funded project-based networks in ICT and their links with regional total factor productivity: the FP7 and the CIP

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Abstract

The research evaluation community has devoted multiple efforts to analyze the effects of Framework Programmes. However, there is little empirical evidence on their impact on economic performance. This paper presents an empirical analysis of the research project-based networks created by 7th Framework Programme (FP7) in the field of Information and Communication Technologies (ICT) and investigates their links with regional total factor productivity (TFP). For comparison purposes, the diffusion network created by the Competitiveness and Innovation Framework Programme (CIP) is also studied. Our results allow us to assess whether (or not) there are any common patterns in the research and diffusion links established by regions in these two European-supported networks and evaluate their (potentially) different connection with productivity. We use tools from Social Network Analysis and, specifically, the novel measure of bridging centrality, which takes into account territories' internal microstructure.

1. Introduction

The European Union (EU)'s Research and Development (R&D) policy has been shaped by its Framework Programmes (FPs) for Research and Technological Development. The FPs have been the most important source of funding for R&D activities across the EU. Besides, they have driven the development of transnational “networks of human capital and organizational learning so as to develop the capacity and capabilities of the innovation systems” (Arnold 2012, p.334), which ultimately contribute to economic growth. Hence, the European R&D policy in general and FPs, in particular, “do not only serve to foster technological innovation but influence the full economic, environmental and social development of the Union” (García-Muñiz and Vicente 2018, p.1134).

The research evaluation community has made numerous efforts to analyze FPs, exploring patterns of participation (European Commission 2016a) and their related outcomes and impacts (Arnold 2012; Muscio, Rid and Rivera-León 2015).

A strand of research has focused on the formation of knowledge networks within the FPs (Heller-Schuh et al. 2011) and studied the dynamics of research collaborative links, the (relative) position of actors and the corresponding outcomes in terms of the co-authorship of scientific papers and patents (Di Cagno et al. 2016).

Of special interest has been the empirical analysis of regional R&D networks, distinguishing between project-based, co-patent, and co-publication networks (Scherngell 2019) and the corresponding knowledge flows across them (Breschi et al. 2009; Paier and Scherngell 2011).¹ Recent studies have paid attention to the effects that FPs' regional knowledge networks have on technological specialization (Cifforilli and Muscio 2018). While all this literature suggests the positive impact of FPs on the creation of R&D networks, there is comparatively less empirical evidence on the extent to which these networks have enhanced regional economic performance (Arnold 2012; Cassi et al. 2008; Muscio, Rid and Rivera-León 2015; Piirainen 2018) and, in particular, have provided the basis for sustained productivity growth. This scarce evidence contrasts with the fact that one of the expected impacts of FPs is to boost the growth of total factor productivity, by creating more knowledge outputs (European Commission 2016b)².

In addition, the economic impact of the participation in FPs has been generally evaluated by taking into account the amount of funding or the number of projects, but not considering collaborative links, that have been widely used to evaluate the production of knowledge outputs (i.e., patents, scientific papers). The aim of this paper is to contribute to research evaluation studies by filling this gap in the literature: it complements the line of research that evaluates the economic effects derived from the participation in EU-funded programmes. Using Social Network Analysis and the concept of bridging centrality (Bergé, Wanzenböck and Scherngell 2017), we analyze the regional project-based networks created by some of these programmes. We focus on the links, as channels to access to external knowledge resources and explore their connection with total factor productivity (TFP).

Specifically, we study the project-based network of the 7th Framework Programme (FP7). We focus on this programme since FPs are the main tools of the EU to support research and the FP7 was an essential piece in the achievement of Lisbon's economic goals (Cassi et al. 2008). The EU has implemented other tools and programmes to support collaborative

¹ See Scherngell (2019) for a review of regional R&D collaboration networks.

² Although disparities in the total factor productivity (TFP) levels are linked to many influencing factors, R&D spending and innovations have a key role (Dettori, Marrocu and Paci 2012). The positive or negative effect of these factors on TFP growth is sensitive to the type of innovation and the critical mass previously being in the region (Lopez-Rodriguez and Martinez-Lopez 2017).

R&D, however their relative importance (both in terms of the number of participants and resources involved) is less compared to the FP.³ In particular, we look at collaboration in field of Information and Communication Technologies (ICT) given the potential of these technologies to boost productivity throughout the economy (Bresnahan and Trajtenberg 1995). Additionally, we examine the project-based network created by the ICT action of the Competitiveness and Innovation Framework Programme (CIP), which addressed ICT diffusion in small-and-medium sized enterprises (SMEs). The CIP is an interesting programme because, being contemporaneous of the FP7, it focused on diffusion while the latter focused on research. As Edquist et al. (2018, p. 207) indicate the “efficient diffusion of innovations is often much more important for development and growth than being the lead innovator”. This is especially important for territories economically lagging behind which cannot afford to involve in pure innovation efforts that tend to characterize by high uncertainty, risk and large time lags.⁴ Hence, by examining these two project-based networks, we will be able to identify whether there are any common patterns in the collaborative relationships established and to assess their (potentially) different links with TFP. To complement this view, we also consider the participation in other regional funds, such as European Structural and Investment Funds (ESIF).

This analysis is particularly pertinent at the present when the guidelines for the FP9 are being defined and the importance of an impact-focused approach is highlighted (Stirbat 2017) along with the need to keep the pace of the new digitalization trends (i.e. industry 4.0, big data) to foster TFP and, hence, sustained growth (Gal et al. 2019). The remainder of the paper is as follows: next section presents the conceptual framework, followed by the description of the network methodological approach and data sources; then, we present results; and finally, we draw some concluding remarks.

2. Conceptual framework: Knowledge networks, TFP and ICT

³ These other programmes are: ERA-Nets, Joint Technology Initiatives (JTIs), Knowledge and Innovation Communities (KICs), Public-Public-Partnerships, Joint Programming Initiatives (JPIs), European Innovation Partnerships (EIPs), ERA Chairs, and Teaming and Twinning for excellence and innovation, among others (Uyarra, Sörvik and Midtkandal 2014).

⁴ In fact, the full realization of the economic potential of ICT requires complementary investments (Marsh et al. 2017), which might delay the impacts of ICT on TFP both at macro and micro levels (Edquist and Henrekson 2017).

With science becoming increasingly complex and interdisciplinary, it is widely acknowledged that research collaboration has become crucial. When two researchers collaborate, not only do they provide their individual expertise to produce a final output, but they also exchange ideas, information and learn from each other (Graf and Kalthaus 2018). Hence, the creation of research networks around project teams generates organizational, transnational and disciplinary abilities, which are influential in technological diffusion (Phelps, Heidl and Wadhwa 2012).

Regional studies have long highlighted the importance of regions' participation in collaborative research networks (Lee and Bozeman 2005). Not only are important the collaborative links among the agents within the region (Storper and Venables 2004) but also external collaborations (Boschma 2005; Breschi and Lenzi 2013). Successful innovation trajectories need to combine "local buzz" and global knowledge pipelines (Bathelt, Malmberg and Maskell 2004). Collaboration with international partners opens up new access to global knowledge networks, what facilitates the use of a wide varied pool of knowledge assets, different from the one owned (Rogers, Bozeman and Chompalov 2001). This access to external knowledge stimulates regional knowledge process (Wazenböck et al. 2015), and significantly contributes "to the overall regional knowledge production output" (Hidas et al., 2013 p.330), which, in turn, will foster TFP growth⁵.

Nonetheless, the external links of a region might not provide it with the same information and opportunities for accessing knowledge flows and hence, might not have the same relevance for knowledge production and ultimately, for TFP growth. Hence, improving

⁵⁵ Recent modelling developments have put attention on R&D as a collective and collaborative process, and on how this collaboration can lead to TFP growth (Varga et al. 2020). TFP has been generally recognized as the main driver of long-term economic growth, accounting "for most of the income and growth differences" across territories (Easterly and Levine 2001, p.177). Such importance has led economists to develop theories and models that identify the drivers and the corresponding paths towards TFP growth. Together with the role played by human capital and institutions to explain TFP (Easterly and Levine 2001), endogenous growth theories have highlighted the importance of R&D for economic growth. R&D activities can rise TFP in at least two main ways: on the one hand, research generates innovations that widen the variety of goods, increasing productivity (Romer 1990); on the other hand, from Schumpeterian view argues that innovations lead to new products of superior quality which replace the old ones and raise productivity (Aghion and Howitt 1998). Moreover, R&D spurs absorptive capacity which is also an important determinant of TFP growth (Griffith, Redding, and Van Reenen 2003).

A recent paper by Varga et al. (2020) presents a model in which regional TFP is a function of human capital, entrepreneurship and knowledge production, which depends on both the current stock of knowledge and the access to external sources through the participation in international research networks (i.e. FPs).

knowledge production (and hence increasing TFP) not only depends on the number of external links to achieve “critical potential”, but also on the extent to which they provide access to “variety” of knowledge resources (European Commission 2012; Broekel et al. 2015). In this sense, the role of regions that act as bridges in collaborative research networks, i.e., they connect groups of other regions not directly connected between them, has been generally emphasized in the literature (Dotti and Spithoven 2017; Kauffeld-Monz and Fritsch 2013; Howells 2006). Not only do these regions have access to varied knowledge but also, they have control over the knowledge flows from/to other regions. Hence, regions in a bridging position may gain some competitive advantage because of their control over knowledge flows. Such advantage might translate into more efficiency in regional knowledge outputs production and, eventually, higher TFP growth.

Within this context, ICT is a technological field of particular relevance due to its character as general purpose technologies (fast pace of technological change, pervasive nature and potential to boost innovation throughout the economy) (Bresnahan and Trajtenberg 1995). All these features along with their widespread diffusion have made ICT especially attractive as source of efficiency gains and TFP growth (OECD 2003). On the one hand, the use of ICT can rise efficiency through organizational and managerial improvements (i.e. improved communication, reduction of transaction costs...). On the other hand, the rapid technological progress of the ICT producing sector itself spurs TFP.⁶ In addition, this sector is characterized by strategic research partnerships through which firms combine their knowledge pools and skills in order to increase the efficiency of their knowledge productions. Moreover, ICT can generate spillover effects since “ICT networks within and between firms also facilitate the rollout of new business ideas and processes” (OECD 2013, p.19). There might be also positive network externalities arising from the increase in the number of users.

Given the economic relevance of these technologies, both ICT diffusion and research through collaborative projects have become key priorities for the EU (European Commission

⁶ The ICT sector includes the software industry which is characterized by marginal costs close to zero (once created, the cost of replication is almost zero) and “non-rivalry”, i.e. it can be used simultaneously by many users. As the OECD (2013, p.28) indicates “this can lead to increasing returns to scale in production, the property that makes ideas and knowledge an engine of growth”.

2009).⁷ This paper then tries to assess the relationship between some of the EU-funded collaborative efforts in the field of ICT and regional TFP.

3. Methodology and data

The present analysis relies on Social Network Analysis (SNA). On the one hand, this methodological approach has been extensively applied to study partnerships in FP projects (Barber, Fischer and Scherngell 2011; Breschi et al. 2009; Cassi et al. 2008; Cecere and Corrocher 2015; Crespo, Suire and Vicente 2015; Di Cagno et al. 2016; Must 2010; Scherngell and Lata 2013; Wanzenböck, Scherngell and Lata 2015). On the other hand, it is part of the collection of methods used by the European Commission to assess the qualitative and quantitative results of FPs (European Commission 2016c). A proper application of this methodology for research evaluation “requires something more than identification and description of networks”; rather, it is necessary to pay attention to examine network’s ability to expand the uses of knowledge (Rogers, Bozeman and Chompalov 2001, p.171).

3.1 Network analysis: Bridging centrality

Concept

A network can be defined as a set of nodes (either individuals, firms, regions or countries) linked by some relational tie. In this sense, research networks would be those in which nodes are connected by some collaborative research relation. In the particular case of analysis, the nodes are regions participating in the FP7/CIP, which would be linked by organizations collaborating in the same ICT research projects. Network analysis allows us to discover the pattern of relationships and the flows of knowledge between network members⁸. Such flows depend not only on the direct relationship to each other, but also on their relationships to everyone else.

⁷ Several papers have previously studied the development of FP-based ICT research networks. Special attention has been devoted to their characteristics and dynamics (Protegeru, Caloghirou and Siokas 2010), complementarities with diffusion networks and links with regional innovation systems (Cassi et al. 2008), the connections with global networks (Breschi et al. 2009). In addition, the academic literature has also studied the determinants of the intensity of regional cooperation (Cecere and Corrocher 2015), the impact of FP funding on ICT-related knowledge outputs (i.e., ICT patents, Varga and Sebestyén 2017) and the effects of projects’ organizational diversity on innovation potential (Nepelski and Piroli 2018), among others. Nonetheless, little has been done on the potential economic effects of these networks (Muscio, Rid and Rivera-León 2015).

⁸ See Feldman and Langford (2019) for a recent review of spillover research under network theory.

A vast variety of network measures has emerged along the years to analyze the links of the nodes in a network. Degree, eigenvector, closeness and betweenness are some popular measures. However, when applied to regional networks, these measures are not able to fully assess the two dimensions of regional links, i.e., internal links and interregional links.⁹

The measure of centrality, proposed by Bergé, Wanzenböck and Scherngell (2017), allows us to properly assess within and between regions links in R&D networks. Their measure is based on the concept of bridging paths or bridging agents: a node can be considered as a bridging agent when it acts as an intermediate in the linkages among groups without direct linkages between them. Hence, a region would have a bridging position within the network when it builds a bridge between regions which are not directly connected (Bergé, Wanzenböck and Scherngell, 2017). This idea can be associated with the concept of knowledge broker in the sense that regions in bridging positions have an advantaged structural situation both for the access and the diffusion of diverse knowledge, since they control knowledge flows from/to other regions. “The triangulation in networks is a key issue for knowledge recombination and the extension of an actor’s knowledge base” (Bergé, Scherngell and Wanzenböck, 2017, p. 1031). Therefore, a bridging region plays a crucial role for these other regions (in order) to access to external knowledge inputs and avoid the constraints imposed by their own resources and structural features.

There are two main reasons why the use of the measure of bridging centrality (BC) is especially suitable (rather than other forms of centrality) for the analysis of regions’ collaborative links and for connecting this indicator with regional TFP. In the first place, it allows to properly assess interregional research links distinguishing them from those intra-regional while other network measures do not. As explained in section 2, successful R&D efforts increasingly depend on the capacity to access to external pools of knowledge and skills.

Especially in science-related fields, the participation in interregional knowledge networks might allow to complement a region’s low own skills (Wanzenböck, Neuländtner

⁹ For example, let us consider a region having a degree value of 2, that is, it has two direct links. This value could correspond to two completely different situations: the two direct links refer to internal (within region) links, or both of them could be interregional (between regions) links.

and Scherngell, 2020). Moreover, this external access is crucial to refrain from negative path dependence effects (Sanz-Ibáñez, Lozano and Clavé 2019) such as those that characterize European lagging regions. Männasoo, Hein and Ruubel (2018, p.1599) highlight the existence of strong path dependencies across European regions “as a very weak starting position in the level of TFP had an adverse effect on further productivity convergence”. Then, by means of the measure of bridging centrality we will be able to properly explore the link between regions’ capacity to access to external knowledge resources. Moreover, to the extent to which the bridging centrality captures interregional connections, it is coherent with the European regional strategy, which highlights the need for an “outward orientation” in research alliances and partnerships to “overcome fragmentation and lack of critical mass and facilitate access to research capacity, production expertise and finance that can be locally scarce” (European Commission 2012, p.5).

In the second place, the measure of bridging centrality takes into account the variety of links. Specifically, the more varied the collaboration links, the more diverse the knowledge that can be accessed. Hence, identifying the variety of links is especially relevant in the case of European networks. Previous research has shown that FP-based collaboration tends to take place among those who have already collaborated (see Balland et al. 2019 for a review of the collaborative research networks in EU). Therefore, as a result of being involved in a large number of research projects, a region can have a large number of external links, but all of them could be with the same organizations (regions); then, the access to variety will be limited. BC allows to capture such a feature, while other centrality measures do not.¹⁰

Analytically, bridging centrality is measured from a weighted network where region i and j are linked by an edge if they have organizations that have been partners in at least one project (Breschi et al. 2009). In this network the nodes are the regions and the edges are the research relationships established between them in the context of FP7/CIP projects. Then, the centrality of a region i ($i=1,\dots,n$), based on the number of bridging actors (BC_i), is calculated as follows (Bergé, Wanzenböck and Scherngell 2017):

$$BC_i = q_i s_i (1 - h_i) \quad (1)$$

¹⁰ Results on other networks measures are available from the authors upon request.

Where the number of bridges depends on the following three elements: (i) the participation intensity (q_i) in R&D projects, defined as the number outer links, that is, the total number of links of i excluding region-internal; (ii) the relative outward orientation (s_i), calculated as the ratio between the number of region's outer (interregional) links and its total number of links; and (iii) the diversification of network linkages ($1-h_i$), where h_i is the Herfindahl-Hirschman (HH) index¹¹.

The higher the number of internal links, the lower participation intensity, and the larger concentration in the links, the less likely the region is to have links with other territories and establish bridges with third regions.

This measure of bridging centrality (BC_i) takes positive values with no upper bound. To make easier its interpretation, Bergé, Wanzenböck and Scherngell (2017) normalize it between 0 and 1.¹²

3.2. Data

Our analysis uses four types of data sources. In the first place, data come from the European Commission (2015) databases on ICT projects funded under the FP7 and the CIP. Specifically, two databases were prepared by European Commission's Directorate General for Communication Networks, Content and Technology (DG CNECT) to track some of the most important EU-funded programmes in the area of ICT. They include data on projects financed by the FP7-ICT Programmes Cooperation and Capacities (e-infrastructures) and the CIP Information Communication Technologies Policy Support Programme (ICT-PSP), respectively.¹³ The former database includes projects signed from 2007 till 2013, the latter from 2008 till 2013.

The most popular databases in the literature to analyze EU-funded R&D networks are CORDIS open data portal (<https://cordis.europa.eu/>) or the more advanced database RISIS-

¹¹ See Bergé, Wanzenböck and Scherngell 2017 for further details on the methodology.

¹² Formally, the measure is normalized as follows: $\frac{(BC_i - BC_{\min})}{(BC_{\max} - BC_{\min})}$. See Bergé, Wanzenböck and Scherngell

(2017) for more details on the methodology.

¹³ Both databases are freely available to download from the following website: <https://ec.europa.eu/digital-single-market/en/news/ict-research-projects-under-eus-seventh-framework-programme-fp7>

EUPRO (<https://www.risis2.eu/risis-datasets/>, see Heller-Schuh et al. 2019 for a complete description of this database; and Wanzenböck, Neuländtner and Scherngell 2020 for a recent application). These detailed databases contain information about all EU-funded programs, including all thematic areas. These databases only include projects in the ICT field as considered by the European Commission, which allows to avoid the problem about the identification of thematic areas when these are not pre-defined in the database^{14,15}. In the FP7 and the CIP ICT databases, a record is generated for each organization that has participated in a project. Each record includes detailed information about the organization (partner id, legal name, role, type of organization, funding, city, country, and region -the latter identified by its NUTS2 code-) and the corresponding project (number, acronym, year of signature, duration, call description, instrument and strategic objective). Using these data and given that regions are the focus of our analysis, we extracted a table that linked regions with projects. For each project, identified for its number and acronym, we examined the participant organizations, the corresponding address that appear on the database, and the assigned region. Review process of regions' NUTS coding was done in order to detect any possible data inconsistencies. In particular, for some organizations there was no information on the region where they were located. In those cases, if there was information about the city, then we looked for the region to which it belonged. If there was no information about the city or if it lacked of precision to properly identify the region (e.g. when the city was London, either the region Inner London or Outer London could apply), we searched the Internet to get further information about the location.

Specifically, we checked both the project and organization's websites to find the address. Once all this information was collected and the region had been identified, these

¹⁴ We have manually checked whether the analyzed databases correspond to project information in CORDIS open data portal. Projects under the Cooperation programme are fairly easy to identify since they mainly correspond to those obtained with the filter FP7-ICT in CORDIS. Projects under the Capacities (e-infrastructure) and the CIP ICT-PSP programmes both require much more detailed queries in CORDIS and to carefully examine the contents of each project to identify whether it belongs to the ICT field.

¹⁵ Funding in FP7-ICT is organized around eleven key R&D areas, representing the European eleven challenges to turn into a world leader in next generation ICT systems. 1: Pervasive and Trusted Network and Service Infrastructures; 2: Cognitive Systems and Robotics; 3: Alternative Paths to Components and Systems; 4: Technologies for Digital Content and Languages; 5: ICT for Health, Ageing Well, Inclusion and Governance; 6: ICT for a low carbon economy; 7: ICT for the Enterprise and Manufacturing; 8: ICT for learning and access to cultural resources; 9: FET; 10: International cooperation; 11: Horizontal actions. These challenges are disaggregated into 24 different strategic objectives.

data were imputed in the database. In addition, for each country we checked that the number of NUTS identified in the database corresponded with the real number. We found some countries where numbers did not match, e.g., Slovenia has two NUTS2 regions but four had been found in the database, because of different coding (SI01, SI02, SI03, SI4). In such cases we proceeded to standardize the codes.

One limitation of these data sources is that they do not include information about the proper teams that are involved in the research projects and, consequently, in the network. Moreover, the geographical registration of the participants is attributed to the legal address of their headquarters and not the place where R&D activities actually take place. Nonetheless, it is a standard practice in the literature to work at project (organization/regional) levels without strictly considering the real team involved and to geographically assign projects to the address of organization's headquarters (Cassi et al. 2008, among others).

Secondly, we have collected data on total factor productivity in European regions. The collection of TFP data is quite a difficult issue since most official statistics are published at country level (OECD 2019) and only isolated regional statistics can be found for particular countries. In our case, data on TFP come from Beugelsdijk, Klasing and Milionis (2018). Using the development accounting methodology, these authors have computed TFP across European NUTS2 regions for the year 2007. Their sample of analysis mostly corresponds to ours. The only difference is that they have not considered in their analysis those countries which are not disaggregated into NUTS regions due to their size (e.g. Cyprus). According to Beugelsdijk, Klasing and Milionis (2018, p. 462), TFP captures “regional differences in technological sophistication and production efficiency”. These authors find that regions along the London–Amsterdam–Munich–Milan corridor show the highest TFP values, while the lowest values are recorded in peripheral Eastern European regions, particularly in Bulgarian and Romanian regions.

Thirdly, we have collected data from the measure of regional structural similarity developed by Navarro et al. (2014) for the European Commission.

Once the BC scores have been computed and the links with TFP have been explored, we have tried to gather further insights by focusing on whether (or not) regions at the Top and Bottom, respectively, have any common structural characteristics. Any successful

innovative process depends upon the local structural conditions. Given that there are several theoretical models about the factors that define a region's structural conditions and none of them is universally accepted (Soete and Corpakis 2003), we have used the afore-mentioned regional structural similarity measure which has been developed as a supporting tool for the design of regional policy. Its aim is to allow the identification and comparison of homogeneous regions across the EU. It integrates the various approaches in the literature by considering the range of factors identified by the different theoretical models. Specifically, it includes a series of social, economic and geographical characteristics, for which interregional distances are computed and summarized. Then, for each EU's region, this measure allows to identify those structurally similar. It is important to bear in mind that, since it is a synthetic measure, it has all the advantages but also the disadvantages of any composite indicator: while it allows to summarize complex and multidimensional phenomena and it is easier to interpret than a battery of indicators, it does not allow to assess the particular structural features in which regions are more similar to. In addition, this measure is not symmetrical in the sense that if region A is found to be structurally similar to region B, the opposite may not be true. The reason for this is that for each region the measure evaluates the distances to all other regions; then, when measuring the distance between B and all other regions, it could be that A is not among the closest.

Finally, to provide an overview of the participation in other regional funds, data on other regional programs funded by the EU during the period 2007-2013 have also been collected (European Commission 2019b, c). In particular, we have looked at the European Structural and Investment Funds (ESIF): the European Regional Development Fund (ERDF), the European Social Fund (ESF) and the Cohesion Fund (CF).¹⁶ Attention has been paid both to the total amount of funding received and to the priority areas of the major projects funded in Top and Bottom regions in bridging centrality.

There is an essential difference between ESIF and FP7 and CIP funds. While the former are given to regions on some predefined criteria, the latter are won by research organizations (institutions, companies) through competitive calls based on excellence criteria. Furthermore,

¹⁶ The European Structural and Investment Funds also include the European Agricultural Fund for Rural Development (EAFRD). This fund has not been considered for our analysis since its area of action is barely related to ICT.

the aims also differ. While FP7 and CIP are oriented to knowledge generation and innovation diffusion in specific areas that are of interest for the EU, ESIF funds have the goal of regional development and are allocated to those regions able to use them for building or reinforcing their knowledge-based capabilities (Uyarra, Sörvik and Midtkandal 2014).

4. Results

4.1. Regional FP7 and CIP networks of ICT projects

Table 1 presents a summary of the participation in ICT projects financed by the FP7 and the CIP (hereinafter referred to as FP7-ICT and CIP-ICT, respectively), and a basic indicator of the corresponding networks, i.e., network density. These networks have been built by considering that two regions i and j are linked if organizations located in them have been partners in at least one project. Similar to Cassi et al. (2008), these links represent channels of collaboration, knowledge and information transfer.

Table 1

The FP7-ICT project-based network includes 245 NUTS2 regions, while the CIP-ICT includes a smaller number, 224. The total numbers of projects and organizations are much higher in the FP7-ICT (2,393 and 13,873, respectively), compared to those of the CIP-ICT (233 and 2,720). These differences are related to funding issues: the FP7-ICT had a budget of €9.1 billion compared to the €730 million of the CIP-ICT. Moreover, any type of organization could participate in the FP while the CIP targeted SMEs. The average number of participants per project was about six institutions in the FP7-ICT, a figure that almost doubles in the CIP-ICT. Last row of Table 1 shows network density, i.e., the ratio between the number of links and the number of potential links. The FP7-ICT project-based network has a quite higher density than the CIP-ICT, suggesting a better exploitation of the networking possibilities offered by this programme. Figure 1 shows the plots of the two networks, with node sizes based on the number of direct links.

Figure 1

Table 2 shows some descriptive statistics of the BC score by regions. The most outstanding feature is that most regions show very small bridging centrality values: the average BC scores are 0.058 and 0.092 in the FP7-ICT and CIP-ICT project-based networks,

respectively; the corresponding medians are 0.022 and 0.032; and the 90th percentiles, 0.157 and 0.258. By components of the BC, the outward orientation is very high, due to the proper nature of EU-funded programmes which generally require projects to be implemented by international teams. It also should be noted the high values of concentration and, consequently, the low diversification of interregional collaborations.

Hence, in both FP7 and CIP ICT project-based networks, regions tend to collaborate with the same regions, a feature that might limit their access to diversified knowledge.

Table 2

Figure 2 maps the spatial quartile distribution of the two distinct components of the BC, i.e. relative outward orientation and diversification. The darker the color, the higher the quartile. In the case of outward orientation (left panel), regions in the 4th quartile are those with the highest weights of external links over their total number of links. This implies that these regions would be taking advantage (to a higher extent than the rest) of the FP7 and CIP ICT project-based networks to access to external knowledge resources, which are essential to avoid regional lock-in (Miguelez and Moreno 2018). In case of the FP7-ICT, focusing on the outward orientation, we note that 4th quartile-regions spread across almost all countries of the EU. In the CIP-ICT, they tend to concentrate in Central-Eastern Europe (and one region in Spain). Then, the patterns of outward orientation appear to be quite different between the two analyzed programmes. As for diversification (right panel), regions in the 4th quartile are those with access to more varied pools of knowledge (compared to the rest) since their links are more diverse. In the FP7-ICT, it is worth noticing that half of French regions, those in Central-Northern France, exhibit the highest levels of diversification. In the CIP-ICT, only a few of these regions continue being the ones with the most diversified links. Nonetheless, it is important to recall that the average levels of diversification were low (Table 2).

Figure 2

As shown in Figure 3, the distribution of bridging centrality is extremely right-skewed, especially in the FP7-ICT project-based network. Dots in a boxplot indicate outliers. In this case, the outliers are the regions outperforming in bridging centrality, that is, regions that have a high number of bridging actors with access to varied pools of ICT knowledge,

and more importantly, they enable that this knowledge flows to regions that are not directly connected. Hence, these regional “outliers” play a key position to articulate and spread ICT knowledge across the EU. Since the BC score is based on bridges, these outstanding regions can be considered as the main sources of interconnections between the different pools of knowledge in the analyzed networks, and then they constitute the base to foster innovation.

Figure 3

Table 3 shows the Top-20 regions in terms of their capacity to bridge paths. The most outstanding region is Île-de-France; it ranks first and second in the FP7-ICT and CIP-ICT project-based networks, respectively. It is remarkable the difference it holds with the region ranking second in the FP7-ICT network: Île-de-France scores 1 while Oberbayern scores 0.55. Such a large difference between the first and second positions is not observed in the CIP-ICT network: Région de Bruxelles-Capitale scores 1 and Île-de-France, 0.886. The outstanding position of Île-de-France in the FP7-ICT network is related to the high level of involvement of organizations in this programme: Île-de-France had 1,851 participants compared to the figure of 922 of Oberbayern, the second region with highest bridging centrality. Furthermore, Île-de-France is one of the key hubs of the European ICT R&D network. The region is characterized by a diverse public research infrastructure with high private R&D expenditures and ownership of R&D centres, a strong business base in the ICT sector and high investments in intangibles by ICT firms. The outstanding role of the region of Île de-France has been also underlined by other authors such as Wanzenböck, Neuländtner and Scherngell (2020) when analyzing EU-funded R&D networks on the generation of key enabling technologies. The rest of regions at the Top-20 are also well-known European ICT clusters (see Hansen and Serin 2010, for an overview of ICT clusters).

To understand the position of Brussels Capital-Region in the CIP-ICT network, where it ranks the first, it is important to take into account that there is a strong concentration of R&D stakeholders around the European Commission, related organisms (as Council and Parliament) with a large variety of scientific and industrial associations. Within the Brussels Capital-Region, there is an unbalanced situation with a growing role for firms and a relative decline in FP participation of universities and public research institutes (Dotti, Spithoven and van Heur 2014). Hence, the observed result for Brussels is related to the fact that many firms

tend to locate in this region in order to take advantage of potential agglomeration economies derived from being close to EU's organisms.

In addition, 14 of the 20 regions that occupy the top are the same in both networks, with slight differences in the positions in the rankings. In fact, the correlation between the BC of these two networks is high: the value of Pearson's correlation coefficient is 0.78, being statistically significant at the 1 percent level.

By countries, the Top-20 is occupied by Germany with the largest number of regions in the FP7-ICT -it has four regions-, followed by France, Italy, the Netherlands, Spain and the United Kingdom with two regions; then, Austria, Belgium, Finland, Greece, Ireland and Sweden with one region. In the CIP-ICT network, Spain has three regions at the Top-20, then, Italy and the Netherlands with two, and finally, Austria, Belgium, the Czech Republic, Denmark, Greece, Ireland, Portugal, Romania and Slovenia with one. It is worth noticing that, only in the CIP-ICT network, there are regions from the New Member States (EU-13) at the Top, i.e, Zahodna, Slovenija, Praga and Bucarest. In fact, the poor centrality of EU-13 in knowledge networks is a recurrent concern (European Commission 2018).

Table 3

Table 4 shows regions at the Bottom-20 according to the BC score. There are two outstanding facts. On the one hand, and in contrast with what happens at the Top-20, regions with the lowest levels of connectivity in the FP7-ICT project-based network do not correspond with those in the CIP-ICT network. In fact, regions at the Bottom-20 are totally different in the two networks, and there is a mix of regions from Old and New Member States, mostly from the Old (12 in the FP7-ICT and 16 in the CIP-ICT).

On the other hand, countries that have regions at the Top also have them at the Bottom; such is the case of France (with Île de France and Rhône-Alpes at the Top-20 versus Limousin, Languedoc-Roussillon and Poitou-Charentes at the Bottom-20), Austria, Germany, the Netherlands, Spain, Sweden, and the United Kingdom, among other countries. This might indicate poor information and knowledge flows between regions within the same country as regards the two analyzed networks.

Table 4

Figure 4 provides further insights into this matter, showing that within countries, there are important regional differences in BC scores. For instance, while Île-de-France scores 1 in the FP-ICT network, the rest of French regions do not reach the 0.2 level. In fact, only regions identified as outliers score over that level of 0.2, except for Finland, the Netherlands and Sweden in the FP-ICT project-based network. Regional differences are also observed between programmes: CIP-ICT tends to have larger boxes than FP7-ICT which suggest bigger internal differences (see for instance, Portugal, Ireland, Spain or Croatia).

Figure 4

4.2. Bridging Centrality in FP7 and CIP ICT projects-based networks and regional total factor productivity

In order to explore the link between regional total factor productivity and the importance of knowledge transfers from the two EU-funded analyzed networks (measured by bridging centrality scores), Figure 5 shows the scatter plots of these two measures. To facilitate interpretation of the charts, TFP is reported relative to the EU average; then values equal to (less/higher than) 1 indicate that regional TFP is the same as (lower/higher than) the European average.

As for BC, due to the high skewness of the distributions, scores are reported in logarithm once multiplied by 100.¹⁷

Negative scores correspond to those regions with very low values of bridging centrality (close to 0). Then, dots in the lower left quadrant correspond to regions which 2007 TFP was lower than the European average and reached very low levels of connectivity within the two analyzed European-funded networks. Correspondingly, dots in the upper right quadrant correspond to regions which TFP was higher than the European average and did not have such low levels of connectivity. Figure 5 shows that dots are distributed across the four quadrants of the scatter plots. We note that there are some regions with very low levels of connectivity that, nonetheless, have TFP scores over the European average (upper left quadrant). Overall, the pattern of dots suggests some positive correlation between regional

¹⁷ Since the initial BS scores are in a scale 0-1, when taking logarithms all the values would become negative. By multiplying scores by 100, they are transferred to a scale 0-100. Then, taking logarithms of normalized 0-100 scores allows to distinguish between regions with extremely low values of bridging centrality, i.e., close to 0, which score in logarithm will result negative, and the rest of regions.

TFP and BC scores, especially stronger in the case of the FP7-ICT than the CIP-ICT. Specifically, the values of the correlation coefficients are 0.44 and 0.29, respectively. It is important to recall that the measure of regional TFP refers to 2007. Accordingly, what we see is that regional bridging centrality in the FP7-ICT project-based network in terms of the access to knowledge spillovers is to some extent related to a region's initial TFP. In the case of the CIP-ICT project-based network, knowledge spillovers appear less related to the initial TFP¹⁸.

Figure 5

If we focus on the regions identified at the Top-20 of BC scores, all of them have a TFP over the European average in either the FP7 or CIP-ICT. Nonetheless, the picture that emerges from the Bottom-20 is a bit more complex. In the FP7-ICT project-based network, five regions out of the Bottom-20 show a TFP higher than the European average. These are: (SE32) Mellersta Norrland, (UKK2) Dorset and Somerset, (NL12) Friesland, (FR63) Limousin and (ITC2) Valle d'Aosta/Vallée d'Aoste. In particular, the latter one has the highest TFP among these five (Valle d'Aosta TFP score is 1.14 relative to EU average=1). In the CIP-ICT project-based network, nine regions out of the Bottom-20 have a TFP over the European average, these being: (FR81) Languedoc-Roussillon, (NL34) Zeeland (EL42), Notio Aigaio, (DE14) Tübingen, (EL62) Ionia Nisia, (UKH3) Essex, (DE22) Niederbayern, (FR53) Poitou-Charentes and (DE27) Schwaben. Among these, the regions recording the highest TFP are Notio Aigaio, Tübingen and Zeeland with TFP scores of 1.30, 1.11 and 1.16 relative to EU average=1. Then, we have examined whether (or not) regions at the Top (Bottom) share any structural features or, in other words, whether they can be considered homogeneous from a structural point of view.

Table 5 summarizes the results of the regional measure of structural similarity for regions at the Top. The first column arranges regions in the three following groups: those which are at the Top of both programmes, those only in the FP7 and CIP ICT Tops, respectively. Then, for each region, the second column indicates the 20 regions which are

¹⁸ If the region of Île de France is dropped from the correlation analysis between TFP and BC in the FP7-ICT project-based network, the coefficient becomes 0.437. If both Île de France and Oberbayern, positioning first and second, are dropped; the coefficient is now 0.432. As to the CIP-ICT network, the correlation coefficient becomes 0.265 when the region of Bruxelles (Capitale) is removed; if both Bruxelles (Capitale) and Île de France are removed, then the coefficient is 0.255.

more structurally similar. For example, according to the regional measure of structural similarity, Cataluña (ES51) has similar structural conditions to Madrid (ES30), Lazio (ITI4) and Lombardia (ITC4) - all of them at the Top of FP7 and CIP-ICT project-based networks- and to Rhône-Alpes (FR71), which only appears in the FP7-Top.

Table 5

Overall, most regions at the Top of both programmes are structurally similar. For some regions, about a half of the territories structurally similar are other Top regions (that would be the case of FR10, ES30, UKI and BE1). The only exceptions are IE02 (Southern and Eastern of Ireland),¹⁹ NL33 (Zuid-Holland,) and NL32 (Nord Holland), RO32 (Bucarest), ES21 (País Vasco) and SI04 (Zahodna Slovenija), this latter one has no structural similarity with other regions at the Top. With regard to the regions at the Bottom, they generally show little levels of structural similarity among them.

Finally, regarding their participation in other regional funds and in particular the ESIF, we note that, in some countries, there are noteworthy differences between the regions at the Top and those at the Bottom. Such differences emerge both in relation to the amount of funding and the priority areas of the main projects funded. In countries such as France, the Netherlands, Italy, Portugal and Romania, regions at the Top have got more funds than those at the Bottom. Moreover, priority areas have been more oriented towards R&D issues in Top regions than in those at the Bottom. For instance, the French regions, Île de France and Rhône-Alpes, both at the Top, received respectively 689 and 714 million of euros from ESIF (not including EAFRD) over the period 2007-2013 compared to the funding got by those at the Bottom: 504 million got by Languedoc-Roussillon, 344 million by Poitou-Charentes, and 214 million by Limousin. In fact, these two latter regions got about a half and a third, respectively, of the amount of funding got by Île de France.

As to the priority areas, Île de France's ERDF funding especially focused on areas 2 and 4, which are both related to R&D, compared to Poitou-Charentes where it went to renewable energies (areas 40 and 41) and Limousin, where it focused on other investments

¹⁹ As explained in the data section, the measure of regional structural similarity is not symmetric. That features explains that IE02 is structurally similar to NL33, but the opposite is not true.

in firms (area 8).²⁰ Something similar occurred in the Netherlands. Regions at the Top, Zuid-Holland and Noor-Holland rank first and second among Dutch regions in the amount of ESI funds received. Zuid-Holland got 254 million of euros and Noor-Holland 178 million euros, with focus on priority areas 2 and 3, which refer to R&D and cooperation networks. Meanwhile, regions at the Bottom, Friesland and Zeeland, received 125 and 66 million, respectively; with these funds going to tourist services (area 57) and renewable energies (area 42).

In other countries, where regions at the Top got an amount of funds lower or similar to those received by regions at the Bottom, we note that the latter are mostly convergence regions which generally need additional funds to compensate their lower level of development. That is the case of Spain, Germany, Greece, the United Kingdom, Austria and the Czech Republic (See details in Annex B).

It is important to notice that these patterns of funding refer to total amount. If expressed in per capita terms, the picture is much more complex and regional differences might be, to some extent, attenuated.

5. Conclusions

This paper presents an empirical analysis of some European-funded project-based networks (FP7 and CIP, respectively) in the field of ICT, exploring whether the links created by these networks have any relationship with regional TFP, in an attempt to shed light on how these networks relates to regional economic performance in the EU.

We have used a novel measure of the position of a node in a network, specifically, the bridging centrality. This measure allows to take into account the internal structure of the network, distinguishing between internal and interregional links.

Such feature is especially interesting since local and international collaborations (while both important for value creation) provide access to different pools of knowledge and, accordingly, may generate different technological and knowledge spillovers. In addition, the measure of bridging centrality evaluates the diversity of links.

²⁰ Area 2 refers to “R&TD infrastructure and centres of competence in a specific technology” and Area 4 to “Assistance to R&TD, particularly in SMEs (including access to R&TD services in research centres)”. See European Commission (2019a) for the list of priority areas.

The exploratory analysis of these EU-funded networks of projects indicates the existence of a minority of very high-connected regions, well ahead of the rest regarding to their capacity to bridge paths by establishing international relationships with valued partners. Furthermore, these “leading” regions appear to be the same in both networks, they tend to be structurally similar and seem to receive more European funds than laggards. While the content and the type of organizations of each network are different, regions’ capacities to access and diffuse valued knowledge flows seem to be the same regardless the type of network. In fact, regions’ bridging centrality scores show a positive correlation between the two networks. Hence, a region with a central position in the FP7-ICT project-based network is highly likely to be also central in the CIP-ICT. In addition, connections in both networks tend to be very little diversified (thereafter, highly concentrated), what limits the possibilities to access to varied sources of knowledge and constraints the full potential of networking.

These results support previous evidence that indicates that FPs tend to concentrate in certain countries and regions, showing core-periphery structures both in diffusion and research networks (European Commission 2018; Wanzenböck, Scherngell and Lata 2015). Furthermore, the lack of high relational diversity underlines the weight, even today, of cultural and geographical proximities as drivers of research collaboration (Bergé, Wanzenböck and Scherngell 2017; European Commission 2018; Scherngell 2019).

Additionally, there are important internal differences within countries, in terms of their capacity to bridge paths. Hence, there seems not to be a successful transmission of knowledge between regions within the same country as regards the two analyzed programmes; specifically, from those regions with a high capacity to bridge paths and to establish international relationships with valued partners, to those whose capacities are low. In fact, countries with regions positioned at the Top-20 also have also other regions at the Bottom-20.

These internal differences appear to be larger in the CIP-ICT project-based network than in the FP7-ICT. It is important to recall that the former network is composed of SMEs (while the latter included all types of organizations). This might suggest the existence of regional differences regarding SMEs’ capabilities to deploy use and ICT-related innovations ready to markets. In the FP7-ICT network, these different capabilities of SMEs might be compensated

by the interaction with other organizations (large firms, research centers, etc.), and by the specialization in different tasks and projects. In fact, SMEs and large firms tend to follow different strategies in R&D: whereas SMEs concentrate on projects with applied orientation, commercialization benefits and business orientation; large firms usually state less explicit aims and seek to build partnerships and access to novel knowledge (Nepelski and Piroli 2018).

As for the relationship between FP7 and CIP ICT project-based networks and regional TFP, we have found that while, positive in both cases, this relationship is much stronger in the FP7 than in the CIP. Then, regions with higher levels of TFP in 2007 tended to exhibit a better performance during the period 2007-2013 in what refers to the establishment of FP7 research connections and the access to knowledge-related spillovers than those with lower TFP. While no causality claims can be made, there seems to be some path dependency as regards regions' abilities to access to external research-related spillovers. This is much attenuated for those related to technological diffusion as regards the CIP- ICT.

Our results allow us to suggest some policy recommendations. On the one hand, it is essential to address the low connectivity of some regions. As we have seen, BC scores are highly correlated between the networks. Hence, regions in peripheral positions in one of the networks will also be it in the other. This requires targeted support actions, starting with a careful identification by national authorities of the major obstacles faced by these regions to join European-funded project-based networks. It is essential to determine the reasons that may explain where the problem lies, i.e., whether it is a problem of weak capabilities, a lack of information, too complex procedures that organizations cannot afford with their resources, etc. Along with this, national and regional authorities should support organizations during the process of applying to European projects to maximize their possibilities to be successful.

In addition, supplementary funds should be provided to facilitate the access to European-funded networks of organizations from regions with lower levels of participation. In this line, it is essential to foster the diffusion of information from high-connected to low-connected regions. The large internal differences observed in our analysis indicate that there is not an effective exchange of information and knowledge between regions within countries. Accordingly, national authorities should implement informative actions such as information

campaigns and diffusion of best practices in order to alleviate this problem. Moreover, the identified association between BC scores in the FP7-ICT project-based network and TFP suggests that fostering the networking capabilities of those lagging regions is essential to avoid greater productivity gaps across European regions.

Some limitations should be considered in our analysis. Firstly, we have examined two EU-funded project-based networks, one referred to ICT research and the other to ICT diffusion. While the analyzed networks are important instruments at European level to establish external collaborations between regions, our results are specific to them and we should not neglect the existence of other national and regional networks and funds. Of special interest would be to study how the different types of R&D networks (eg. project-based, co-patents and co-publications networks) interact (Lata, Scherngell and Brenner, 2015; Scherngell, 2019) and how networks of related technologies might influence each other (Balland et al., 2019), taking into account that regional network centrality vary among thematic orientations (Wanzenböck, Neuländtner and Scherngell 2020). Secondly, our analysis focuses on the regional level. However, the effects of R&D networks are not limited to geographical borders (Audretsch and Felman 2004) and, as several scholars have highlighted, more local analysis should be done to properly identify and understand the knowledge diffusion processes boosted by EU-funded programmes (Asheim and Coenen 2005; Tödtling-Schönhofer et al. 2009). Finally, to analyze the relationship between spillovers from FP7 and CIP project-based ICT networks and regional TFP, we have used data that referred to 2007 TFP, the year when these networks were launched. It would be interesting to explore such relationship once the programmes were finished, using data of TFP for 2013 and onwards and to compare results with other regional R&D networks, based on other data sources.

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