Technological Diversity in FP7-sponsored projects: Time for a rethink in European research policy

Alessandro Muscio
University of Foggia
SAFE
alessandro.muscio@unifg.it

Andrea Ciffolilli
Ismeri Europa
ciffolilli@ismerieuropa.com

Antonio Lopolito
University of Foggia
SAFE
antonio.lopolito@unifg.it

Abstract

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Programme for research and technological development to investigate technological diversity in European regions. CORDIS Data are analysed at the NUTS2 regional level and categorised on the basis of an original taxonomy of technologies created with the support of a team of European experts. Thanks to the analysis of regional research networks we draw policy indications to support the technological competitiveness of the European economy. Our results show that the capacity to obtain funding and high regional degree of centrality in collaborative networks both promote technological diversity in European regions. We also find that network centrality has a moderating effect on FP funding and that higher inter-sectoral technological diversity is also associated to higher infra-sector regional technological diversity. This has relevant implications in terms of the effectiveness of European policy in promoting the adoption of a Smart Specialisation Strategy.
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Keywords: Smart Specialisation; Technological diversity; Social Network Analysis; European Regions; Framework Programme.

JEL Codes: O18, O31, O38, R58
1 Introduction

In the programming period 2007-2013, the European Commission invested a significant amount of resources on research and innovation. Considering only the main instruments such as the European Regional Development Fund (ERDF) and the 7th Framework Programme (FP) for RTD, over 100 billion were devoted to support policies in these fields. While ERDF and the Structural Funds in general finance activities characterised by a different degree of innovativeness, from interventions on the contexts aiming at making them more innovation friendly, to technology transfer and even break-through research, the Framework Programme was entirely devoted to subsidise research, both basic as well as applied and market oriented.

There is a growing literature analysing the participation in FP and the outcomes and impacts of this important European policy instrument. These studies are likely to produce precious evidence to guide and steer Structural Funds initiatives in 2014-2020 as well as Horizon 2020, an 80 billion follow-up to FP7. Regardless of its results and weaknesses, the FP7 experience and, in particular, the mass of co-financed research projects, provide already unique information on the European, and often international, research trends as well as on regional assets and research specialisations, which have not been investigated thoroughly in the scientific literature, at least with respect to the technological specialisation of European regions with few notable exceptions (Muscio and Cifolilli, 2017; 2018).

This paper presents the results of the analysis of the FP7 projects pertaining to all the most important European industries. The FP7 projects considered in this paper are research cooperation endeavours involving enterprises, universities and other research-performing organizations. FP7 projects are classified by call in CORDIS (the Community Research and Development Information Service) and there is no official classification of projects by key research area (KRA) or technology. Each call does not identify a research area but only a general theme (e.g., NMP - nanotechnologies, materials and new production technologies; KBBE - knowledge-based bio-economy). The database we use in this paper has been assembled on the basis of a project-by-project analysis, focusing on the primary objective of each project and the type of technology developed. These technologies have been classified on the basis of an original taxonomy of KRAs developed by ISMERI Europa, with the contribution of expert peer reviews for each technological domain.

In this paper we do not deal with sectoral specialisation versus diversification but narrow down the focus on the degree of technological diversity by concentrating on technologies. Regional technological diversity can be defined as a region’s capacity to carry out research activity across different knowledge domains (Wang and Von Tunzelmann (2000). We argue that investigating technological specialisation and diversity at the regional level can provide key indications on the drivers of specialisation and on the coherence of research, technological development and
innovation (RTDI) policy in supporting it or not. In fact, while from the theoretical standpoint technological diversity is a ‘good thing’ we do not know whether European R&I policy is fostering diversity.

We focus on the analysis of two drivers: the total amount of FP7 funding that was granted to each European region and their degree of network centrality in interregional research collaborations. We pay particular attention to the investigation of the moderation effects of networking. From a methodological viewpoint, we test this argument by extending an econometric model previously developed to investigate the effect exerted on technological diversity by the regional capacity to obtain FP7 funding and the regional degree of centrality in collaborative networks (Muscio and Ciffolilli, 2017). In particular, we extend this methodology in two respects: we analyse the effects of FP7 funding and network centrality on technological diversity across all the technological sectors sponsored by the FP7, extending considerably the size of the database used by the authors; secondly, in order to investigate whether there is a trade-off between breadth and depth of regional research efforts, we test whether regional capacity to carry out research across different technological fields affects the capacity to extend research efforts within specific domains.

The potential applications of the empirical framework proposed in this paper are multiple. One direct application related to the priority setting and implementation of Smart Specialisation Strategies (S3) and more in general facilitate the identification of topics on which research and innovation incentives can be concentrated as opposed to spread resources thinly across a wide range of technological fields. Another application is research and innovation policy monitoring and evaluation. The paper is organised as follows: Section 2 presents the literature background to technological diversity in Europe and to the potential role of and potential impact of FP; Section 3 presents the data and the methodology underlying the taxonomy for grouping FP7 projects; Section 4 presents the econometric analysis; Section 5 draws the concluding remarks and the policy implications.

2 Theoretical Background

2.1 Regional Innovation Policy and S3

Regional innovation policy is at the heart of the EC’s political agenda. In Europe, the EC introduced a range of policy programmes that are designed along the two principles of integrating innovation and industrial policy and developing the innovation system to increase the absorptive capacity of lagging regions. The FPs and the SFs have invested a significant amount of resources in research and innovation both in the private and public sector. However, the evidence on the extent to which these measures have boosted regional innovation performance, fostered structural change towards higher value-added activities and ultimately created a basis for
sustained competitiveness across the EU is not conclusive (Muscio et al., 2015). In addition, data shows that, over the years, European regional innovation policy has produced little convergence in regional innovation performance (Hollanders et al., 2012), hindering structural shifts to knowledge intensive and higher valued added goods and services. Such observations are part of the rationale for the EC’s decision to introduce an ‘ex-ante conditionality’ to improve the quality of strategic plans for the 2014-2020 programming period. In the attempt to increase efficiency and effectiveness of regional innovation policy, the EC had adopted the concept of S3. S3 is a new innovation policy concept designed to promote the efficient and effective use of public investment in research. S3 aims to focus available funds on a limited set of priorities that have the potential to drive economic transformation (McCann and Ortega, 2013a). in the view of the EC:1

"...its goal is to boost regional innovation in order to achieve economic growth and prosperity, by enabling regions to focus on their strengths. S3 understands that spreading investment too thinly across several frontier technology fields risks limiting the impact in any one area. A smart specialisation strategy needs to be built on a sound analysis of regional assets and technology. It should also include an analysis of potential partners in other regions and avoid unnecessary duplication. Smart specialisation needs to be based on a strong partnership between businesses, public entities and knowledge institutions - such partnerships are recognised as essential for success”.

S3 involves an entrepreneurial discovery process that reveals what a country or region does best in terms of R&D and innovation (Foray et al., 2011). This approach does not necessarily mean focusing resources in few high-technology sectors, while offering a range of advantages for the design of appropriate innovation policy-making, while allowing for the varied evolutionary nature of regional economies (McCann and Ortega, 2013b). However, despite the fascination with S3 and its implementation in regional policy, smart specialization-based regional policy-design sets some relevant challenges. In fact, as noted in David et al. (2012), in order to shift the discussion on S3 from conceptual issues to empirical evidence, it is vitally important to demonstrate that statistical measurement is feasible to encourage countries and experts to take part in the debate.

2.2 Technological diversity in European research

The core principle of the S3 literature is that resources (public-private) should be concentrated on selected technological or market priorities that have the potential to foster the emergence of new activities and the adoption, dissemination and adaption of ‘general purpose technologies' (GPT) across a wide range of sectors (Foray and Goenega, 2013). With the FPs the EC has invested a significant amount of resources

1 http://ec.europa.eu/research/regions/index_en.cfm?pg=smart_specialisation
in the attempt to strengthen transnational research networks to support technological development. Over the past fifteen years the economic literature has provided empirical evidence on the scientific and economic results of the FPs and on the extent and characteristics of the partnerships promoted (Arnold et al. 2005; Arnold, 2012; Muscio et al., 2015). Nevertheless, there is still little empirical support to the technology dimension of research activities carried out with the support of FPs. In fact, while we know what the principal scientific sectors that receive support from the FPs are, we do not know much on the kind of technologies that are developed with the support of this important policy instrument. In this respect, only very recent papers have started to address the technological diversity of European regions. The concept of technology diversity refers to the regional capability to carry out research in several technology fields. The expansion of R&D activity and technological competence into a broad range of technical areas (Cecere and Ozman, 2014; Granstrand and Oskarsson, 1994) is considered as a vector of technological change and innovation (Van Rijnsoever et al., 2015). While there is agreement on the idea that technological diversity drives innovation performance (Breschi et al., 2003; Gemba and Kodama, 2001; Granstrand, 1998; Quintana-Garcia and Benavides-Velasco, 2008), there is little evidence about how research policy can do and about the underlying driving mechanisms of technological diversity (Van Rijnsoever et al., 2015). This is particularly relevant with respect to S3 policy, as we don’t know yet whether FPs are fostering diversity across disciplines and within disciplines and, therefore, if FPs act in contrast with S3.

2.3 Research hypotheses

We investigate the determinants of technology diversity, shedding light on the potential role of European research policy on the regional capacity to 'diversify' or 'specialise' their technological development.

Few papers provide evidence that FP funding has a strong positive effect on knowledge creation and technology development. Defazio et al. (2009) investigate European-funded research training programmes and demonstrate that while researchers do not increase their research production during the period of funding, in the post-funding period the impact of collaboration on productivity is positive and significant. Therefore, European funding may be an important promoter of effective collaborations in the long-run. Some authors (Lee and Bozeman, 2005) point out that research funding provides beneficial effects to researchers that are most likely to derive from the access to research resources rather than from collaboration and networking. However, the intensity of these effects varies depending on the amount of funding (Banal-Estañol et al., 2015; Bolli and Somogyi, 2011; Godin, 2003). According to some, there is some path-dependency in regional capacity to acquire funding, as those participants that already participated in previous FPs are much more likely to acquire FP funding (Paier and Scherngell, 2011). In fact, networks funded by
the FPs are dominated by a small group of core regions (Breschi and Cusmano, 2004) whose centrality is often reinforced by their capacity to secure successive rounds of funding. Hoekman et al. (2013) investigate the relationship between the acquisition of European research funds and international scientific collaboration, measured in terms of co-authored publications. The authors are particularly interested in finding out whether or not FP funding stimulates co-publication between pairs of European regions. Their results indicate that the effect of funding on co-publication is especially significant for regions that did not intensively co-publish before participating in FP programmes. Therefore, the authors conclude that the returns to FP funding are highest when involving scientifically lagging regions and, in this respect, the current FP policy is in line with cohesion policy. With special reference to technological development and diversity, Muscio and Ciffolilli (2017) demonstrate that, in the specific case of research collaborations sponsored by the FP7 in the agri-food sector, European funding is strongly associated with greater technological diversity. In the attempt to extend these findings to the whole range of technological sectors, we posit the research hypothesis that FP7 funding allows regions to extend their breadth of technologies they develop across different technological sectors. Therefore:

H1. There is a positive relationship between FP funding and regional technological diversity across different technological sectors

Some papers have analysed the characteristics of regional networks and the effectiveness of the FPs for knowledge dissemination across networks and Member States (Breschi and Cusmano, 2004; Roediger-Schluca and Barber, 2006; Breschi et al., 2009; Paier and Scherngell, 2011; Pandza et al., 2011; Scherngell and Barber, 2011). The purpose of collaborative research programmes such as FPs is to promote international networks that ‘add value’ to joint research activity which cannot be obtained through country-level programmes (Fahrenkrog, 2002; Georghiou, 2001). They draw together a much larger pool of financial and human resources, allowing to tackle technological problems that could be difficult to address by individual peers (Muscio, 2006). Therefore, international collaborations undertaken under FPs are expected to create the opportunity to achieve a critical mass of research performers, increasing the chances to include key players in joint research programmes (Clark et al., 2004). Cecere and Corrocher (2013) show that the geographical distance reduces the strength of cooperation in FP-sponsored collaborations in the ICT sector, while cultural proximity, individual regions’ involvement in research collaborations and the strength of the ICT sector have a positive effect. Few recent works analyse the geographical dimension of technological diversity (Muscio and Ciffolilli, 2017), providing evidence that the position in collaborative research networks and the composition of collaborative innovation projects influence diversity in emerging technologies (Van Rijnsoever et al., 2015). A higher network embeddedness in regional networks fosters agents’ access to information and knowledge (Wanzenbock
et al., 2015), increasing their competitive advantage in the creation of new collaborations and alliances (Gilsing et al., 2008; Maggioni and Uberti, 2007) and creating better conditions for knowledge production and innovation (Powell and Grodal, 2005). Supporting this, Muscio and Ciffolilli (2017) analyse collaborative research networks promoted by the FP7 in the agri-food domain, providing evidence that regional network centrality is strongly associated with greater technological diversity. This aspect is particularly relevant with respect to FPs. In fact, while EU-funded research networks require researchers to collaborate as a condition for securing research funding, there is evidence that these collaborative networks increase researchers’ productivity in the longer term (Defazio et al., 2009; European Commission, 2016). Therefore, although funding has a significant direct impact on researcher productivity (Defazio et al., 2009), long-term collaborations, have a stronger impact on researcher productivity.

Interaction in research networks plays a fundamental role in knowledge creation. The relevance of networking in easing and facilitating the exploitation of external knowledge and fostering technological diversity extends to the point of influencing the relevance of research funding itself. Research-performing organizations increasingly activate interregional relationships (Muscio, 2013; Schemgell and Barber, 2009, 2011), for their higher effectiveness in reaching high valued and specific piece of knowledge (Wanzenbock et al., 2015). As a consequence, high degree of centrality in collaborative networks represents an actual immaterial asset for research-based companies which eases the drawing of the diffused partnership know-how. Hence, at certain levels, network centrality is supposed to act as a substitute for FP7 funding in promoting diversity in technological breath of regions. This means that, from an operative point of view, high degrees of network centrality are expected to reduce the effect on the technological diversification of FP7 funding, negatively moderating its impact.

In this respect and in line with the aforementioned arguments, we argue that:

H2a. Network centrality degree in the research collaboration network is positively correlated to higher technological diversity.

H2b. High degree centrality in the research collaboration network is correlated to a reduced FP7 effect on technological diversity.

A final relevant issue for the purpose of technological diversity is whether greater diversity or specialisation in given domains is obtained at the expense of greater diversity or specialisation among S&T domains. In other words, we don’t know whether regional capacity to develop technologies in several sectors, say ICT, agri-food and health, comes at the expenses of regional capacity to develop different technologies within specific sectors, say health and functional claims or innovative industrial processes for food production and conservation in the agri-food domain.
Catching up between different regions crucially depends upon the diffusion of technology (Cappelli and Montobbio, 2016) which is, however, constrained by the geographical dimension. Technological development and diffusion are characterized by substantial agglomeration effects and, eventually, increasing returns at the regional level (Grossman And Helpman, 1991; Keller, 2004; Krugman, 1991). Over the past 20 years, scholars have debated on specialization and diversification in regional economies (Boschma and Iammarino, 2009; Van der Panne, 2004). While some scholars have stressed the positive role of localization economies, arguing that the sectoral specialization of a region is a positive factor because firms are expected to learn mainly from other local firms in the same industry, others have claimed that the more diversified a regional economy, the more knowledge spillovers will occur because firms get new and better ideas through other local firms that are active in many different industries (Boschma and Iammarino, 2009). The concept of ‘related variety’ (Frenken et al., 2007) suggests that strength in a particular sector, or part of a value chain, can have positive spillovers in other related sectors (Muscio et al., 2015).

The concept of regional branching claims that new industries and technologies emerge more easily in regions when they are related to pre-existing ones (Frenken and Boschma, 2007; Boschma and Frenken, 2011a; Essletzbichler, 2015). In this respect, Montresor and Quatraro (2017) stress the role of regional branching for the purpose of S3 and point out the relevance of GPT, defined as those technologies with the potential to drastically alter societies through their impact on economic and social structures, in boosting regional branching and technological diversification. The authors point out that the six KETs identified by the EC,\(^2\) represent a new generation of GPTs that can support the development of a wide range of products and industrial processes in today’s economies. According to this, Foray et al. (2009) point out that although regions differ in their capacity to develop GPTs, they can all benefit from the development and application of these technologies. The added value of S3 is the attempt to concentrate financial resources into high potential technological sector or markets for the reinforcement of GPT adoption, diffusion and adaptation (Foray et al., 2011; Foray and Goenaga, 2013). Along this line, Wanzenbock et al. (2015) analyse the effects of regional technological specialization, showing that a region’s specialization in only a few technological fields does not affect regional centrality in R&D networks. Therefore, we argue that:

\[ H3: \text{The higher a region’s overall technological diversity, the higher infra-sector regional technological diversity will be.} \]

\(^2\) The six KETS are: industrial biotechnology, nanotechnology, micro- and nanoelectronics, photonics, advanced materials and advanced manufacturing technologies.
3 Data and methodology

FP7 projects embed information that is organised on the basis of the funding calls and of scientific areas rather than on the basis of the actual technological content of sponsored projects. This information is often used for scientific purposes in the economic literature, but hardly provides any insight with respect to the key technologies on which European and international research stakeholder choose to invest. Any attempt to draw useful information to the policy maker, requires a project-by-project analysis of the beneficiaries and of the research activities that are carried out. Fitting these purposes, in this paper we analyse data from all the 9,591 participations in research cooperation projects sponsored by the “Cooperation” and “Capacities” programmes of the FP7. This information is contained in the RED database developed by Ismeri Europa. The data is classified on the basis of a detailed taxonomy of 62 KRAs, which have been defined via peer reviews in each technological domain. This data allows the identification of the technologies developed with the support of the FP7, indirectly providing some insights on the alignment between the variety of European research investments and the technological focus promoted by the S3.

FP7 project data included in the database were regionalised at NUTS2 level. The database contains information on project budgets, type and name of partner organisations involved, geographical location of partners and, of course, key research areas and technologies developed through the projects. The identification of the key research areas and technologies promoted by the FPs required a peer review process. The team of experts identified 62 main KRAs. The key research areas represent the main scientific and technical fields of FP7 projects, each of them comprising a “family” of key technologies, as shown in the Appendix in Table 1A. The regional-level data contained in the FP7 database were matched to Eurostat and OECD data on regional economic and research performance. Our dataset covers 295 regions, including a non-EU category, which includes regions outside the EU, not considered in the econometric analysis because of missing data. Table 1A presents the total number of projects in each of the identified 11 Sectors and the corresponding 62 KRAs. The large majority of funding is concentrated in the sector “Health” and “TLC/ICT” (23% and 20% respectively), followed by IPP (11%). Each of all the other eight sectors accounts for less than 10% of funding.

Table 1 presents information on the top-twenty performing European regions in terms of number of participations and funding. By far, the region that was awarded the largest number of projects and amount of funding was Île de France (FR), followed at a distance by Comunidad de Madrid (ES) and Lombardy (IT). Overall the data shows the presence of some agglomeration effects, with capital regions concentrating funding and participations.
4 Econometric analysis

4.1 Econometric specification

In order to investigate regional technological diversity in FP7 projects, we adopted the econometric strategy proposed in Muscio and Ciffolilli (2017), estimating the following models:

\[ Eq.1 \quad SDI_i = \alpha + \beta_1 \text{REGIONAL\_CONTROLS}_i + \beta_2 \text{DISTANCE\_PARTNERS}_i + \beta_3 \text{INTRAREGIONAL\_LINKS}_i + \beta_4 \text{EIGENVECTOR}_i + \beta_5 \text{FP7\_FUNDING}_i + \beta_6 \text{EIGENVECTOR}_i \times \text{FP7\_FUNDING}_i + \epsilon_i \]

where SDI\(_i\) represents the Shannon Diversity Index (SDI), a measure of technological diversity.\(^3\) The SDI is an entropy index that can be applied to the context of industrial diversification (Attaran and Zwick, 1987; Aiginger and Davies, 2004). The index can be expressed as follows:

\[ Eq.2 \quad SDI_i = -\sum_{i=1}^{N} P_i \ln P_i \]

\(P_i\) represents the ratio between the number of FP project participations in sector \(i\) and the total FP project participations in a region. The SDI index measures technological diversity, increasing when specialisation decreases so that its minimum (zero) means complete specialisation, and at its maximum represents total diversification. REGIONAL\_CONTROLS is a group of independent variables analysing regional socio-economic drivers. DISTANCE\_PARTNERS accounts for the average physical distance of region \(i\) from its partner regions,\(^4\) INTRAREGIONAL\_LINKS represents the share of research collaboration within the region, and accounts for the internal density of public-private ties, FP7\_FUNDING amount of EC funding measured with its natural

\(^3\) To check the robustness of the results, we tested our model with two alternative measures of technological diversity: (1) the Herfindahl-Hirschman Index of Diversification (HHID) and (2) a scalar indicator ranging from 1 to 11 sectors, which takes into account the number of sectors in which region \(i\) has participated ones or more times. The HHID is becoming a popular alternative measure of technological diversification (Quintana-Garcia and Benavides-Velasco, 2008). Both indicators confirmed the results obtained with the SDI. The results are available upon request to the authors.

\(^4\) The distance was calculated using data on latitude and longitude of the central city of each region involved in FP7 projects.
logarithm, approved for research unit belonging to the region \( i \), EIGENVECTOR is an index of network centrality accounting for the eigenvector centrality degree. The use of the eigenvector instead of the simple centrality degree allows to refine the analysis proven that, this network measure account not only for the number of connections of the single region with the others — that is a warranty of influence and accessibility to knowledge \textit{per se} — but also for the quality of the connections (Scherngell and Barber 2011). In other words, eigenvector is a measure of how central are the partners of the single region, and thus how much effective are these links to assure higher influence and knowledge access. Summarising, for each region the eigenvector accounts both for the number of research collaboration activated, and the quality of these collaborations based, in turn, on the centrality of the partners (Bonacich, 1987).

In order to test H3, we run a revised version of Eq.1, expressed as follows:

\[
Eq. 3 \quad \text{InfrasectoralSDI}_i = \alpha + \beta_1 \text{REGIONAL\_CONTROLS}_i + \beta_2 \text{DISTANCE\_PARTNERS}_i + \beta_3 \text{INTRA\_REGIONAL\_LINKS}_i + \beta_4 \text{EIGENVECTOR}_i + \beta_5 \text{FP7\_FUNDING}_i + \beta_6 \text{EIGENVECTOR}_i \ast \text{FP7\_FUNDING}_i + \beta_7 \text{SDI}_i + \epsilon_i
\]

where \( P \) in InfrasectoralSDI denotes the proportion in a region of FP projects in KRA \( i \). Therefore, this model does not account for diversity between sectors but between KRAs ‘within’ the same sector.\(^5\) This model includes among the regressors the SDI as expressed in Eq.2, accounting for the impact of overall technological diversity on infra-sector technological diversity.

Table 2 presents the definition of the variables used in the regressions. Table 3 presents the descriptive statistics. Appendix (Table 2A) presents a correlation matrix measuring the variance inflation factors (VIF) to detect multicollinearity. This test is used for all variables with big margins.

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\(^5\) I.e. instead of accounting for diversity between the aerospace and agrifood sector as in Eq.1, Eq.3 measures diversity between, say, the KRAs aeronautics and earth observation ‘within’ the aerospace sector.
4.2 Factors related to technological diversity

The results of the econometric exercise are presented in Table 4. We test our research hypotheses regarding the factors associated to technological diversity developed with the support of the FP7 running ordinary least squares (OLS) methods on the econometric models presented above.

Columns (1) presents the results obtained adopting Eq.1 and the overall SDI, while columns (2) to (12) presents the results obtained using Eq.3 on each of the 11 sectors described in Table 1A. Proven that the data used are inter-sectional, we are aware that our econometric exercise may exhibit reversal in cause-effect relations. This issue is potentially relevant in the case of the variable FP7 funding, as while funding is potentially positively associated to technology diversity, it is also possible that regions that rely on more technologically diversified research activities, are in a better position to secure funding across a wider range of technological areas.

Following Muscio and Ciffolilli (2017), we addressed endogenous FP7 funding instrumenting the natural logarithm of regional FP7 funding (IV) with the following: 1) the regional endowment of population with the level of tertiary education or employment in Science and Technology (HRST) of the population of the region in year 2006 (the FP7 started in the 2007) measured by its natural logarithm; 2) ration between the project coordinated and the total amount of the project in the region; 3) the natural logarithm of inhabitants within the region (2006). It is worth noting that a crucial driver of the capacity to attract research resources is represented by the human capital present within the region. High levels of human capital favours the involvement in research projects and help to access to large FP7 funding. Moreover, as expected and testified by DG Research data, coordination role in FP7 projects is associated in mean with larger funding with respect to the other participants. Finally, we included regional population in the model as a proxy of regions’ dimension. Statistics support the need for instrumenting the EC contribution variable (Durbin-Wu-Hausman test). The related results are included in the Appendix (Table 3A).

First of all, the results of the regressions show that some control factor matter for the purpose of technological diversity in the first model specification, testing for intrasectoral technological diversity. As expected, Students in education is positively correlated to technological diversity, while GERD per capita is negatively correlated, revealing the existence of some convergency process.

It is worth noting that participation in FP7, measured by funding achieved by regions from the EC (FP7 funding), is positively associated to higher technological diversity both at the aggregate level and in several sectors. Furthermore, the coefficient magnitude is basically unaffected in the estimated models.

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6 Durbin-Wu-Hausman chi-sq test: 0.41009, Chi-sq(1) P-value = 0.52192, where H0: Regressor is exogenous.
Table 4 presents the results from the statistical analysis, which provide strong confirmation for H1. In fact, network degree has positive and highly significant coefficient for all model specifications. This provides evidence that, as expected, regions that attain more central network position augment their opportunity to establish research collaboration in several technological areas. Moreover, region with stronger internal collaboration (intra-regional links) will have more participations in FP7 projects, but there is no evidence that they are favoured in diversifying technological research. In other words, regions with more intra-regional links, and therefore with a stronger regional innovation system, have better chances of being involved in many participations.

The results on the variable controlling for the network moderating effect on EC funding (FP7 funding * Eigenvector) confirms this finding. All the three model variations contain this term which measures the moderating role of regional research cooperation on FP7 funding. It is negative and highly significant, confirming that being very central in the network negatively reduces in negative sense the positive effect of FP7 funding on technological diversity. Thus, while FP7 funding positively affects technological diversity, the magnitude of this effect depends on the regional centrality degree. This implies the existence of a diversity threshold above which the propensity to diversify technology caused by the funding diminishes. This reveals two paths by which centrality can impact technological diversity, that are directly by its effect on involvement in diverse technology research, and indirectly, by means it effect on the effectiveness of FP7 funding. Since eigenvector provides a measure accounting both for the number of collaborations and their quality, it is reasonable to conclude that FP7 funding effect on the technology is stronger for regions with moderate interregional linkages. Nevertheless, regions rooted in high dense connections are characterised by a decline in the chance of develop diverse technologies.

The results for individual scientific areas reveal that the higher a region's overall technological diversity, the higher infra-sector regional technological diversity will be. Therefore, greater technological diversity or specialisation is hardly obtained at the expense of greater diversity or specialisation in other S&T fields. This has obvious implications for S3 policy: our results show that with the FP European research policy is supporting the growth of variety in regional technological capacity. While this is undoubtedly promising for the technological development of Europe, what the FP is achieving seems hardly in line with the modern strategy in regional innovation policy as defined in the S3.

In conclusion, FP7 is effective in sponsoring R&D regional activities pushing on physical and human capital and via knowledge sharing across a multitude of regional partners. According to our results, the amount of FP7 funding and network centrality are significantly associated with regional technological diversity in Europe. However,
the higher network centrality will be, the less important will be receiving large sums of research funding.

Table 4 Determinants of technological diversity and participation in FP7 projects

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5 Concluding remarks

The primary aim of the European Framework programmes is the strengthen of the European scientific and technological basis by supporting excellence in research. Indirectly, this provide some level of protection to novelties experimentation which are not yet ready to face a too harsh competition in their natural layout markets. Along with these research-related issues, European framework for research support, provides also huge opportunities and support for cooperation between organisations and regions at an international level, mobility of people and means, etc.

Although, the European Commission endorse a convergence process in research performances among EU regions to warrant an even distribution of benefit, (European Commission, 2013), the impacts of FPs and other policies on the technological structure of regions is still undervalued in economic literature. To overcome this lack, the present research focused on the role of the FP7 resources and connectivity in the supported network of research cooperation are closely correlated to higher levels of diversity technology research. We found that regions more deeply embedded in these collaboration networks are very active in diversifying their range of technology research and exhibit some reluctance in undertake well established and fixed specialisation paths in narrowed technology selection. Instead, more “bordering” and relatively isolated regions reveal a marked attitude for technological specialisation.

Our findings made emerge a clear core-periphery pattern in the operation of the FPs founding scheme, with a remarkable diversification effect on the most central regions where fund-seeking capacity spread-out, and a certain level of technology concentration through the peripheral side of the research collaboration network. How this dynamic contributes to the achievement of the S3 purposes and to a more competitive communal research system deserves further investigation. Including the technological dimension in the analysis of the RTD policy impact at the European level, this study provides the basis for such line of research.

The major limitation of this study relates to the validity of the information contained in FP projects that is useful only at the cumulative level at the end of the programming period (2014). Data from single calls are affected by cyclical trends and factors that limit the information obtained from any econometric exercise. The need to use stock data requires the use of cross-sectional analyses, which in turn expose to risks of
reverse causality, with regions with higher technological diversity applying more intensely for FP support.
References


European Commission (2016), An analysis of the role and engagement of universities with regard to participation in the Framework Programmes, DG Research and Innovation (study carried out by Ismeri Europa, Politecnico di Torino and IRRES-CNR).


Foray, D., David, P.A., Hall, B.H., (2011) Smart specialization: From academic idea to political instrument, the surprising career of a concept and the difficulties involved in its implementation. MTEI-WORKING_PAPER-2011-001.


Mccann, P., Ortega-Argilés, R., 2013b. Smart Specialization, Regional Growth and Applications to European Union Cohesion Policy. Regional Studies 1-12.


### Table 1  Top-20 regions for FP7 funding and participations

<table>
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<th>NUTS2</th>
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### Table 2  Description of variables

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<tr>
<td>SDI</td>
<td>Shannon diversity index</td>
<td>based on DG Research data</td>
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Control variables
RCE Objective Regional Competitiveness and Employment (RCE) region Eurostat
GERD per capita (Ln) Gross Expenditure on Research and Development per capita (2006) Eurostat
Tertiary education (Ln) Tertiary educational attainment, age group 25-64 (2006) Eurostat

FP7 indicators
Distance partners (Ln) Average distance from partners (square kilometres) based on DG Research data
Intra-regional links Share of FP7 links established between organisations located in the same region based on DG Research data
FP7 funding (Ln) Total EC contribution for the analysed FP7 projects (Euros, instrumented) based on DG Research data
Eigenvector Network centrality degree: eigenvector based on DG Research data

Instruments
Share projects coordination Share of regional participations in FP7 projects coordinated by local organisations based on DG Research data

Table 3 Descriptive statistics

<table>
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<tr>
<th>Variable</th>
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<th>Mean</th>
<th>Std. Dev.</th>
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<th>Max</th>
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Table 4: Determinants of technological diversity and participation in FP7 projects

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<td>0.033</td>
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<td>0.460**</td>
<td>0.552**</td>
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<td>0.613**</td>
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Robust standard errors in brackets
** p<0.01, * p<0.05, + p<0.1