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Technological diversity in Europe: empirical evidence from agro-food projects sponsored by the 7th Framework Programme

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Abstract

This paper focuses on the concept of regional technological diversity, as opposed to specialisation, which refers to the capacity of regions to carry out research in several key research areas and related technology fields. We investigate whether the 7th European Framework Programme for RTD promoted regional technological diversity or, conversely, specialisation in the field of agro-food sciences. To do so, we use a database of 730 collaborative research projects, carried out in the period 2007-2013, and regionalised and categorised on the basis of an original taxonomy of key research areas and related technologies developed with the support of a team of European experts in the field. We focus on two factors that are potentially positively related to technological diversity: the total amount of competitive research funding obtained and the degree of centrality of each region in collaborative networks. We find evidence that both the amount of research funding and network centrality promote regional technological diversity, with the latter having a moderating effect on the impact of funding, implying that for regions that are very central in European networks, the positive effect of increasing funding on diversity diminishes beyond a certain threshold. The results of this paper raise several policy relevant questions. For instance, analysis suggests that Framework Programmes are not neutral with regard to specialisation and must be well coordinated with other policy initiatives, such as Smart Specialisation Strategies, if public resources are to be used effectively.

Jelcodes:O38,O18

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Keywords: Framework Programme, Technological Diversity, Smart Specialisation, Network Analysis, European Regions

JEL Codes: O18, O31, O38, R58

1. INTRODUCTION

In the programming period 2007-2013, the European Commission (EC) invested a significant amount of resources in research and innovation. Considering only the main instruments such as the European Regional Development Fund (ERDF) and the 7th Framework Programme for Research and Technological Development (FP7), over 100 billion euros were devoted to supporting policies in these fields. While the ERDF and the Structural Funds in general finance a wide range of initiatives in support of innovation, from the creation of an innovation friendly environment to collaboration and technology transfer, the FP7 was entirely devoted to subsidising research, both basic as well as applied and market oriented. This is one of the largest competitive R&D programmes in the world, funding a significant volume of research and innovation and accounting for over 5% of the European Member States' expenditure on R&D. The rationale behind Framework Programmes, in a nutshell, is that they are supposed to promote research excellence in Europe and 'add value' which cannot be obtained through national programmes (Muscio, 2006).

However, the policy stance has also evolved in recent years as a consequence of the international economic crisis. Framework Programmes for RTD are not only aimed at promoting excellence, but also at facilitating "research cohesion" within the European Research Area (European Commission, 2013), two goals not necessarily aligned whose joint pursuit is challenging. In this context, the Smart Specialisation Strategies (RIS3), whose approval was ex-ante conditionality for accessing the European Structural and Investment (ESI) Funds in 2014-2020, are instruments aimed at facilitating the harmonisation and alignment of EU-level and regional policies which, ultimately, could contribute to providing a solution to addressing the difficult trade-off: developing excellence vs. promoting cohesion. To do so, RIS3 must really help to focus on a limited set of specialisations characterised by a high growth potential rather than, according to a business as usual approach, on sectors and investment priorities picked up without any regard for RTD specialisation and capacity or simply advocated by industrial lobbies. Unfortunately, there is little information available on real specialisations of European regions which can guide policy makers in facilitating an entrepreneurial discovery process. As a consequence there is also little evidence on the drivers of technological specialisation and diversity, or at least, on the relation between public funding, regional standing in the research networks, technological diversity, and specialisation.

There is a growing literature that analyses the participation in FPs and the outcomes and impacts of this important European policy instrument (Arnold et al. 2005; Arnold, 2012; Muscio et al., 2015). The empirical literature has emphasised the effects of geographical, technological and cultural proximity on the formation of research collaborations (Cecere and Corrocher, 2013). Particular attention has been paid to an analysis of the characteristics of regional networks and the effectiveness of the FPs for knowledge dissemination across networks and Member States (Breschi and Cusmano, 2004; Roediger-Schluga and Barber, 2006; Breschi et al., 2009; Paier and Scherngell, 2011; Pandza et al., 2011; Scherngell and Barber, 2011).

Despite the growing empirical evidence on the scientific and economic results of the FPs and on the extent and characteristics of the promoted partnerships, there is still little evidence on the technological specialisation of research carried out with the support of this important policy instrument. In other words, while we know what the principal scientific sectors that receive support from the FPs are, we do not know much about the kind of technologies that are developed within each of these sectors. Regardless of the estimated results and weaknesses of the FP experience, the mass of co-financed research projects provides 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 an attempt to fill this gap in the literature, this paper presents the findings of an analysis of a large sample of FP7 projects relevant for one of the most important European industries, the agro-food sector, based on an original taxonomy of key research areas and technologies developed by ISMERI Europa.[1] FP7 projects embed information in key research areas and related key technologies in which many European and international research stakeholders have chosen to invest in over the last seven years. Unfortunately, this information is organised, and often used for scientific purposes in the economic literature, on the basis of funding calls and scientific areas rather than on the basis of the actual project contents, and therefore provides little insight in terms of technological specialisation and technological change. In order to provide useful information for the policy maker, it has been clear for some time that a project-by-project analysis must be carried out and the project-level data reorganised on the basis of their primary objective and the type of technology developed. In line with these purposes, this paper uses for the first time an original database that classifies each FP7-funded project on the basis of a detailed taxonomy of agro-food research areas and key technologies which have been defined with the help of expert peer reviews for each technological domain. This exercise helps to understand where and on which technologies the European industrial research supported through the FP7 was concentrated, providing some early evidence of the alignment between the focus of FP7 investments and the regional RTDI strategies promoted by RIS3.

We focus on the concept of technological diversity which refers to the regional capacity to carry out research in several technological fields. We investigate the determinants of technological diversity, shedding light on the factors that are associated with greater regional capacity to 'diversify' research activities or 'specialise' them. In particular, we focus on two factors: the total amount of research funding granted to each region and the degree of centrality in interregional collaboration promoted by the FP7. The paper is organised as follows: Section 2 summarises the theoretical and policy background with special reference to the EU research and innovation policy, the role of FP and the recent concept of RIS3; Section 3 presents the data and the methodology underlying the taxonomy for grouping agro-food FP projects in key research areas and related key technologies; Section 4 presents the econometric analysis; Section 5 draws concluding remarks and policy implications.

2. THEORETICAL AND POLICY BACKGROUND

2.1. EU research and innovation policy

Regional innovation policy is at the heart of the EC's political agenda. The regional dimension has been recognised as the most appropriate context for the development of innovation based learning economies (Asheim and Isaksen, 1997; Cooke and Morgan,

[1] The database was compiled by extracting project information from the Cordis online repository. All FP7 projects financed under Cooperation and Ideas programmes have been categorised and included in the database. Variables such as the real geographical location of participants (NUTS2) and the distribution of resources among partners have been added.

1998) and this has led to the growing relevance of regions in multi-level governance systems. One priority of regional policy in the EU is to harmonise living standards and reduce chronic disparities as quickly as possible. In this context, innovation and knowledge diffusion are important for all regions, whether or not they are at the forefront of research. During the last decade, the main European instruments supporting research and technological development across countries and regions have been EU Cohesion Policy, specifically the ERDF, and the FP7. In short, the objectives of the former were to support convergence of lagging regions as well as competitiveness and employment across Europe. On the other hand, the main objectives of the FP7 were to develop research excellence and build networks. Therefore, as mentioned in the introduction, there is a certain degree of misalliance between the goals of the two policies even though, also as a reaction to the international economic crisis, there was a progressive adjustment in FP7 goals over the years with an increasing focus on reducing regional gaps in research and technology rather than simply promoting excellence.

A key aim of FPs, most notably FP6 and FP7, was to contribute to building and strengthening research networks. Research networks are a fundamental component in the global research landscape since the pace of technical change and the emergence of complex technologies, platforms and applications increasingly require the joint contribution of different private and public organisations with complementary knowledge and technological competences (Cecere and Corrocher, 2013). With the FPs, the EC has invested a significant amount of resources in research and innovation both in the private and public sector. While there is a wide consensus on the positive impact of FPs on the creation of networks, 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). Moreover, there seem to be little convergence in regional innovation performance (Hollanders et al., 2012) which is hindering structural shifts to knowledge intensive and higher value added goods and services.[2]

To increase the efficiency and effectiveness of regional innovation policy and promote harmonisation and synergies between different funding sources, most notably Cohesion policy and FPs as well as national and regional interventions, the EC adopted the concept of RIS3. RIS3 is meant to promote an intelligent allocation of available funds on a limited set of priorities that have the potential to drive economic transformation (McCann and Ortega, 2013). In the view of the EC[3]:

"…its goal is to boost regional innovation in order to achieve economic growth and prosperity, by enabling regions to focus on their strengths. RIS3 understands that spreading investment too thinly across several frontier technology fields risks limiting the impact in any one area".

2.2. Technological diversity

There is considerable empirical evidence both in the scientific literature and in the form of consultancy reports about the outcomes of FPs and the networks they promote (*see*

[2] Such observations are part of the rationale for the EC's decision to introduce 'ex-ante conditionality' to improve the quality of strategic plans for the 2014-2020 programming period.
[3] http://ec.europa.eu/research/regions/index_en.cfm?pg=smart_specialisation

Cecere and Corrocher, 2013). Even if their value added remains questionable (Clark et al., 2004), the FPs have contributed to promoting the growth of European research. Yet little is known about what technologies have been developed with the support of FPs while it would be vitally important to determine what EU policy has done so far in promoting technology specialisation or diversification, also considering the concerns over an efficient implementation of a RIS3 strategy.

The debate on specialisation and diversification in regional economies (Boshma and Iammarino, 2009; Van Der Panne, 2004) that has taken place over the past twenty years suggests that knowledge spillovers within a region, or smaller country, occur primarily among related sectors, and only to a limited extent among unrelated sectors (Boshma, 2005). 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). In this context, the core principle of the RIS3 literature is that public and private resources should be concentrated on selected technological or market priorities that have the potential to not only foster the emergence of new activities, but also foster the adoption, dissemination and adaption of 'general purpose technologies' across a wide range of sectors (Foray and Goenega, 2013; Foray et al., 2011).

In this paper, we do not deal with sectoral specialisation vs. diversification, but we narrow down the focus on technological specialisation by concentrating on key research areas and technologies developed within a specific domain, that of agro-food. We argue that investigating technological specialisation and diversity at the regional level, in a specific domain such as agro-food, can provide key indications on drivers of specialisations and therefore on the effectiveness of policy initiatives designed to foster specialisation as well as on the coherence with other RTDI policy such as European Framework Programmes for RTD.

Following Wang and von Tunzelmann (2000), technologies can be thought of as bodies of knowledge that are person-embodied. Therefore, regional technological diversity can be defined as a region's capacity to carry out research activity across different knowledge domains. Studies on technological diversity primarily focus on the intersectoral level using patent and publication data to measure technological complexity. Some works highlight the powerful role of firms' technological diversity in driving their innovation performance (Breschi et al., 2003; Granstrand, 1998; Gemba and Kodama, 2001; Quintana-Garcia and Benavides-Velasco, 2008).

Government funding is viewed as having a strong positive effect on knowledge creation and technology development to the extent that some authors (Defazio et al. 2009; Lee and Bozeman, 2005) point out that the beneficial effects of research funding 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 (Bolli and Somogyi, 2011; Banal-Estanol et al., 2015). For these reasons, we argue that the benefits of research funding and collaboration could be extended to the breadth of technologies developed with the support of EU collaborative schemes such as FPs. Therefore:

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

Collaborative research programmes such as FPs are supposed to 'add value' which cannot be obtained through national programmes (Fahrenkrog, 2002; Georghiou 2001). The most obvious addition is the ability to tackle technological problems drawing together a much larger pool of resources, both financial and human (Muscio, 2006). In fact, although international collaborations undertaken under FPs may be expected to offer benefit over national programmes for several reasons, the opportunity to achieve a 'critical mass' of research performers – and users – is unlikely to be achieved nationally, or where a national focus would exclude 'key players' from the joint venture. Therefore, the FP provides an opportunity to tackle research questions at a scale that few EU member states would contemplate or could afford (Clark et al., 2004).

Larèdo (1998) investigated the characteristics of the networks promoted by previous iterations of the FP. The history of FPs is characterised by a series of changes in institutional arrangements that determine the nature and structure of research collaboration networks funded from EU sources (Pandza et al., 2011). Scientists get involved in government-funded collaborative research projects such as the FP because of the increasingly interdisciplinary, complex, and costly characteristics of modern science (Lee and Bozeman, 2005). The question of whether collaboration promotes research productivity has concerned the economic literature for quite some time. The interaction between researchers employed in academic institutions or research centres and in the business sector is expected to bring together different sets of knowledge and cognitive approaches that is likely to lead to the creation of new knowledge. However, as noted in Lee and Bozeman (2005), both collaboration and productivity may be influenced by access to grants which can dictate team-based goals.

EU-funded research networks require researchers to collaborate as a condition for securing research funding and there is evidence that collaborative networks positively affect researchers' productivity in the longer term (Defazio et al., 2009). In this respect, we argue that the networks promoted by the FP7 allow a critical mass of competencies to be reached that are positively related to the technological capabilities of regions and hence their technological diversity.

H2. There is a positive relationship between the degree of centrality in interregional networks promoted by the FP7 and technological diversity

3. DATA AND METHODOLOGY

So far, the technology and market orientation of FPs have been explored mainly by directly interviewing the stakeholders (e.g. participating firms or academic institutions) as in Luukkonen (2002) who suggests that both technology and market orientation are important reasons for companies in their participation in the EU FP. Aggregate FP project databases undoubtedly offer precious evidence about relevant issues such as the networks promoted by the FPs (Cecere and Corrocher, 2013), their spatial dimension (Scherngell and Barber, 2011), the persistence of given actors in FP participation (Breschi and Cusmano, 2004; Breschi et al., 2009), and the dynamics of knowledge diffusion (Cassi et al., 2008).

The core of our analysis is based on an original database of projects funded by the FP7 within the "Cooperation" and "Ideas" programmes. For the purpose of this study, we focus on the scientific domain of the agro-food sector. Food and beverages is one of the highest ranked manufacturing sectors in Europe and this is particularly significant if we consider that it was the fastest growing manufacturing sector during the years that followed the recent world financial crisis. This industry is mostly based on low R&D investment levels and mature, pervasive technologies, where – in general, but not always – static capabilities dominate over dynamic capabilities (Ghemawat and Costa, 1993; Gruner et al., 1997; Martinez and Briz, 2000; Zahra et al., 2006). Despite having great innovative potential, the food industry is generally based on 'redundant technologies'. Science and technology offer wide opportunities to change and improve the taste of products, preparation and nutritional characteristics, but the industrial structure is generally mainly composed of SMEs with low R&D capacity (Muscio et al., 2010). The introduction of innovations in the food industry is strongly influenced by demand conditions. Although final consumers are getting more interested in food characteristics every day and are showing greater willingness to pay for new and improved products, they do not substantially change their alimentary regime (Galizzi and Venturini, 1996). Consequently, product innovations in the industry are hardly radical and much more often of an incremental nature. This feature makes innovation dynamics in the food industry similar to those in other mature industries such as textiles, clothing and footwear and despite its relevant innovation potential, differentiates the industry from science-based sectors where the contribution of scientific institutions to innovation is much more important (Pavitt, 1984).

FP7 project data 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 led by agro-food experts. The team of experts identified five main key research areas (KRA). 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 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 an non-EU category, which includes regions outside the EU, not considered in the econometric analysis because of missing data. Only 12 regions out of 295 did not participate in any FP7 project.

Table 1 - Identified key research areas and related key technologies

KEY RESEARCH AREAS	**KEY TECHNOLOGIES** (Techniques, methods, knowledge and procedures)
PRIMARY PRODUCTION IN AGRICULTURE, FORESTRY, AQUACULTURE AND FISHERIES The sustainability and security of European production in agriculture, forestry, aquaculture and fisheries is under threat from intensive production practices, global competition and climate change factors. To maintain its competitiveness, while safeguarding the sustainable production of land, forest and marine resources, Europe will have to strike a balance between socio-economic goals (higher yields; rural employment; self-sufficiency) and responsible natural resource management (fewer negative externalities, fewer incidence of plant and animal diseases, greater resilience to extreme weather and stop overexploitation of natural resources). Research addressing these challenges is mainly grounded in agricultural, forestry and fishery sciences which are broad multidisciplinary fields that apply basic knowledge from exact, natural (in particular biology), economic and social sciences to optimise production and processing in agriculture, forestry and fishery.	- High-efficient plants and trees - Plant and tree protection - Improved livestock - Competitive and Sustainable Aquaculture - Animal Health and Welfare - Environmentally-friendly farming
INNOVATIVE INDUSTRIAL PROCESSES FOR FOOD PRODUCTION AND CONSERVATION Products of agricultural, forestry and fisheries production increasingly reach the consumer only after being processed, packaged and distributed. Off-farm value addition in the agro-food value chain (i.e., food processing, wholesale and retail) exceeds that of primary production by a factor of more than two. The food processing industry in the EU comprises a small group of large companies (some 3,000) capturing about half of the turnover in the food processing industry and a very large group of SMEs (some 283,000) capturing the other half. Greater efficiency at this stage of the agro-food value chain is warranted in order for the agro-food industry to stay competitive, while maintaining or improving food quality and safety. At the same time, negative externalities of food processing have to be contained. This often requires systemic analysis of production processes. Research addressing these challenges is mainly grounded in food sciences, which is usually classified as a subcategory under agricultural sciences.	- Processing technologies for high food quality and safety - Innovative food packaging - Smart food processing machines and equipment - Environmentally-friendly processes
HEALTH AND FUNCTIONAL CLAIMS Both easy availability of food products and contemporary sedentary lifestyles have generated increasing rates of obesity, diabetes, allergies and cardiovascular diseases among the EU population. In order to address these health concerns, there is a need for research on diet-health relations and on developing targeted communication strategies to promote the adoption of healthy diets and lifestyles. In addition, there is a need for research on functional foods (i.e., foods with specific health claims) and on tailor-made foods for specific vulnerable groups. Research addressing these challenges is usually based on a mix of food and medical sciences.	- Tailor made foods, functional foods and ingredients - Improving diet-health relations
FOOD QUALITY, SAFETY AND TRACEABILITY Industry has primary responsibility for food safety. However, governments have an important controlling role to play. Both industry and governments require research to provide a robust understanding of safety issues along the food/feed supply chains and adequate tools to assess quality and trace contamination. Research addressing these challenges is mainly grounded in food sciences and chemistry.	- Traceability, feed/food supply chain security - Tools for food quality / safety assessment and control

POLICY STUDIES AND KNOWLEDGE TRANSFER This residual category comprises: (a) projects that, strictly speaking do not conduct research, but address issues that help to advance agro-food research by disseminating research results or facilitating research networking and cooperation; and (b) projects that conduct research in support of policy decision making rather than production (i.e., impact analysis and studies). The latter category of projects often has a strong social and economic sciences component.	- Agriculture, Fisheries and Food policy - Knowledge transfer, RTDI coordination, etc.

Source: adapted from 2015 Ismeri Europa taxonomy of agro-food key research areas and key technologies

Table 2 – Agro-food projects sponsored by the FP7: basic project statistics and network features

	Key Research Areas	No. projects	No. particip ations	EC EUR million	Average path length	Overall graph clustering coeff.	Average centrality degree
1	Primary production in agriculture, forestry, aquaculture and fisheries	314	4275	423.61	1.93	0.76	18.74
2	Innovative industrial processes for food production and conservation	165	1844	151.97	1.86	0.74	23.70
3	Health and functional claims	73	1082	132.49	1.94	0.66	29.42
4	Food quality, safety and traceability	62	784	71.55	1.74	0.67	60.18
5	Policy studies and knowledge transfer	116	1606	105.41	1.80	0.73	28.28
	Total	730	9591	885.01	1.65	0.72	96.41

Source: authors' elaboration on 2015 Ismeri Europa data covering FP7 agro-food projects.

presents the total number of projects in each of the 5 different KRAs discussed above. The large majority of projects and participations is concentrated in KRA 1: primary production in agriculture, forestry, aquaculture and fisheries. This is followed by: Innovative industrial processes for food production and conservation; Policy studies and knowledge transfer; Health and functional claims; Food quality, safety and traceability.

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In order to provide some insights into regional partnerships in FP projects in each of the knowledge domains identified with the peer review process, we analysed the structure of the networks promoted by the FP. The last three columns of Table 2 – Agro-food projects sponsored by the FP7: basic project statistics and network features

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present the results obtained from some standard indexes of social network analysis (SNA). The results show that KRAs differ significantly in relation to the way regional partners network to perform research tasks.

Regions can be embedded in networks of different complexity. A measure of complexity is provided by the average path length, a measure of relational distance between regions in FP7 networks. Large distances as opposed to proximity may represent an obstacle to knowledge diffusion. In our case, we find that the average path length (Column 6) is between 1.7 and 2, depending on the area, where two directly connected regions in a FP7 project are at a distance of 1. This shows that, in agro-food, FP7 is promoting tightly connected, direct networks where each region in connected in less than 2 steps. Closely connected networks such as these can be considered conducive to relatively fast and effective information diffusion between regions.

We estimated the clustering coefficient which represents the average of the densities of the neighbourhoods of all of the regions in the network. A high level of clustering increases the chances that complex knowledge is spread more effectively. The results of the estimated clustering coefficients support the results of the average path length discussed above, ranging between 0.755 and 0.662, and confirm that regions are embedded in relatively highly clustered neighbourhoods.

Finally, the average degree index can be used to allow unbiased comparisons among several networks since its magnitude is not affected by the dimension of the network. This index measures the average number of ties between each region and its partners in FP7 agro-food projects. The average number of links at the aggregate level is 96,407, which is very high as our network includes just 295 regions, but, as expected, the estimated average values are much lower at the disaggregated level, ranging from 60,183 links in KRA 4, food quality, safety and traceability, to just 18,739 links in KRA 1, primary production in agriculture, forestry, aquaculture and fisheries.

In conclusion, the analysis of descriptive statistics and SNA indicators shows that, while the FP7 has promoted relatively dense networks, with high degrees of centrality and relatively low relational distance between regions, there is great diversity in how networks are shaped in different research areas.

4. ECONOMETRIC ANALYSIS

4.1. Econometric specification

In order to investigate regional technological diversity in FP7 projects, the following model is estimated:

$$Eq.1 \qquad TECHDIV_i = \alpha + \beta_1 REGIONALCONTROLS_i + \beta_2 FP7\ NETWORK_i + \beta_3 FP7\ FUNDING_i + \varepsilon_i$$

where TECHDIV_i represents a measure of technological diversity measured with a scalar indicator ranging from 1 to 5 KRAs, taking into account the number of areas in which region *i* has carried out in one or more FP7 projects. REGIONAL CONTROLS is a set of explanatory variables controlling for regional socio-economic factors. FP7 FUNDING measures the natural logarithm of the total EC contribution, expressed in Euros, granted to institutions and organisations located in region *i*. FP7 NETWORK represents a set of indicators accounting for the characteristics of regional networks promoted by the FP7. This set of indicators includes an indicator that controls for the average distance of region *i* from other regions involved in the same projects, an indicator of the share of intra-regional linkages, which measures the intensity of linkages between institutions and organisations within the same region, and an index of network centrality. This index accounts for eigenvector centrality, a more sophisticated version of the centrality degree discussed above. As suggested in Scherngell and Barber, 2011, the eigenvector is particularly useful in the analysis of regional networks and stems from the idea that while having many connections ensures that a region can exert influence and is able to access to knowledge, it is also arguable that not all connections are the same. Typically, connections to regions which are themselves well connected will provide regions with more influence and knowledge resources than connections to poorly connected regions. Eigenvector centrality thus assigns each region a centrality that depends both on the number and the quality of its connections by examining all regions in parallel and assigning centrality weights that correspond to the average centrality of all linked regions (see Bonacich, 1987).

As a robustness check, we tested our model with alternative measures of technological diversity. Alternative ways of measuring technological diversity include the Herfindahl-Hirschman Index of Diversification (HHID) (Berry, 1975) which is derived from the Herfindahl–Hirschman Index (HHI) and the Shannon Diversity Index (SDI). The HHI index is conventionally used in industrial organisation to measure industry concentration, but it is becoming popular to measure technological diversification (Quintana-Garcia and Benavides-Velasco, 2008). The HHID can be expressed as follows:

$$Eq.2 \qquad HHID_i = 1 - HHI_i = 1 - \sum_i P_i^2$$

where P_i denotes the proportion in a region of FP projects in KRA *i*. The index equals zero when a region carries out research activity only in a single area, and it is close to one when the region spreads its research activity over a broad technological knowledge base.

The SDI belongs to the group of entropy indices that has been applied in the context of industrial diversification (Attaran and Zwick, 1987; Aiginger and Davies, 2004). This is defined as the negative sum of project shares, multiplied by the natural logarithm of project shares of each single KRA *i*. Because of the log-form, the relative weights of areas with a large number of projects are reduced compared with the HHID. The SDI is a measure of diversity, increasing with decreasing specialisation so that the lower bound (zero) gives absolute specialisation and the upper bound complete diversification. The SDI can be expressed as follows:

$$Eq.3 \qquad SDI_i = -\sum_{i=1}^{N} P_i ln P_i$$

Table 3 - Description of variables

Variable	Definition	Primary source of data
Dependent variables		
TECHDIV	N. KRAs (1-5) in which the region participates	Ismeri Europa (based on DG Research data)
HHID	Herfindahl–Hirschman index	Ismeri Europa (based on DG Research data)
SDI	Shannon diversity index	Ismeri Europa (based on DG Research data)
Regional indicators		
English proficiency	EF English Proficiency Index (1-5)	EF Education First
Ln Distance from Brussels	Log of distance from Brussels (Km2)	Eurostat

Ln Population	Log of population (headcounts)	Eurostat
Share students in educ.	Pupils and Students in all levels of education (ISCED 0-6) as % of total population	Eurostat
Ln GDP per capita	Log of Gross Domestic Product, per capita (stock level in the base year 2006)	Eurostat
Ln GERD per capita	Log of Gross Expenditure on Research and Development, per capita (stock level in the base year 2006)	Eurostat
FP7 indicators		
Ln distance from partners	Log of average distance from partners (Km2)	DG Research
Share intra-regional links	Share of links between actors of the same region	DG Research
SNA Eigenvector	Network centrality degree: Eigenvector	DG Research
Ln total EC contribution	Log of Total EC contribution (Euros)	DG Research

presents the definition of the variables used in the regressions andSource: authors' elaboration

Table 4 - Descriptive statistics

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Dependent variables					
TECHDIV	294	3.578	1.512	0.000	5.000
HHID	294	-7.001	1.500	-8.210	0.000
SDI	294	0.998	0.463	0.000	1.592
Regional indicators					
English proficiency	293	3.154	1.034	2.000	5.000
Ln Distance from Brussels	294	6.547	1.182	-6.908	9.152
Ln Population	290	14.068	0.867	10.195	16.261
Share students in educ.	280	0.219	0.034	0.147	0.356
Ln GDP per capita	278	9.906	0.666	7.783	11.427
Ln GERD per capita	275	5.296	1.437	1.099	7.875
FP7 indicators					
Ln distance from partners	282	7.016	0.345	6.353	9.079
Share intra-regional	294	0.079	0.028	0.000	0.174

links					
SNA Eigenvector	294	0.050	0.029	0.000	0.108
Ln total EC contribution	282	14.675	2.034	-6.908	18.500

presents some descriptive statistics. A correlation matrix is presented in the Appendix.

Table 3 - Description of variables

Variable	Definition	Primary source of data
Dependent variables		
TECHDIV	N. KRAs (1-5) in which the region participates	Ismeri Europa (based on DG Research data)
HHID	Herfindahl–Hirschman index	Ismeri Europa (based on DG Research data)
SDI	Shannon diversity index	Ismeri Europa (based on DG Research data)
Regional indicators		
English proficiency	EF English Proficiency Index (1-5)	EF Education First
Ln Distance from Brussels	Log of distance from Brussels (Km2)	Eurostat
Ln Population	Log of population (headcounts)	Eurostat
Share students in educ.	Pupils and Students in all levels of education (ISCED 0-6) as % of total population	Eurostat
Ln GDP per capita	Log of Gross Domestic Product, per capita (stock level in the base year 2006)	Eurostat
Ln GERD per capita	Log of Gross Expenditure on Research and Development, per capita (stock level in the base year 2006)	Eurostat
FP7 indicators		
Ln distance from partners	Log of average distance from partners (Km2)	DG Research
Share intra-regional links	Share of links between actors of the same region	DG Research
SNA Eigenvector	Network centrality degree: Eigenvector	DG Research
Ln total EC contribution	Log of Total EC contribution (Euros)	DG Research

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Source: authors' elaboration

4.2. Factors related to technological diversity

We test our hypotheses regarding technological diversity developed under the FP7 using the econometric strategy proposed above. Since the dependent variable TECHDIV is based on scalar values ordered progressively from 1 to 5, we chose an ordered logit model for the analysis. Error! Reference source not found.**Error! Reference source not found.** reports in Column 1 the ordered logit estimates and the corresponding marginal/impact effects only for the top value of the ordered scale. Column 2 presents the marginal effects. The marginal effects of changes in the independent variables in an ordered logit model are not easy to interpret. As Greene (2002) indicates, in an ordered logit model, the sign of any parameter can only clearly determine the marginal effect of each variable on the extreme probabilities (the probability of technological diversity being broadest).

First of all, the results of the regressions show that in all model specifications, the only regional characteristics, apart from those related to participation in FP7, that matter for the purpose of technological diversity are regional size and GERD. Regional size, expressed in terms of population head count, is significantly correlated with technological diversity, with scale effects allowing larger regions, alias regions with a higher number of research performers, being more likely to possess wider technology competencies in food sciences. As expected, we also find that regions with larger efforts in R&D as expressed by the GERD are also more likely to carry out research in more key research areas.[4]

As far as FP7 indicators are concerned, it is especially important to note that participation in FP7, as expressed by the amount of funding that regions are granted from the EC, always has a positive effect on the probability of having high levels of technological diversity.

The coefficient for network centrality (SNA Eigenvector) is positive and highly significant in all model specifications, confirming that more centrally networked regions have better chances of being involved in R&D activities in different areas of technology. While distance from partners is not a significant aspect for the purpose of technological diversity, the higher the share of participants from the same region involved in FP7 projects, the higher the probability of being involved in the development of diverse technologies. Therefore, regions with greater intra-regional networks have better chances of being technologically diversified than regions relying more extensively on external partnerships. This reflects, in a way, regional size. In other words, while technological specialisation seem to need geographically close partnerships, technological diversity is characterised by research activities that are carried out to a higher extent between partners of the same region.

These results are supported by the findings on the interaction term. All specifications include an interaction term between regional networking as expressed with the Eigenvector and FP7 funding. This variable accounts for the moderating role of regional networking on FP7 funding. The interaction term is negative and highly significant, showing that having access to a larger amount of resources and, at the same time, being highly central decreases the probability of being involved in a higher number of technological areas. According to our results, while FP7 funding is positively related to technological diversity, there is a funding threshold above which the propensity to diversify technology diminishes. This result shows that centrality does not only influence technological diversity directly, but also through its relationship with FP7 funding. Since Eigenvector centrality provides a measure of centrality that depends both on the number and the quality of its connections, we conclude that the relation of FP7 funding and technology is stronger when regions are characterised by moderate interregional linkages. However, regions embedded in dense collaboration networks see a decline in the probability of being involved in the development of diverse technologies.

In conclusion, FP7 can support research and technological development by promoting the acquisition or development of physical and human resources and via knowledge sharing across a multitude of regional actors. According to our evidence, the amount of FP7 funding and network centrality is significantly associated with regional technological diversity in agro-food science in Europe. However, excessive reliance of participants on external partners diminishes the beneficial effects of research funding on technological diversity.

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[4]As an alternative measure of regional human capital to the share of students in education, in the regressions we used the share of population with tertiary education or employment in Science and Technology (stock level in the base year 2006). The results were consistent with those presented in the paper. Therefore we opted for the former indicator because of its much lower degree of correlation with other regressors.

Table 5 - Determinants of technological diversity

VARIABLES	(1) o.logit TECHDIV	(2) M.E. pr.out.=5	(3) OLS HHID	(4) OLS SDI
English proficiency	0.115	0.016	0.019	0.024
	[0.162]		[0.020]	[0.018]
Ln Distance from Brussels	0.167	0.024	-0.012	-0.007
	[0.141]		[0.013]	[0.011]
Ln Population	0.556*	0.079*	0.091**	0.078**
	[0.258]		[0.030]	[0.027]
Share students in educ.	7.122	1.013	0.768	0.706
	[5.064]		[0.641]	[0.562]
Ln GDP per capita	-0.561	-0.080	-0.052	-0.049
	[0.613]		[0.068]	[0.064]
Ln GERD per capita	0.538+	0.077+	0.073*	0.070*
	[0.297]		[0.033]	[0.031]
Ln distance from partners	-0.664	-0.094	-0.098	-0.096
	[0.662]		[0.075]	[0.071]
Share intra-regional links	27.481**	3.909**	2.096*	2.605**
	[7.634]		[0.829]	[0.785]
SNA Eigenvector	351.897**	50.057**	45.444**	53.610**
	[74.568]		[7.008]	[6.652]
Ln total EC contribution	0.840**	0.119**	0.045**	0.051**
	[0.310]		[0.014]	[0.016]
Ln TOT EC contribution * Eigenvector	-16.275**	-2.315**	-2.417**	-2.804**
	[4.457]		[0.397]	[0.374]
Constant cut1	17.117+			
	[9.574]			
Constant cut2	19.936*			
	[9.548]			
Constant cut3	22.336*			
	[9.591]			
Constant cut4	24.970**			
	[9.601]			
Constant			-9.183**	-0.957
			[0.989]	[0.914]
Observations	260	260	260	260
R-squared			0.540	0.645
Pseudo R-squared	0.485			

Robust standard errors in brackets

** $p<0.01$, * $p<0.05$, + $p<0.1$
Source: authors' elaboration

5. CONCLUDING REMARKS

European Framework programmes are primarily aimed at promoting research excellence and, to do so, they support high-risk basic and applied research, transnational networking between organisations and regions, mobility of people etc. Over time growing attention has been paid to reducing the wide regional variation in research and innovation performance across the EU (European Commission, 2013) and hence a sort of convergence between FPs, most notably the FP7 and H2020, and other important instruments such as Cohesion policy, which also finances RTD massively, has emerged. The extent to which these policies are aligned and whether there are actual synergies deserves to be studied more extensively in order to be able to assess the effectiveness of public intervention in supporting RTD.

The literature pays little attention to the regional technological effects of FPs and other policies. The analysis presented in this paper partly aims to fill this gap and shows that, in an important domain such as agro-food, FP7 funding and centrality in the promoted collaborative networks are strongly associated with greater technological diversity. This implies that the most engaged and (relationally) central regions are more likely to follow a path of technological diversity rather than specialising in one or few key research areas and in a limited number of related technologies. On the contrary, "peripheral" and less engaged regions are more likely to specialise in a limited set of key research areas and related technological fields.

Even though these results are limited to one domain, agro-food, they suggest that the FPs implicitly tend to foster a core-periphery pattern where technological diversity is promoted in central territories that attract lots of funding while, as can be expected, technological diversity does not prosper in more isolated territories. The extent to which this kind of narrowed down diversity of periphery or, to put it differently, greater specialisation, means higher capacity to compete and is in line with the philosophy underlying the Smart Specialisation Strategy remains to be studied further. The current exercise is a first attempt to incorporate the technological dimension in an exploration of the effect of RTD policy, a point often disregarded by the literature, in the authors' opinion.

This study has relevant policy implications, yet it faces some important limitations. First, the information contained in FP projects is useful only at the aggregate level at the end of the programming period, in our case 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. Secondly, given the focus of the paper on one specific scientific field, the agro-food sector, we can explore European engagement in this area thoroughly, but we cannot tell whether greater technological diversity or specialisation is obtained at the expense of greater diversity or specialisation in other science and technology fields. This brings us to future developments of this study which could be extended to all scientific sectors supported by the FPs and hence provide a more complete picture of technological diversity in Europe.

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APPENDIX

	TECHDIV	HHID	SDI	English proficiency	Ln Distance from Brussels	Ln Population	Share students in educ.	Ln GDP per capita	Ln GERD per capita	Ln distance from partners	Share intra-regional links	SNA Eigenvector	Ln total EC contribution
TECHDIV	1.000												
HHID	0.856	1.000											
SDI	0.923	0.983	1.000										
English proficiency	0.088	0.097	0.107	1.000									
Ln Distance from Brussels	-0.152	-0.209	-0.199	-0.127	1.000								
Ln Population	0.483	0.429	0.448	-0.119	-0.029	1.000							
Share students in educ.	0.191	0.184	0.189	0.301	-0.314	0.001	1.000						
Ln GDP per capita	0.365	0.315	0.339	0.251	-0.369	-0.084	0.148	1.000					
Ln GERD per capita	0.534	0.472	0.503	0.210	-0.361	0.097	0.224	0.888	1.000				
Ln distance from partners	-0.036	-0.144	-0.119	-0.144	0.575	-0.116	0.019	-0.268	-0.298	1.000			
Share intra-regional links	0.172	0.090	0.114	-0.112	0.042	0.056	-0.105	0.084	0.067	0.112	1.000		
SNA Eigenvector	0.840	0.632	0.707	0.032	-0.161	0.530	0.196	0.386	0.534	0.031	0.123	1.000	
Ln total EC contribution	0.695	0.572	0.636	0.092	-0.172	0.344	0.112	0.453	0.557	0.032	0.183	0.751	1.000

Source: authors' elaboration